Retinotopy Tutorial

What defines a visual area?

Visual areas are defined by FACTs!

(F)unction
(A)rchitectonics
(C)onnections
(T)opography

(F)unction

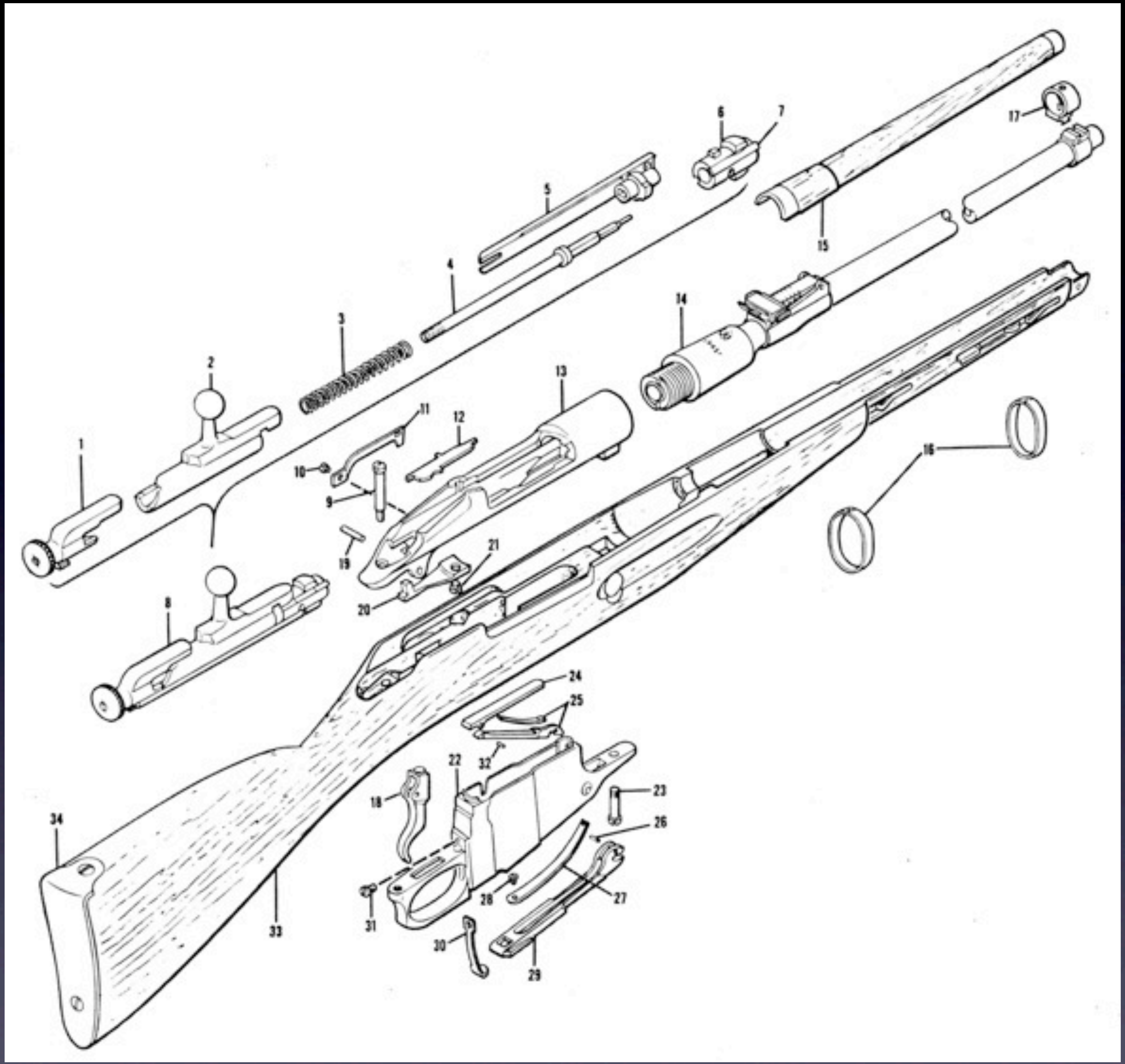
(A)rchitectonics

(C)onnections

(T)opography

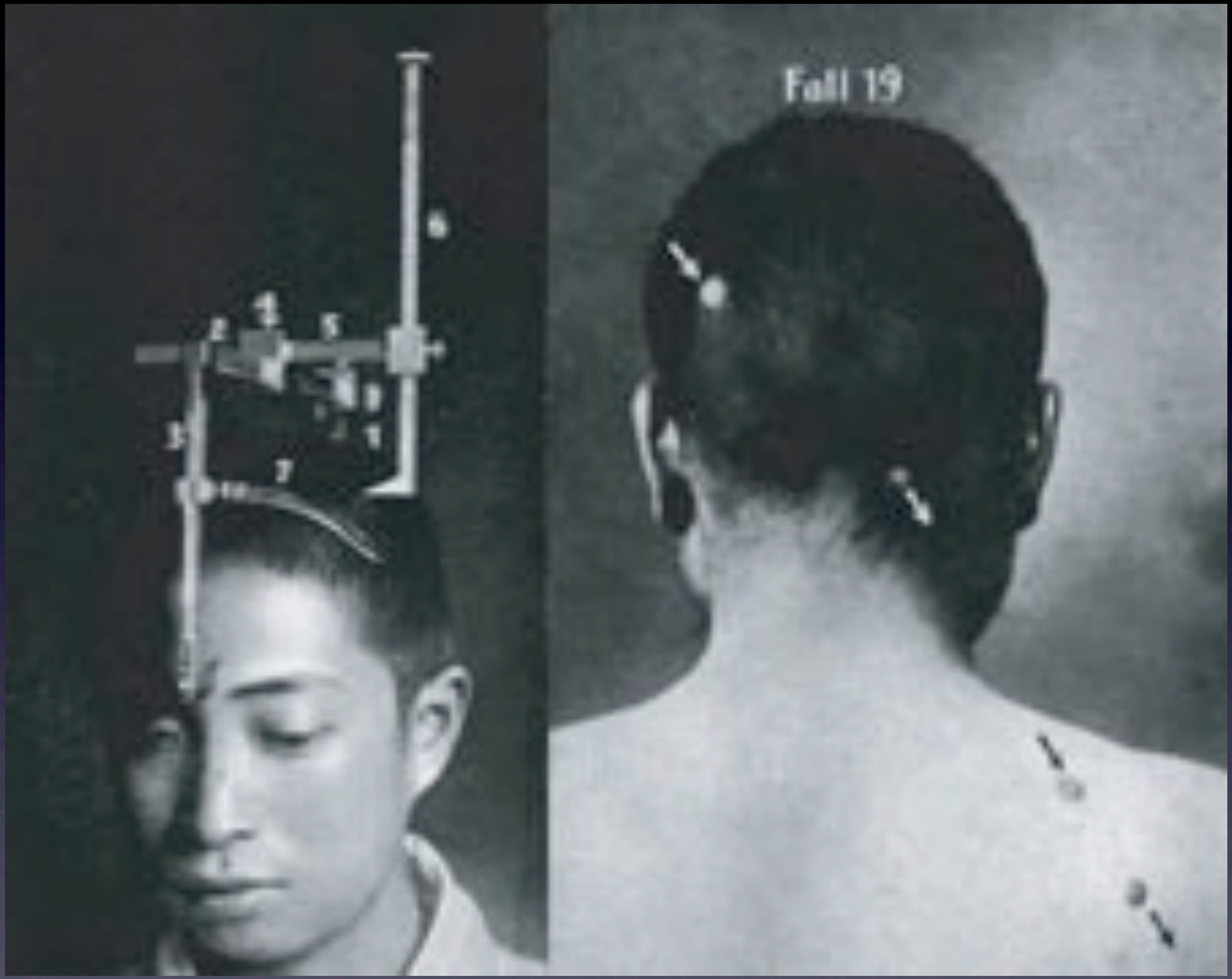
What technical development allowed
for the topographic mapping of primary visual cortex?

Microelectrode

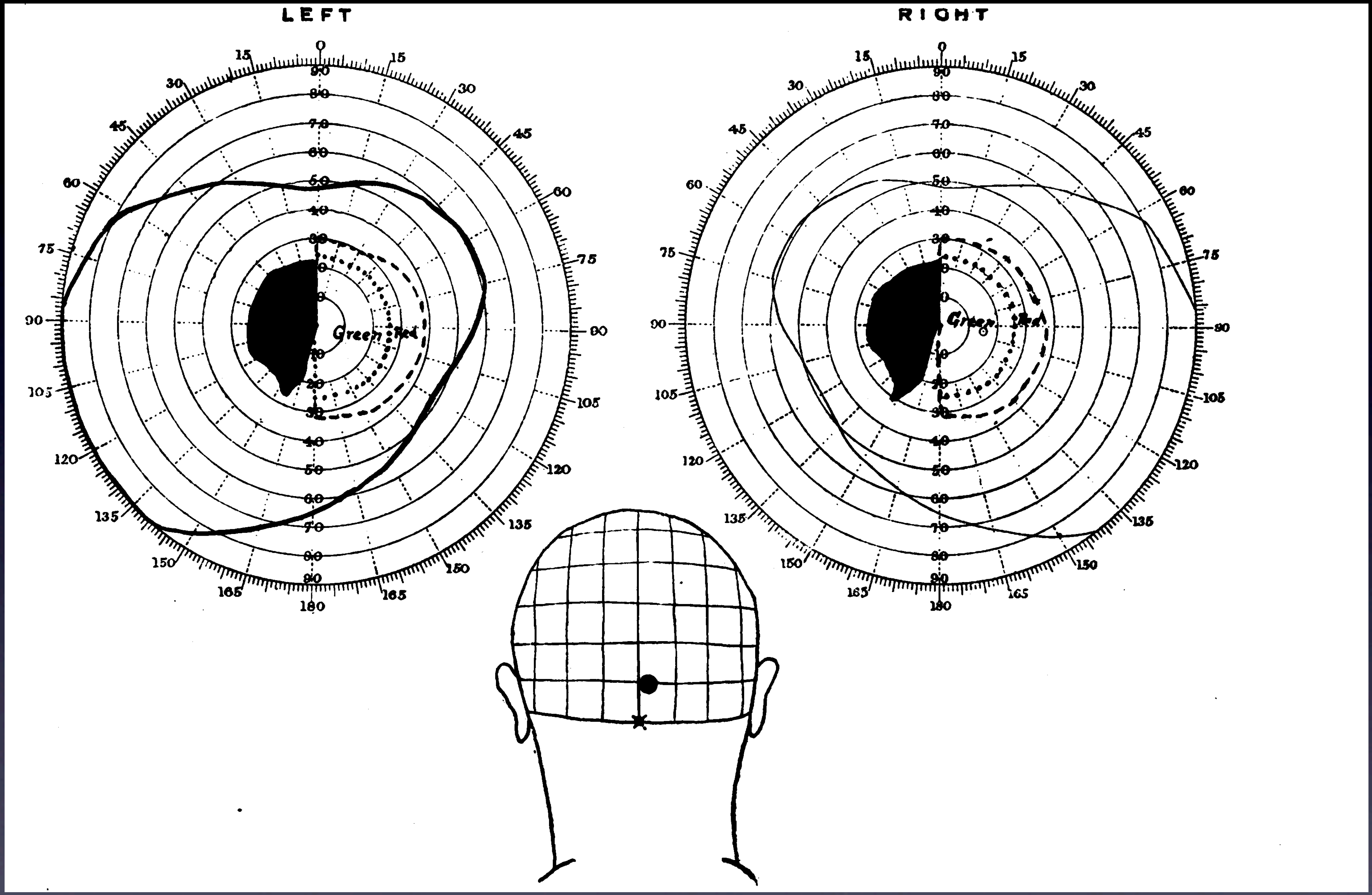


Mosin–Nagant Model 91 military rifle

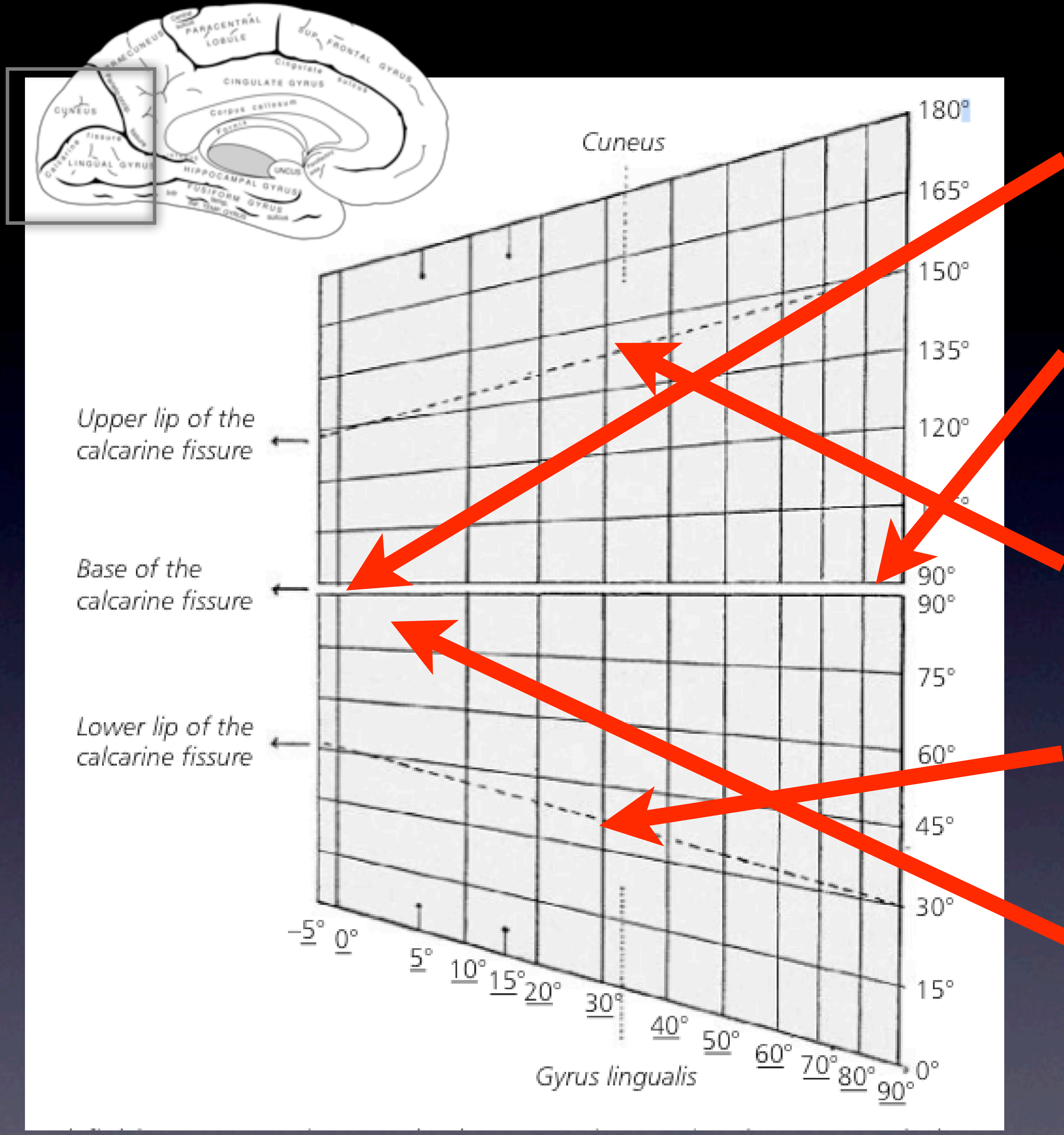
Tatsuji Inouye



Tatsuji Inouye (1909) W. Engelmann (Translated from German by Glickstein and Fahle)



Holmes (1918) British Journal of Opthalmology



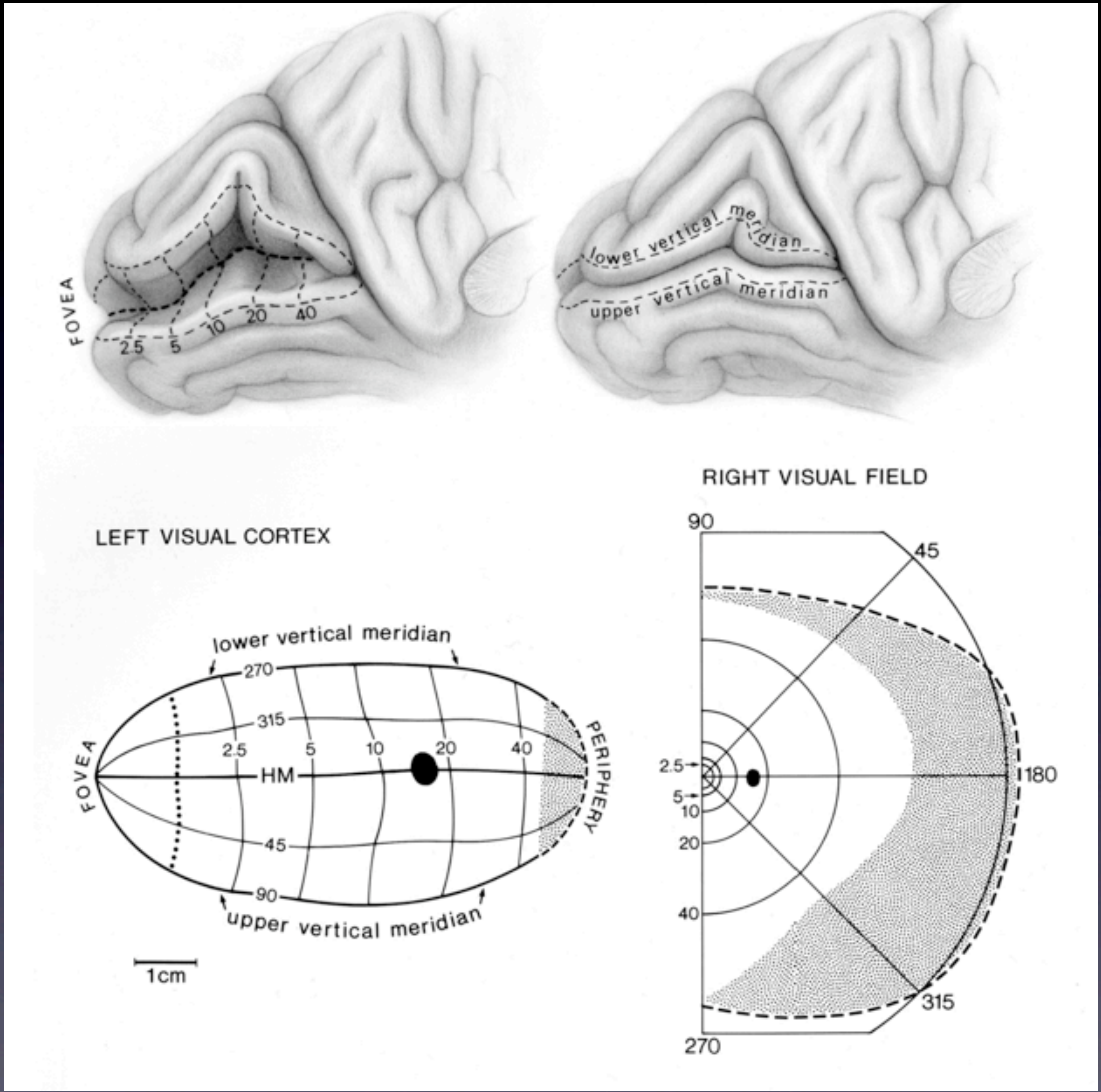
Fovea at occipital pole

Periphery at anterior end of calcarine

Lower visual field on the upper bank

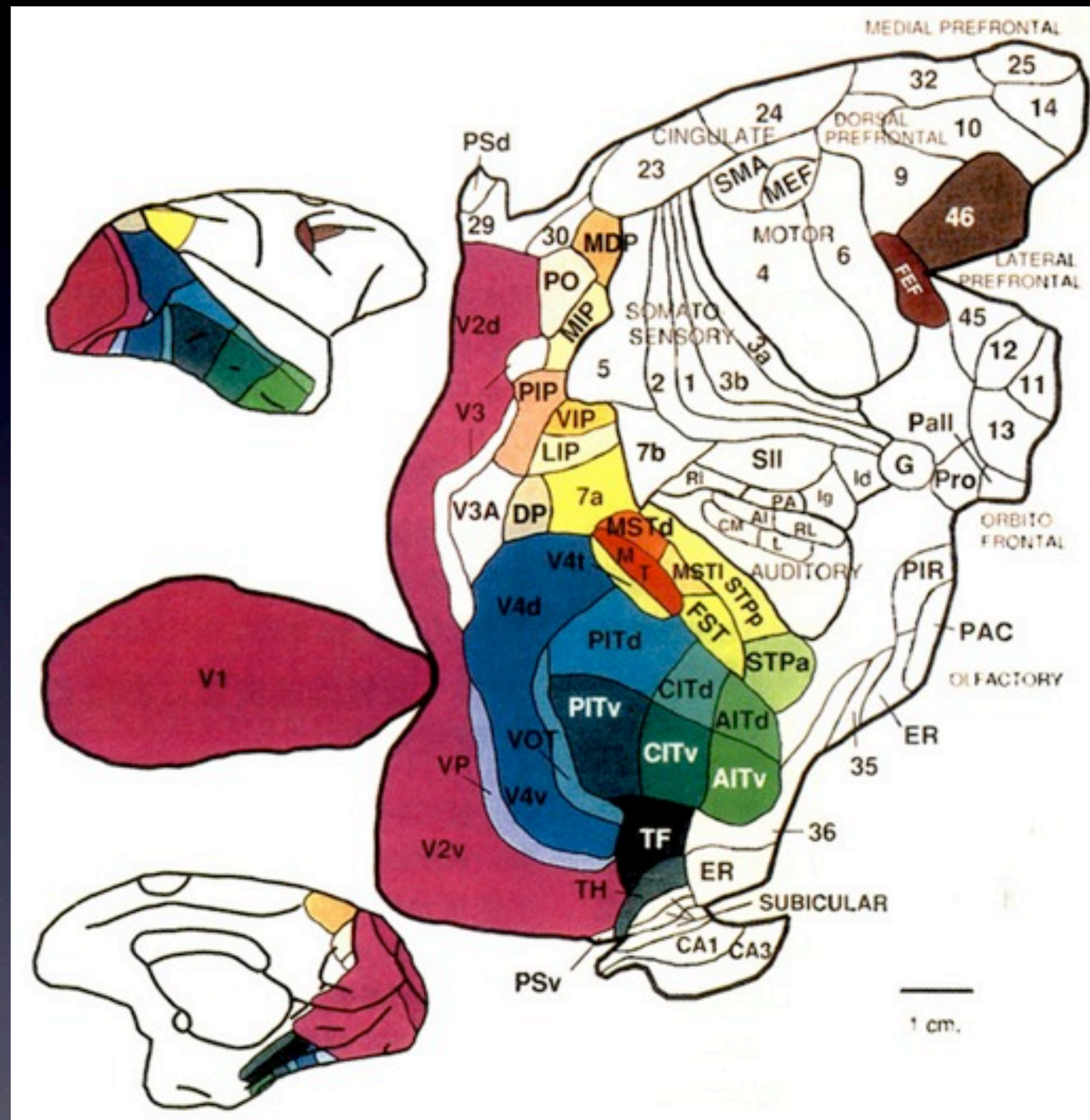
Upper visual field on the lower bank

Foveal visual field magnified



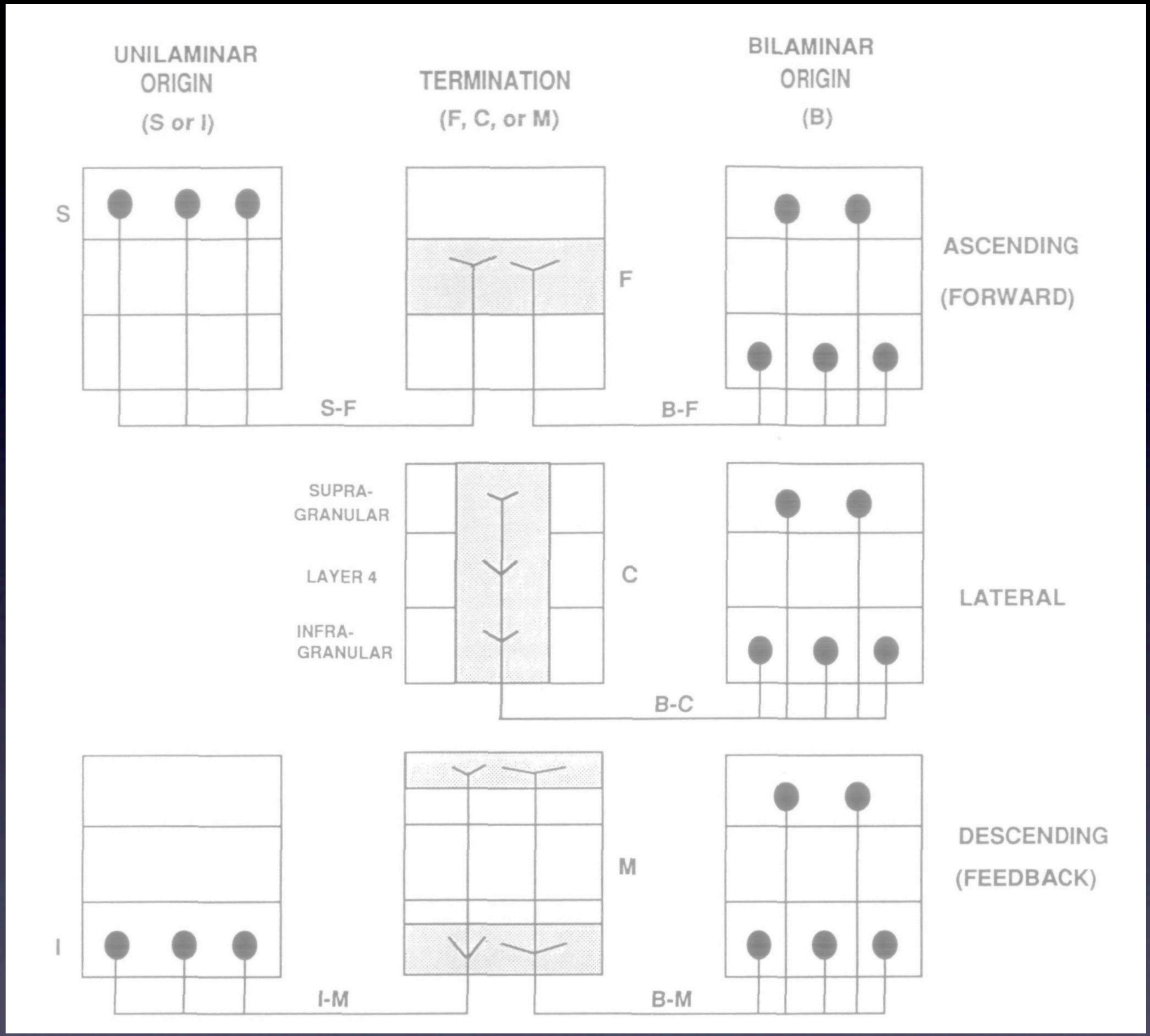
Modern reconstruction of Inouye's map by Jonathan Horton

(F)unction
(A)rchitectonics
(C)onnections
(T)opography

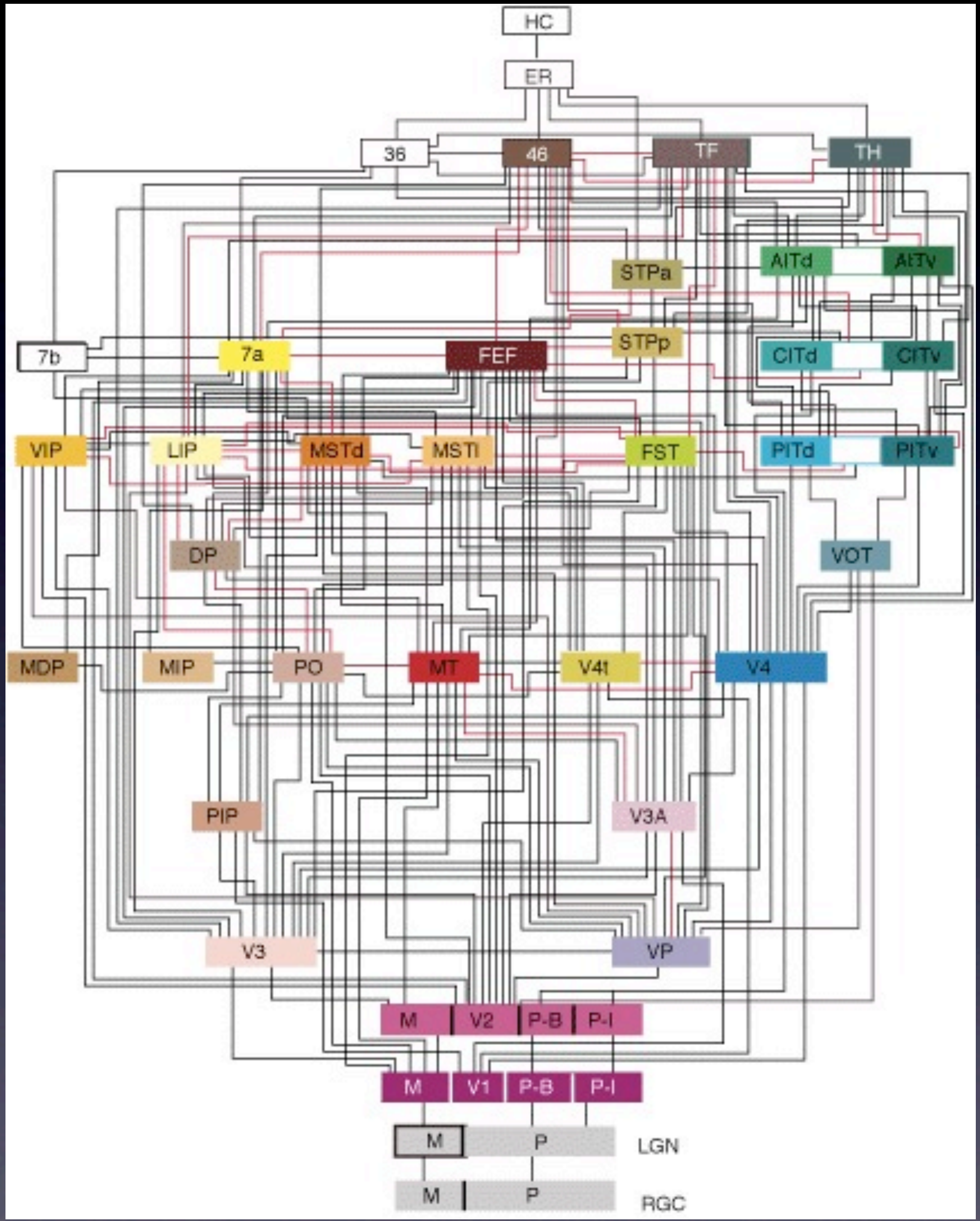


Felleman & Van Essen (1991) Cerebral Cortex 1:1-47

Ascending, descending and lateral connections



Felleman & Van Essen (1991) Cerebral Cortex 1:1-47



Felleman & Van Essen (1991) Cerebral Cortex 1:1-47

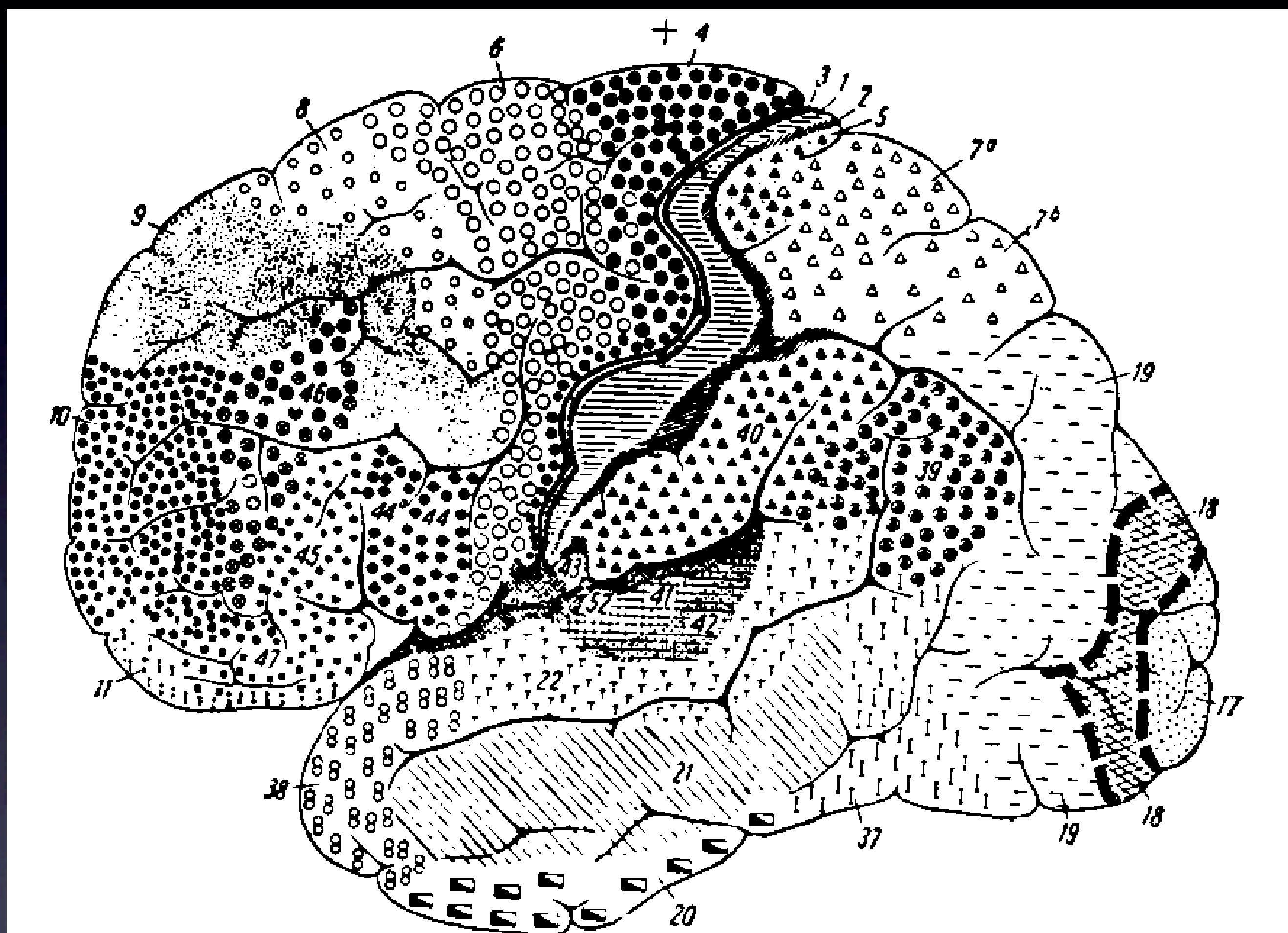
(F)unction

(A)rchitectonics

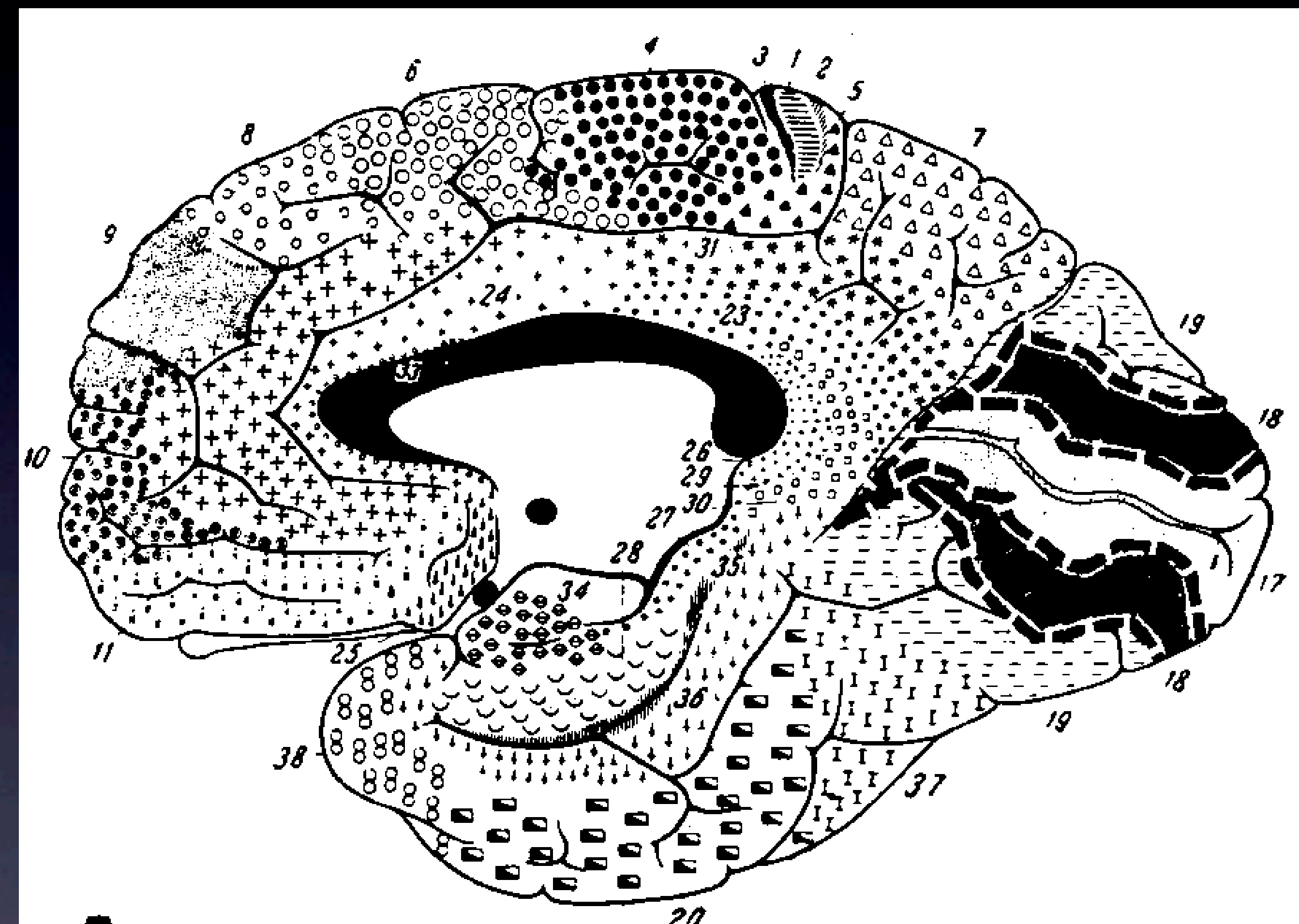
(C)onnections

(T)opography

Lateral

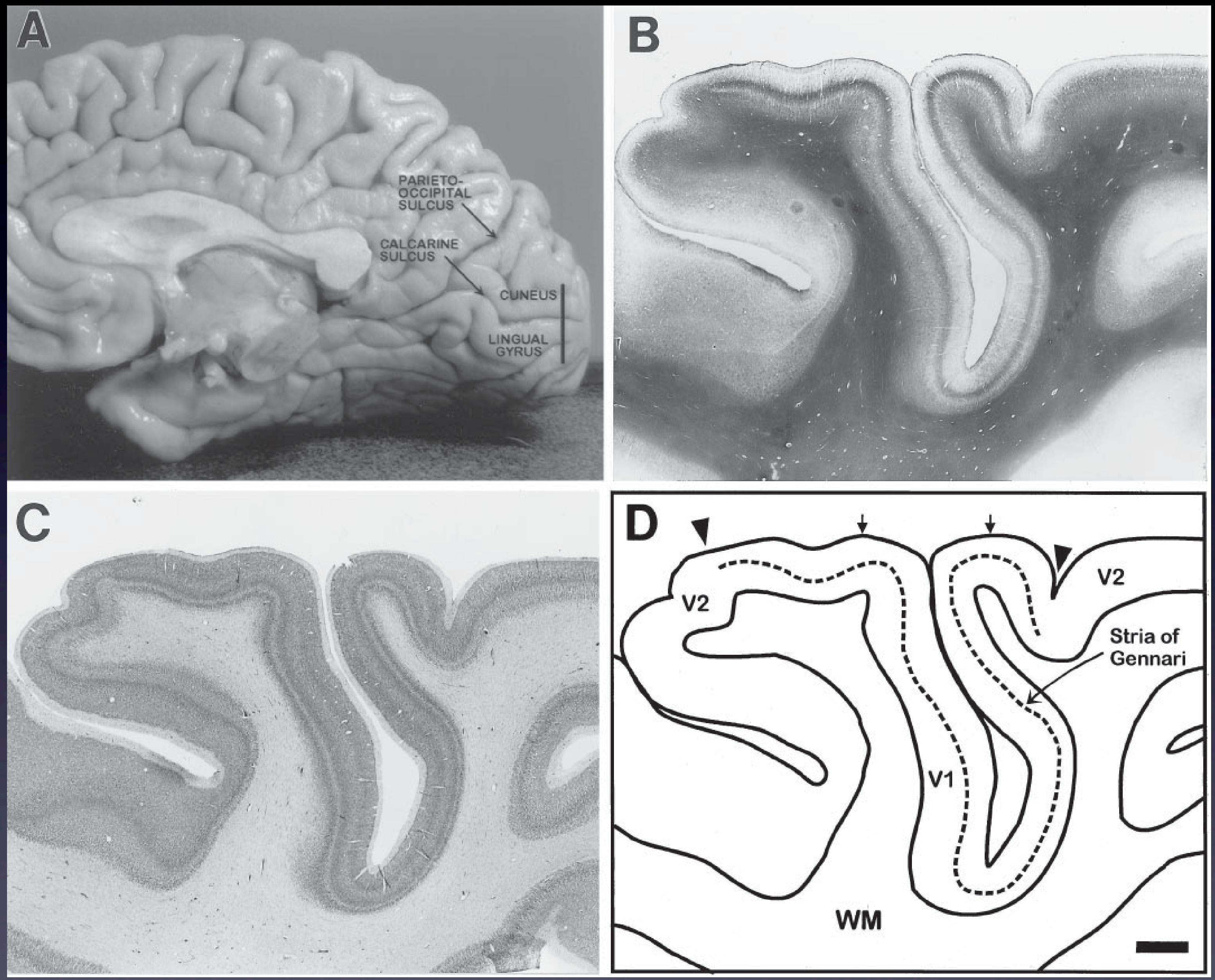


Medial

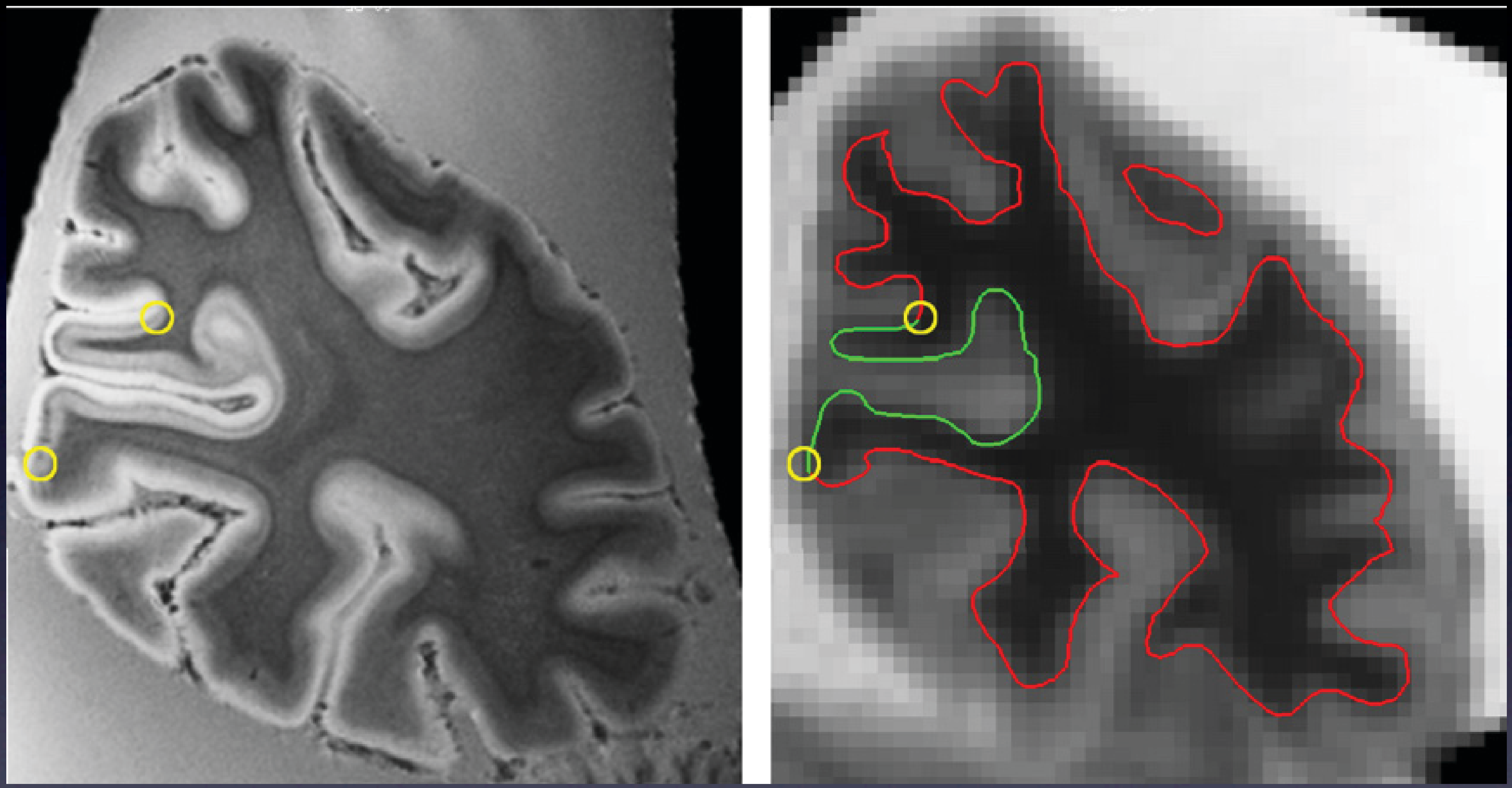


Brodmann 1909

Stria of Gennari (1782)



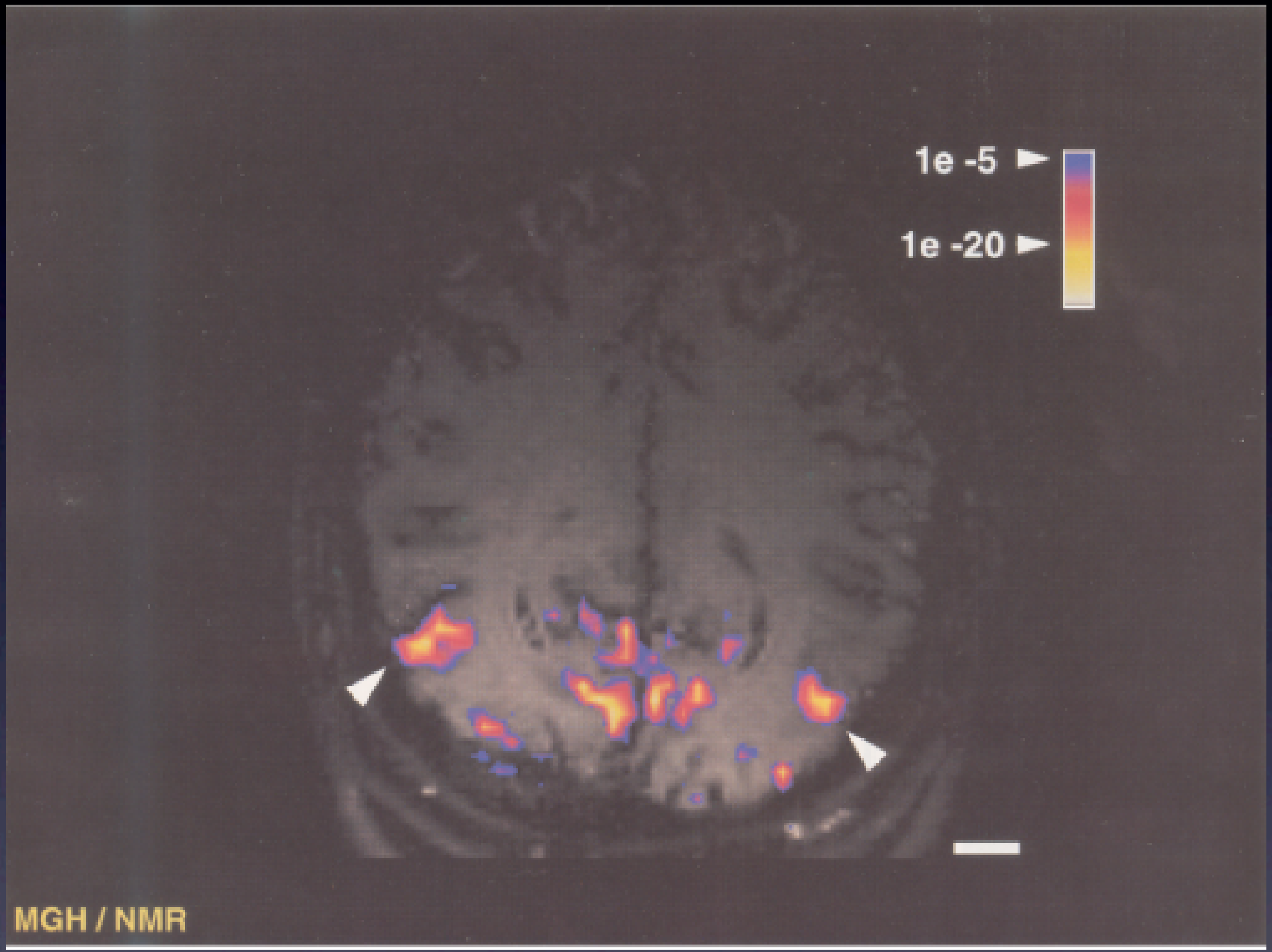
Andrews, Halpren & Purves(1997) JN 17:2859

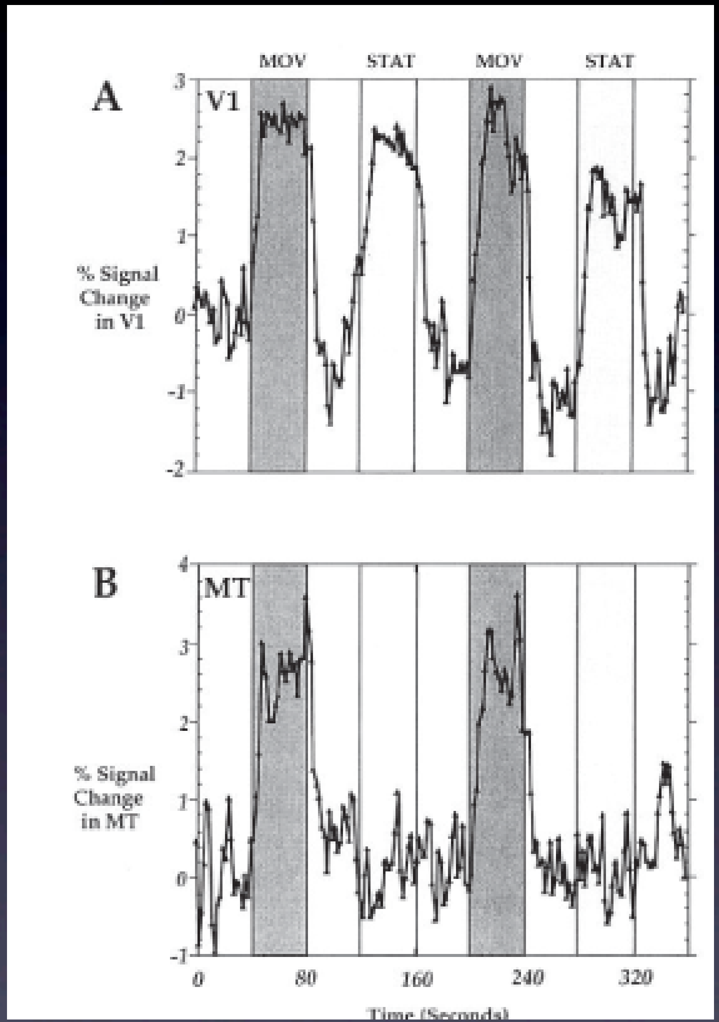


Hinds, Rajendran, Polimeni, Augustinack, Wiggins, Wald, Rosas, Potthast, Schwartz, Fischl (2008) Neuroimage 1585-99

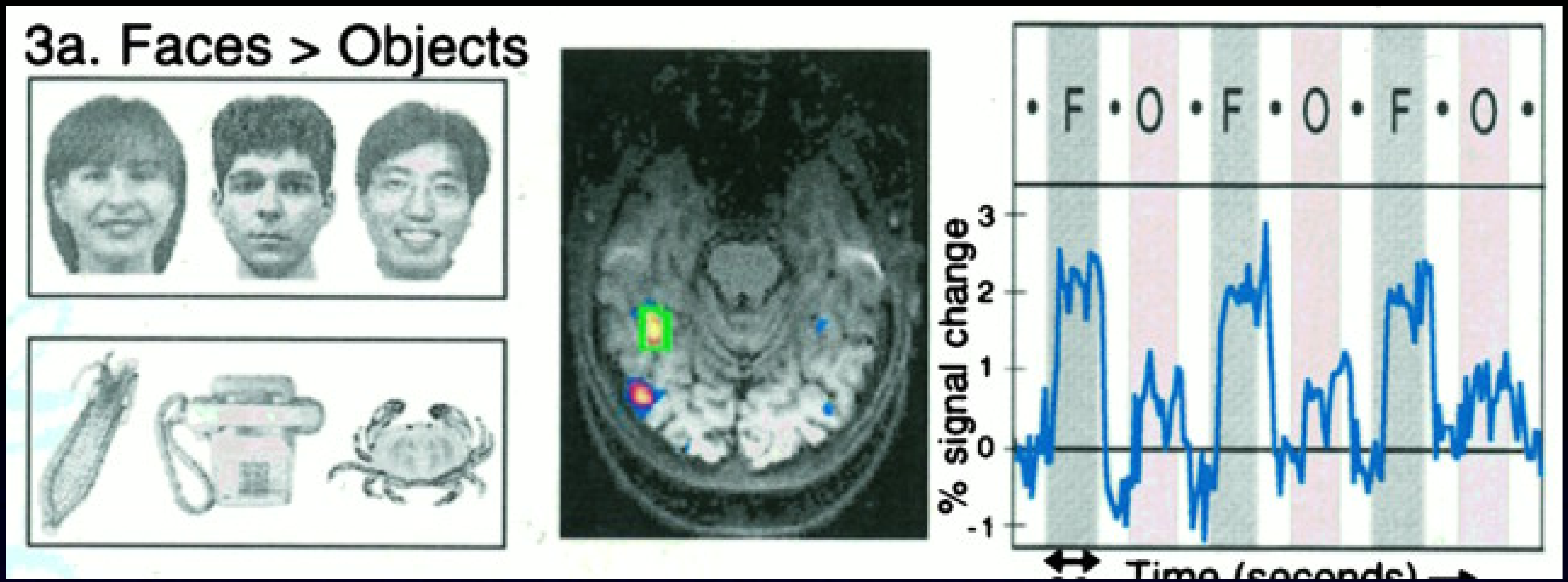
(F)unction
(A)rchitectonics
(C)onnections
(T)opography

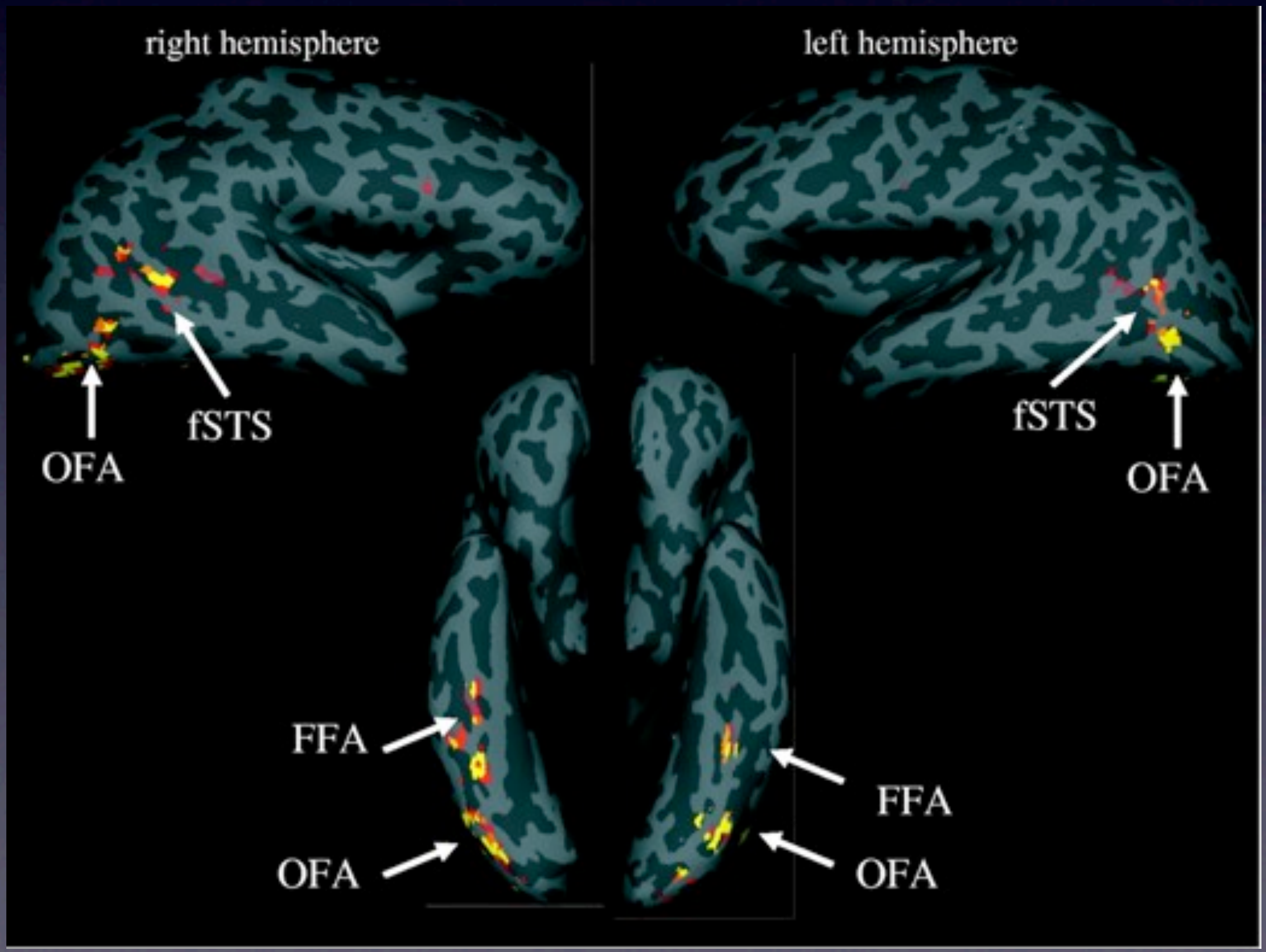
Area MT





Tootell, Reppas, Kwong, Malach, Born, Brady, Rosen, Belliveau (1995) JN 15:3215-3230

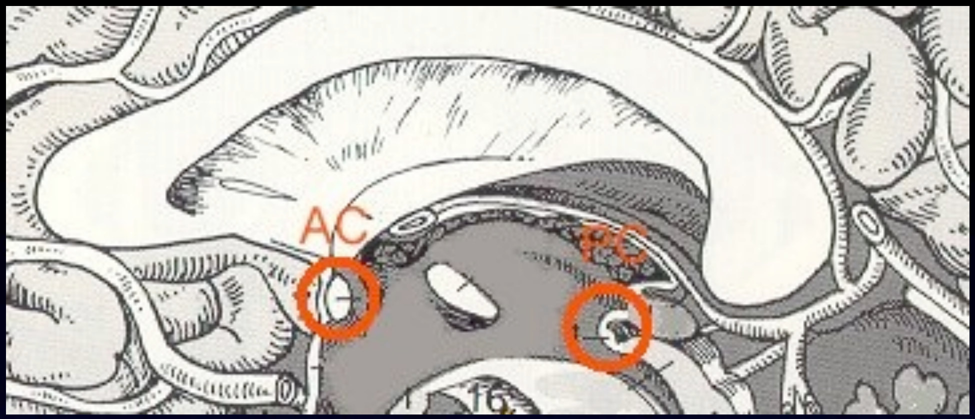


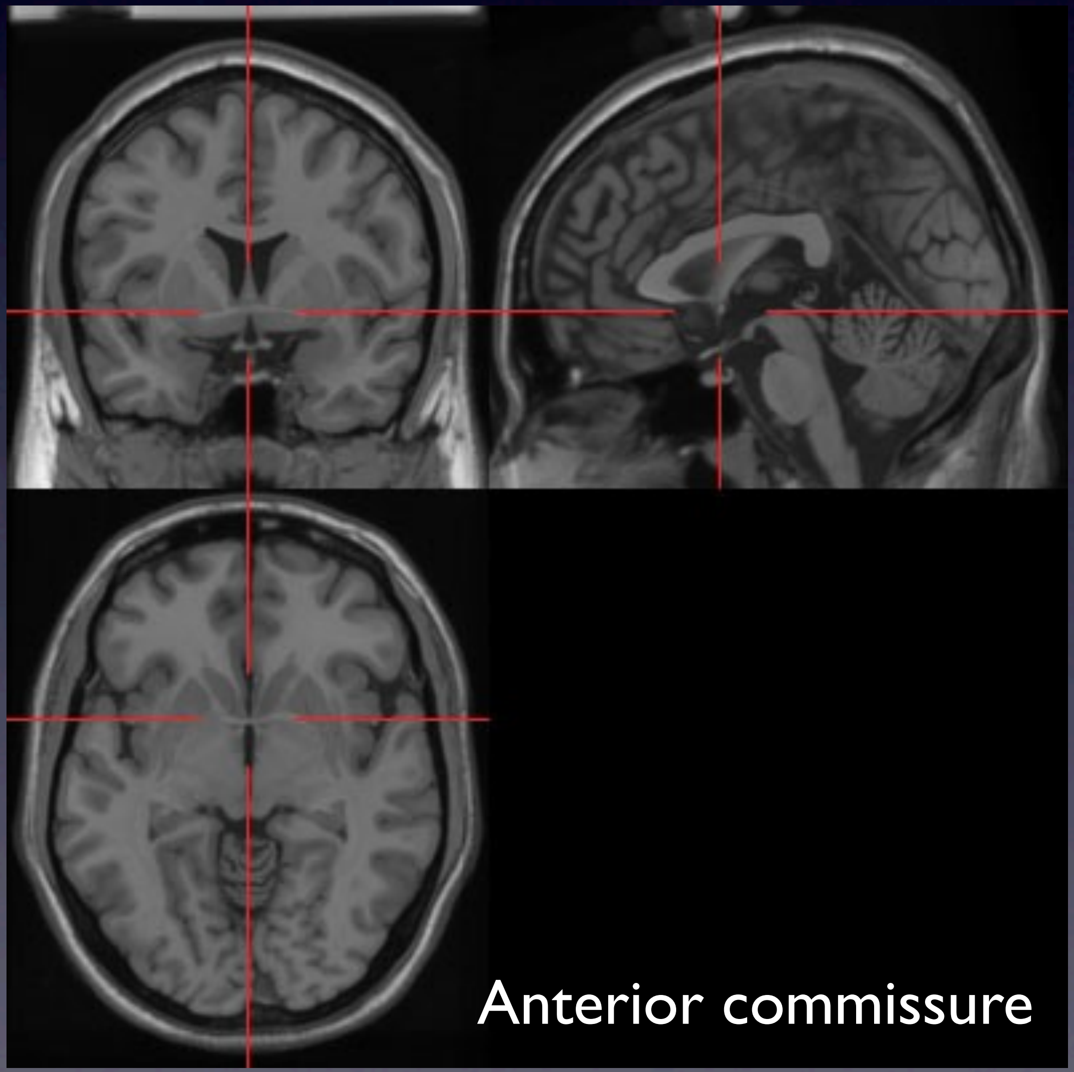


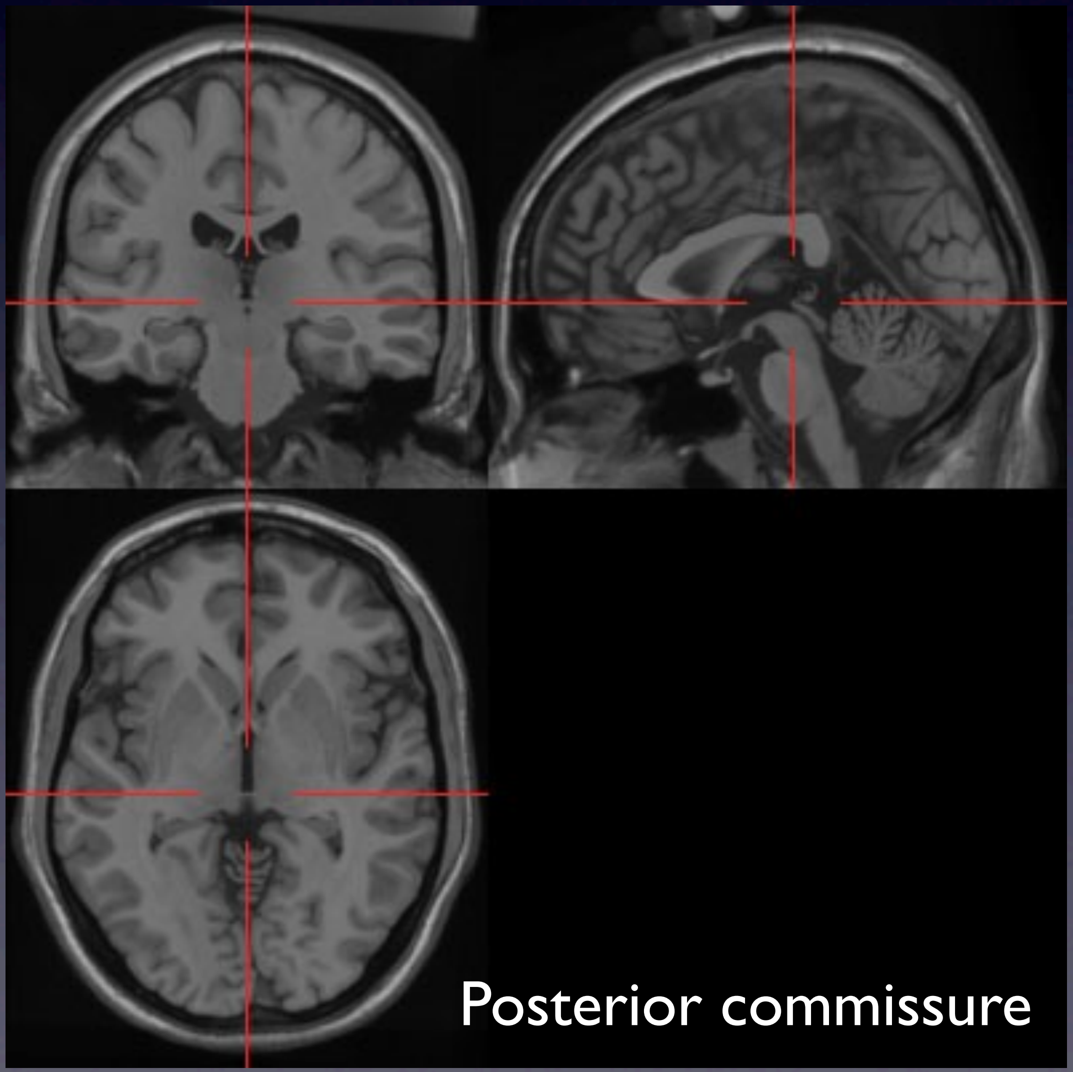
Kanwisher, McDermott & Chun (1997) JN 17:4302-11

Anatomical versus physiological localization of visual areas

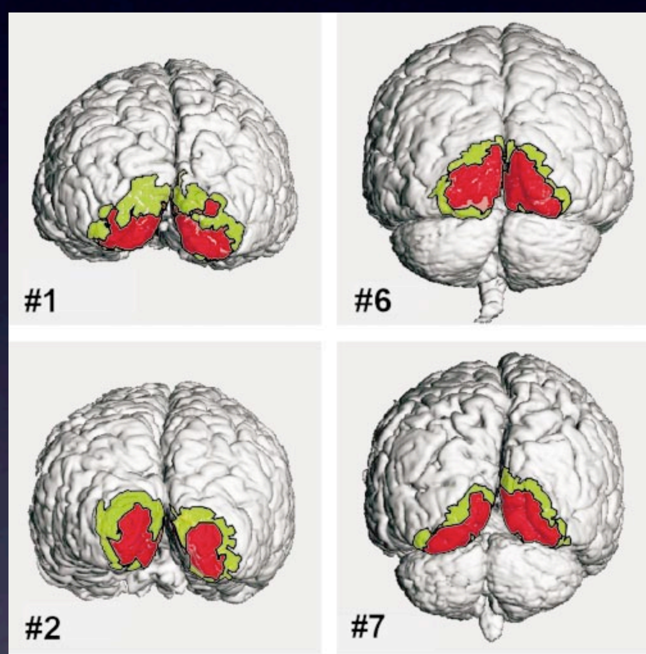
Talairach coordinates - AC/PC

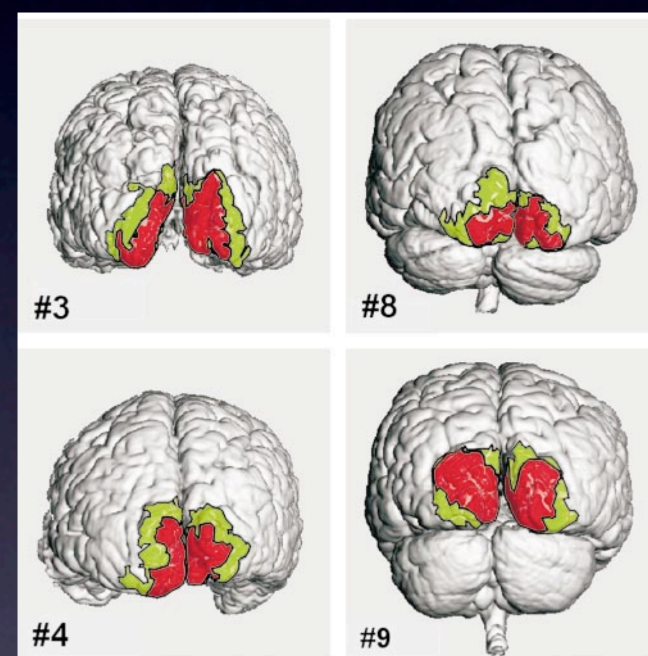


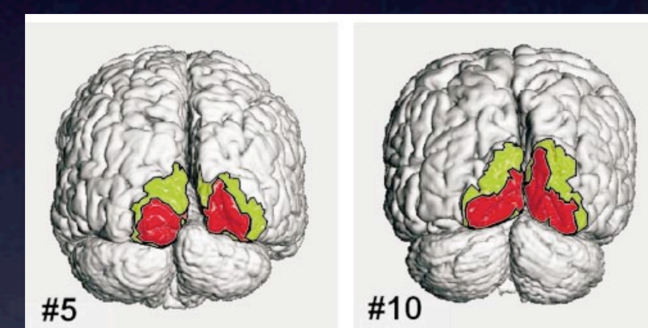




Location of V1 in stereotaxic coordinates is extremely variable

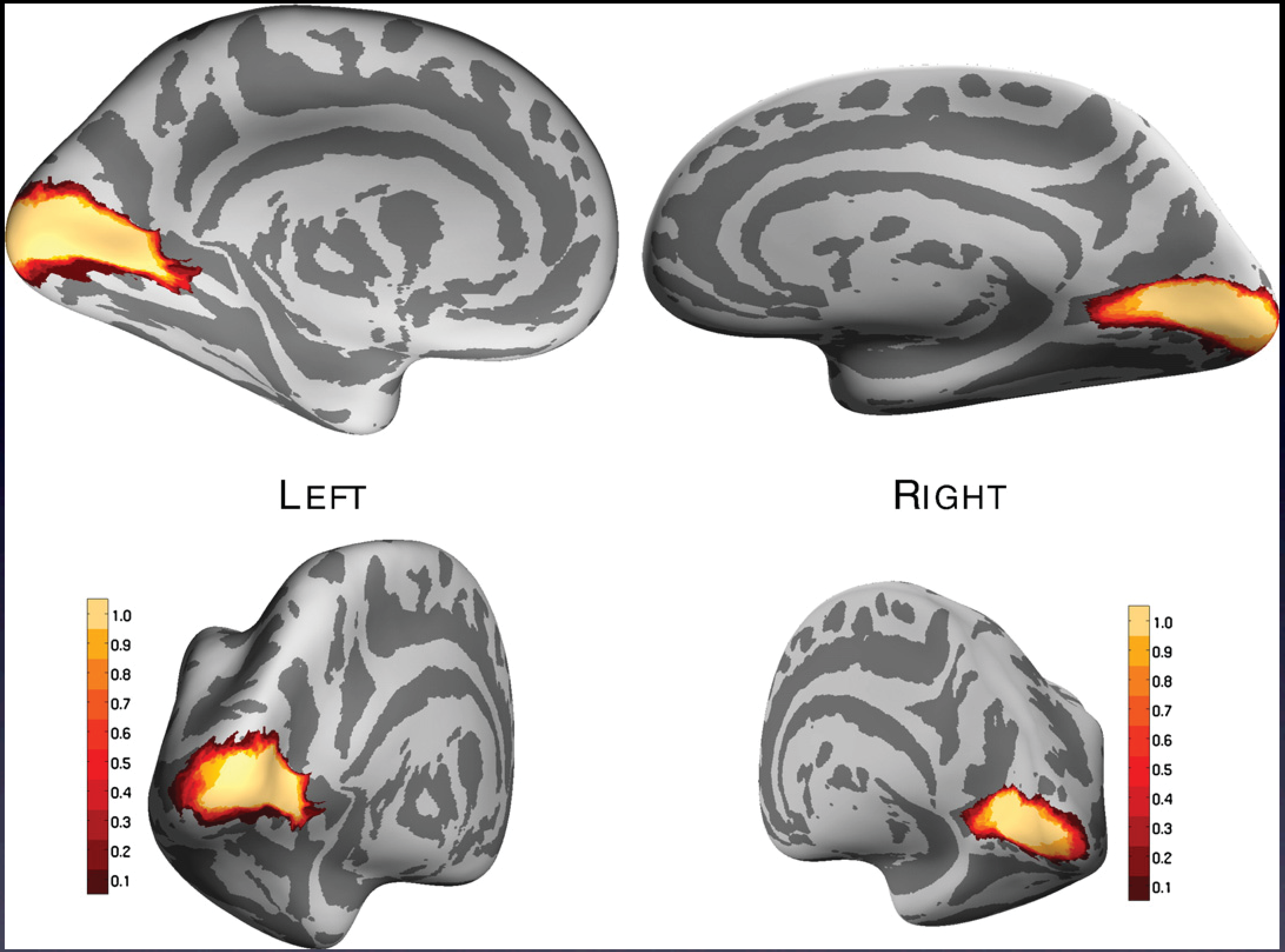






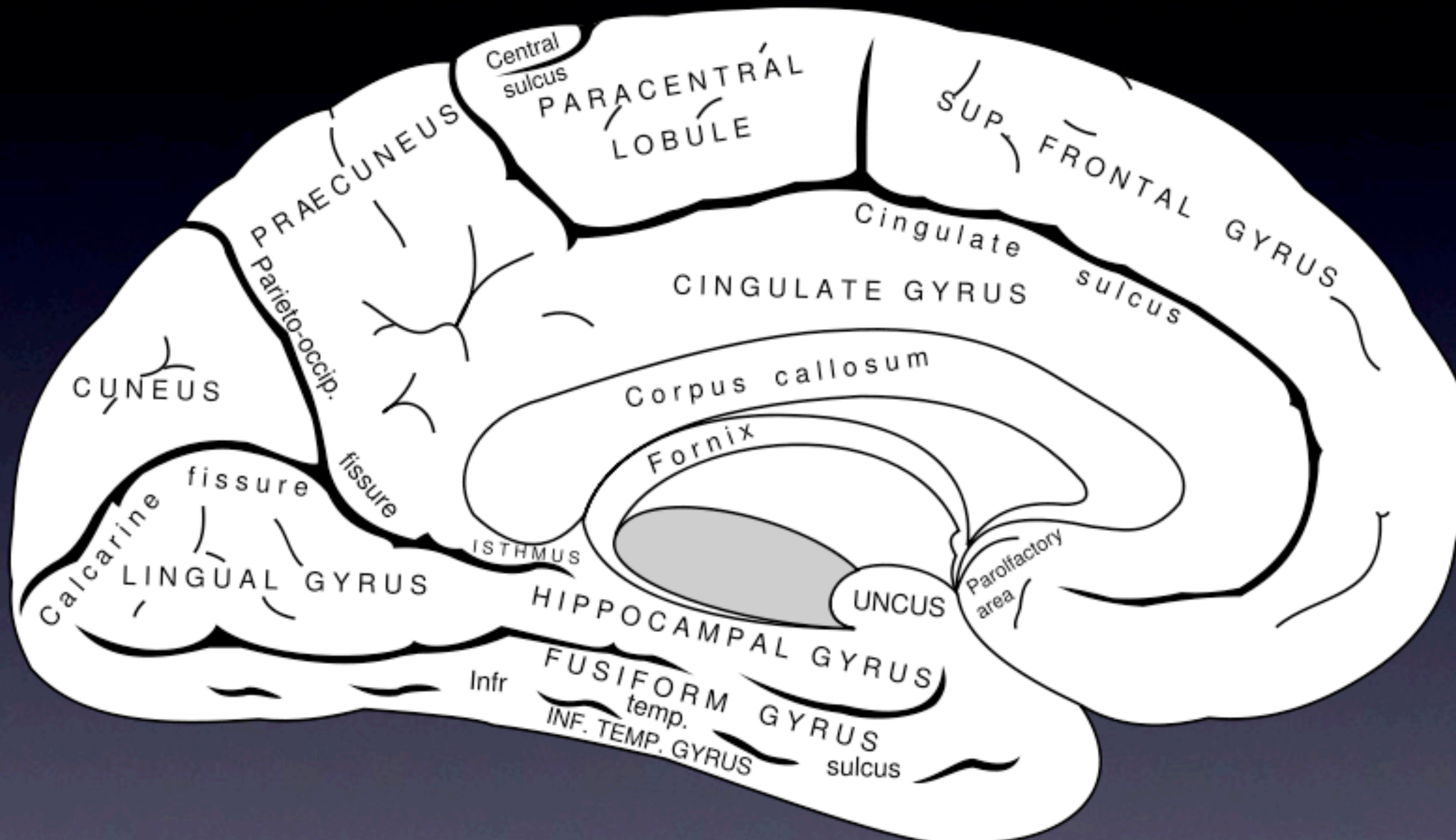
Amunts, Malikovic, Mholberg, Schormann & Zilles (2000) Neuroimage 11:66-84

“Surface based alignment” may help

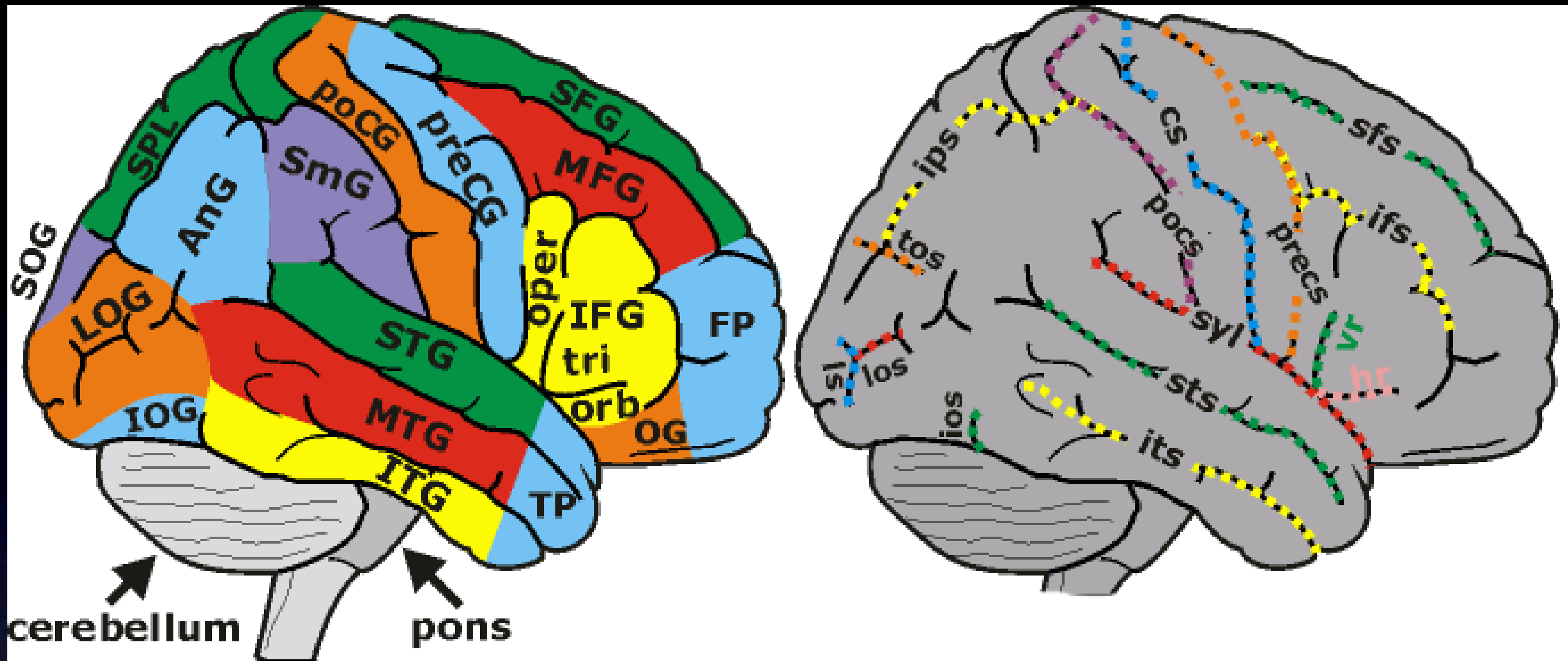


Hinds, Rajendran, Polimeni, Augustinack, Wiggins, Wald, Rosas, Potthast, Schwartz, Fischl (2008) Neuroimage 1585-99

Sulci/gyri on the medial surface of the brain

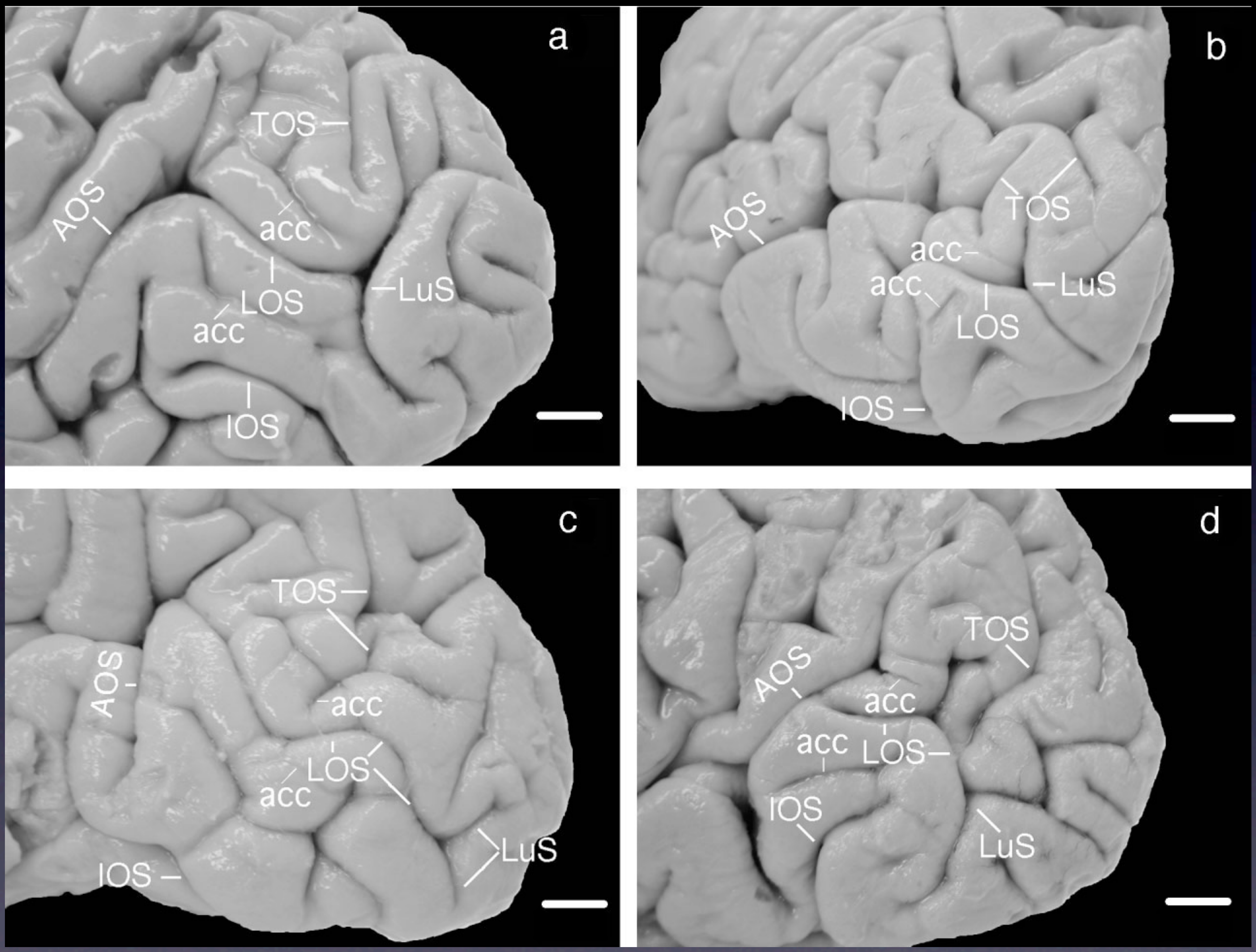


Sulci/gyri on the lateral surface



Nickname:	Lateral Gyri	Nickname:	Lateral Sulci	Nickname:	Medial Landmarks
AnG	angular gyrus	cs	central sulcus (Rolandic)	ac	anterior commissure
	cerebellum	hr	horizontal ramus	cals	calcarine sulcus
FP	frontal pole	ifs	inferior frontal sulcus	cings	cingulate sulcus
IFG	inferior frontal gyrus	ios	inferior occipital sulcus	CingG	cingulate gyrus
IOG	inferior occipital gyrus	ips	intraparietal sulcus	ccb	corpus callosum (body)
ITG	inferior temporal gyrus	syl	lateral fissure (Sylvian)	ccg	corpus callosum (genu)
LOG	lateral occipital gyrus	los	lateral occipital sulcus	ccs	corpus callosum (splenium)
MFG	middle frontal gyrus	ls	lunate sulcus		cuneus
MTG	middle temporal gyrus	pof	parieto-occipital fissure		fornix
OG	orbital gyrus	pocs	postcentral sulcus	lingual	lingual gyrus
	pons	precs	precentral sulcus	mb	mamillary bodies
oper	pars opercularis (IFG)	sfs	superior frontal sulcus	PL	paracentral lobule
orb	pars orbitalis (IFG)	tos	transoccipital sulcus		precuneus
tri	pars triangularis (IFG)	vr	vertical ramus	q	quadrigeminal plate
poCG	postcentral gyrus				
preCG	precentral gyrus				
SFG	superior frontal gyrus				
SOG	superior occipital gyrus				
SPL	superior parietal lobe				
STG	superior temporal gyrus				
SmG	supramarginal gyrus				
TP	temporal pole				

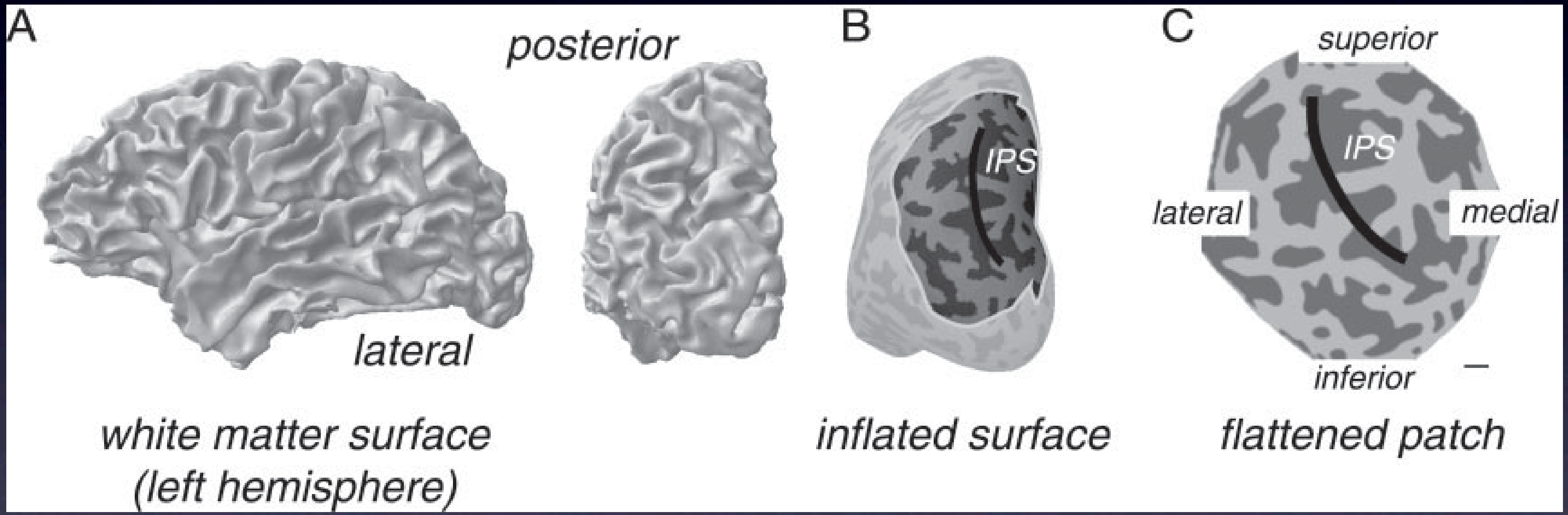
Sulci can be variable!!



Lateral surface of occipital lobe
acc accessory lateral occipital sulci AOS
Anterior occipital sulcus
IOS Inferior occipital sulcus
LOS Lateral occipital sulcus
LuS Lunate sulcus
TOS Transverse occipital sulcus

Iaria & Petrides (2007) JCN 501:243-59

Flat maps



Schluppeck, Glimcher & Heeger (2005) JNP 94:1372-84

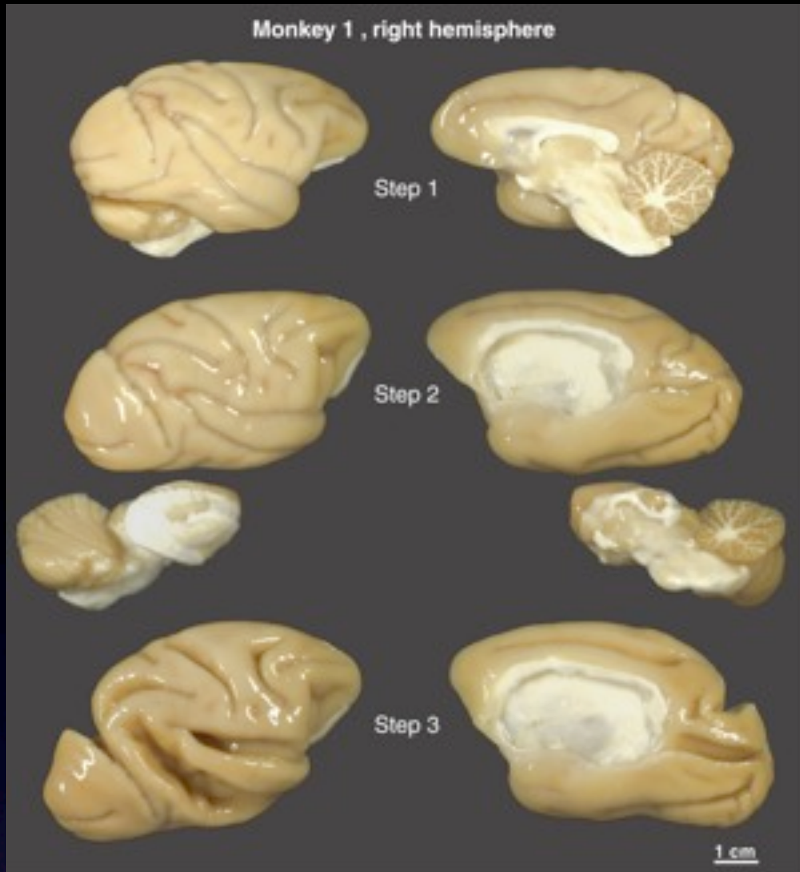


Figure 1, part 1

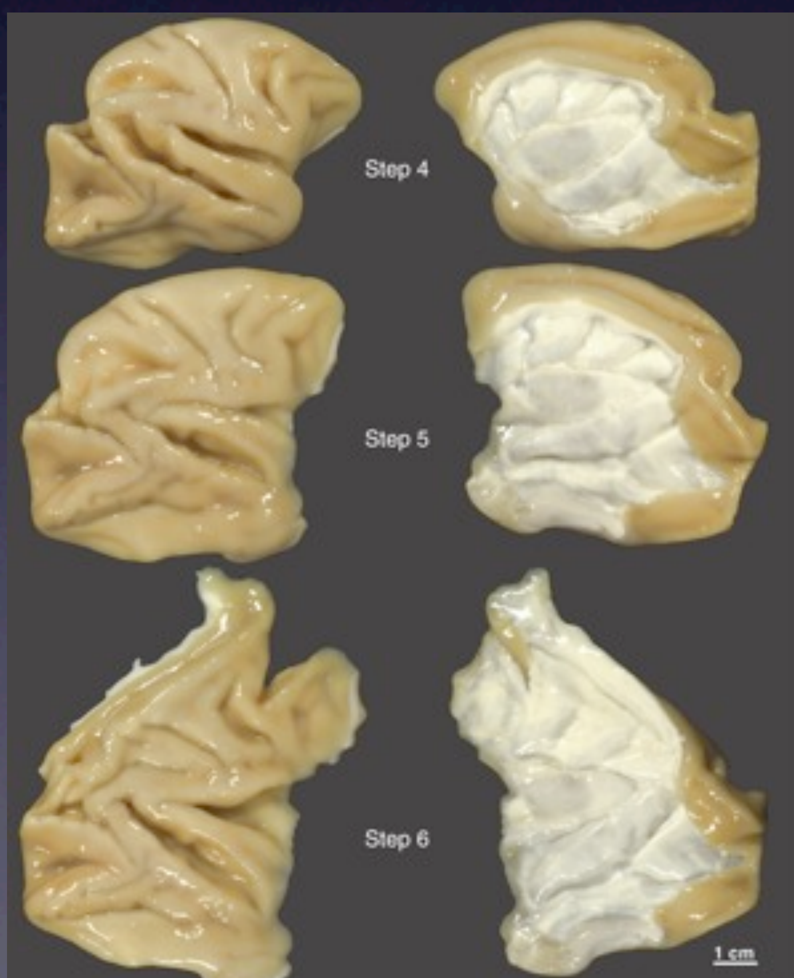


Figure 1, part 3

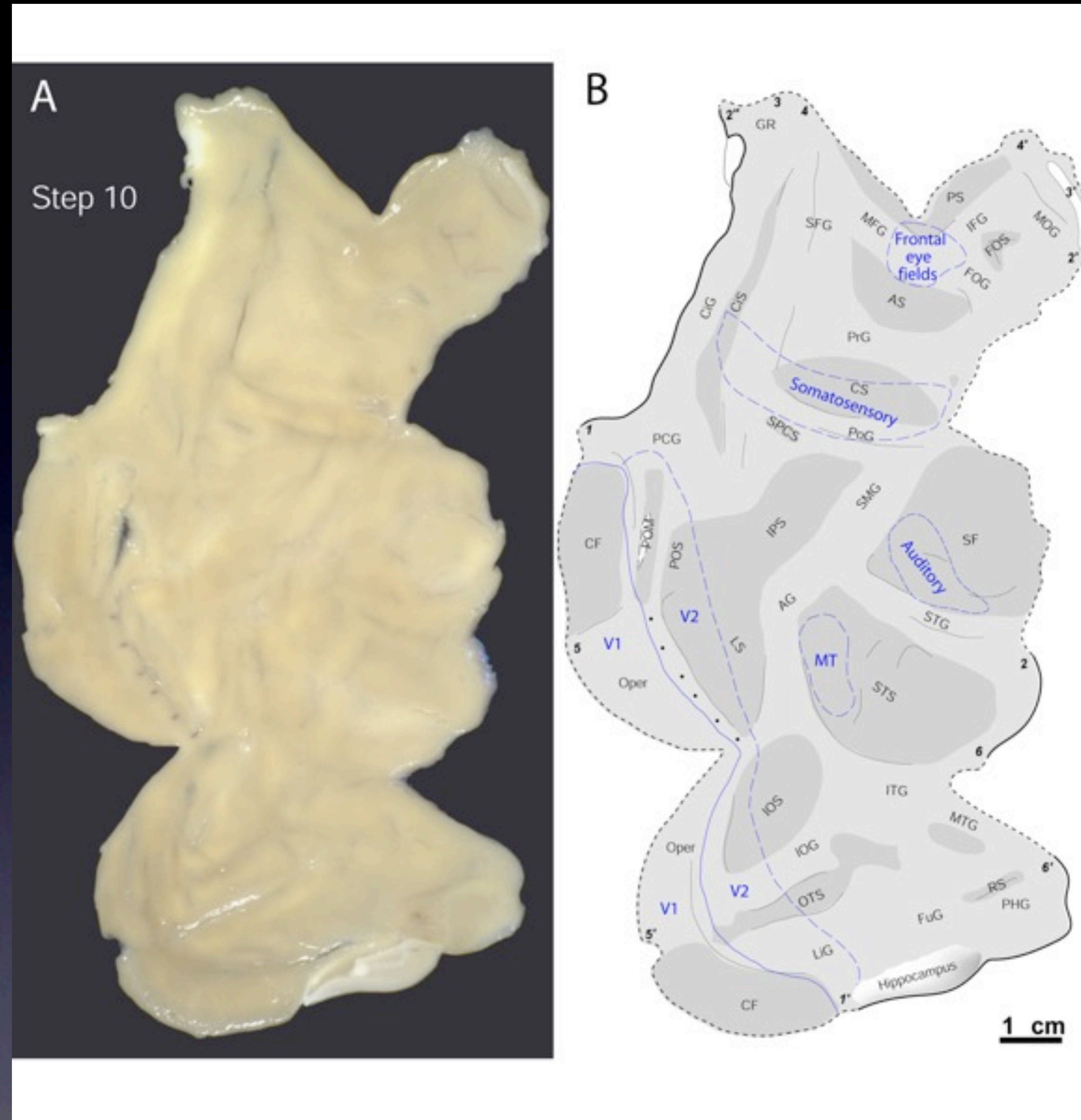
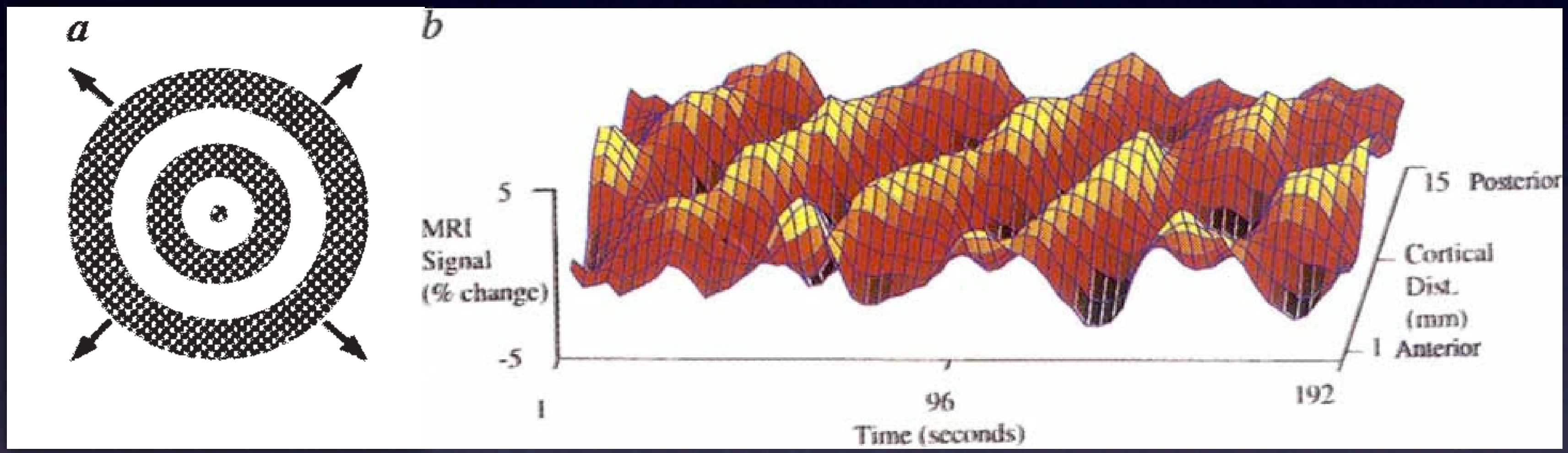


Figure 3

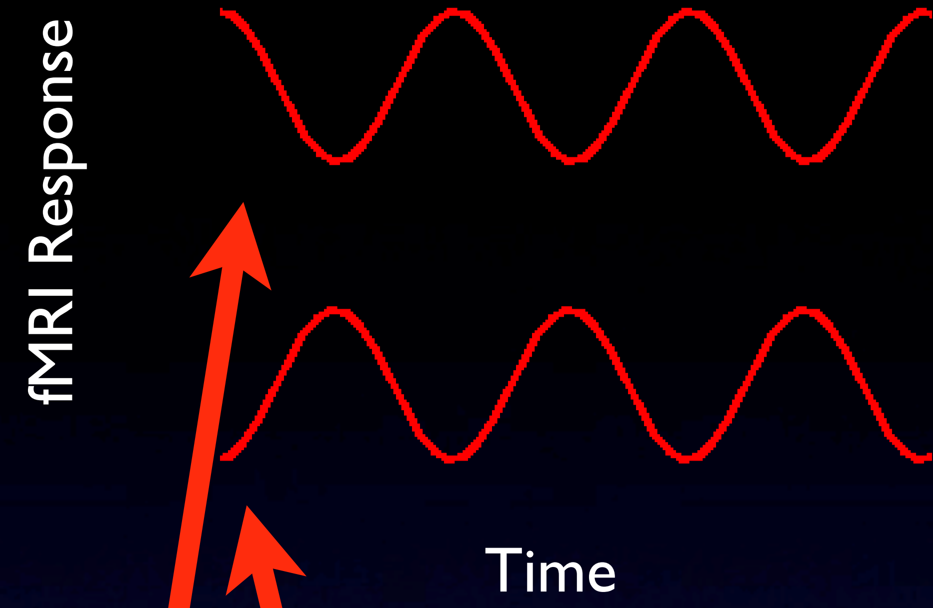
Sincich, Adams & Horton (2003) Vis Neurosci 20: 663-86

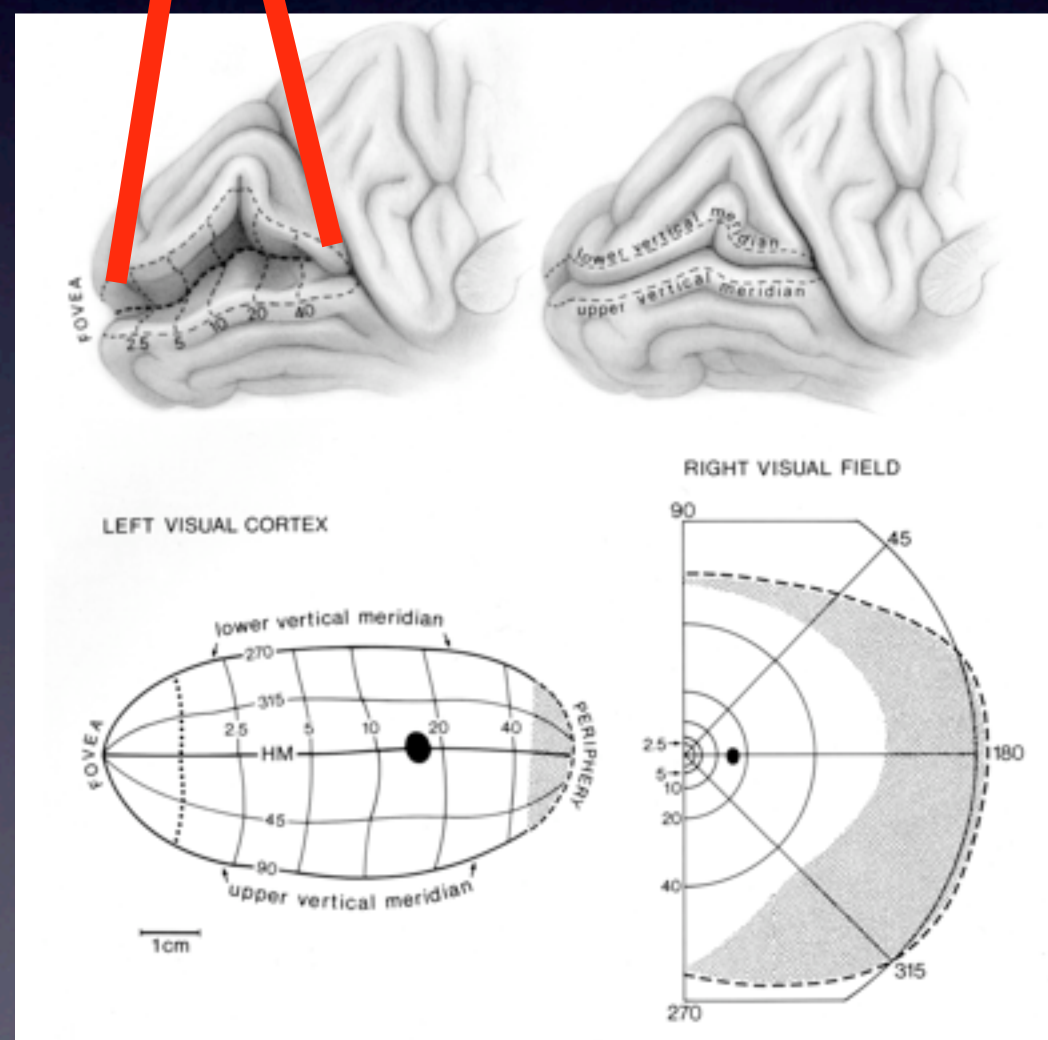
Measuring topography with fMRI

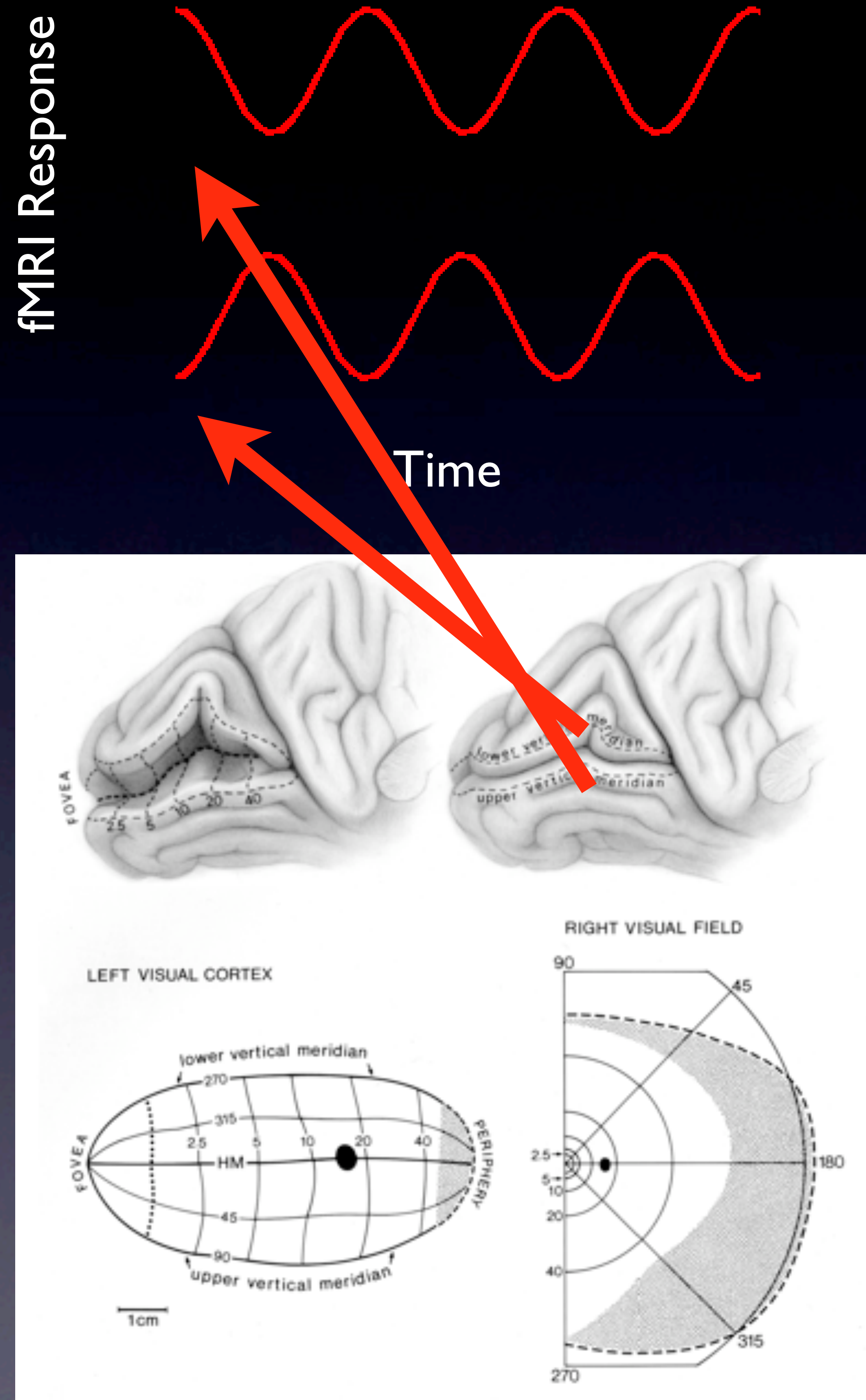
Travelling wave stimulus

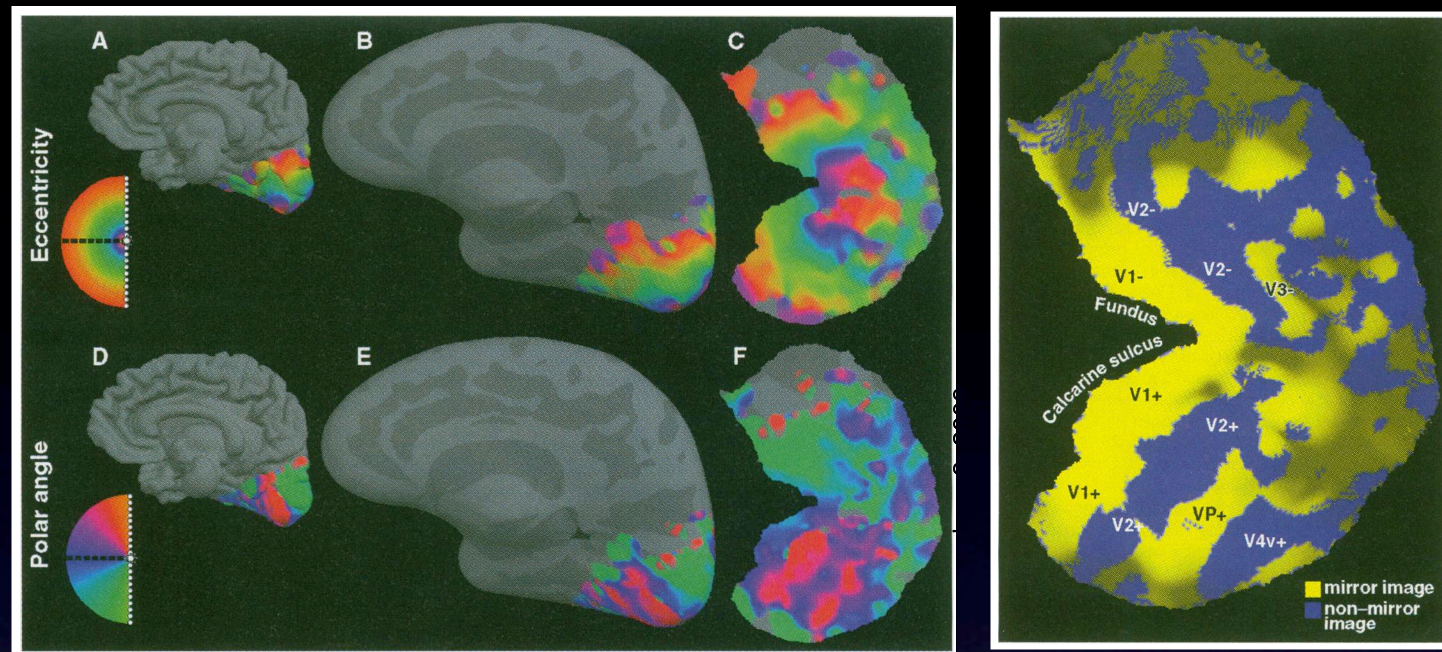


Engel, Rumelhart, Wandell, Lee, Glover, Chichilnisky, Shadlen (1994) Nature 369:525


fMRI Response
Time

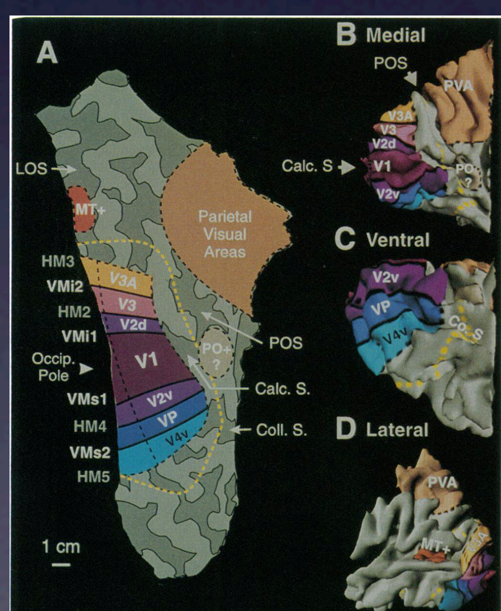

FOVEA
2.5
5
10
20
40
lower vertical meridian
upper vertical meridian
LEFT VISUAL CORTEX
RIGHT VISUAL FIELD
270
315
HM
45
90
PERIPHERY
1cm
180


fMRI Response
Time
LEFT VISUAL CORTEX
RIGHT VISUAL FIELD
lower vertical meridian
upper vertical meridian
FOVEA
PERIPHERY
HM
1cm
90
45
180
315
270

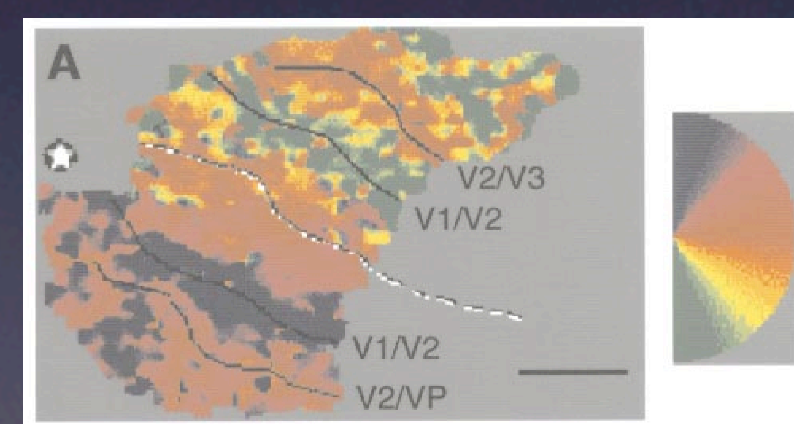


Sereno, Dale, Reppas, Kwong, Belliveau, Brady, Rosen & Tootell (1995) Science 268:889-93

Note: VP is V3v

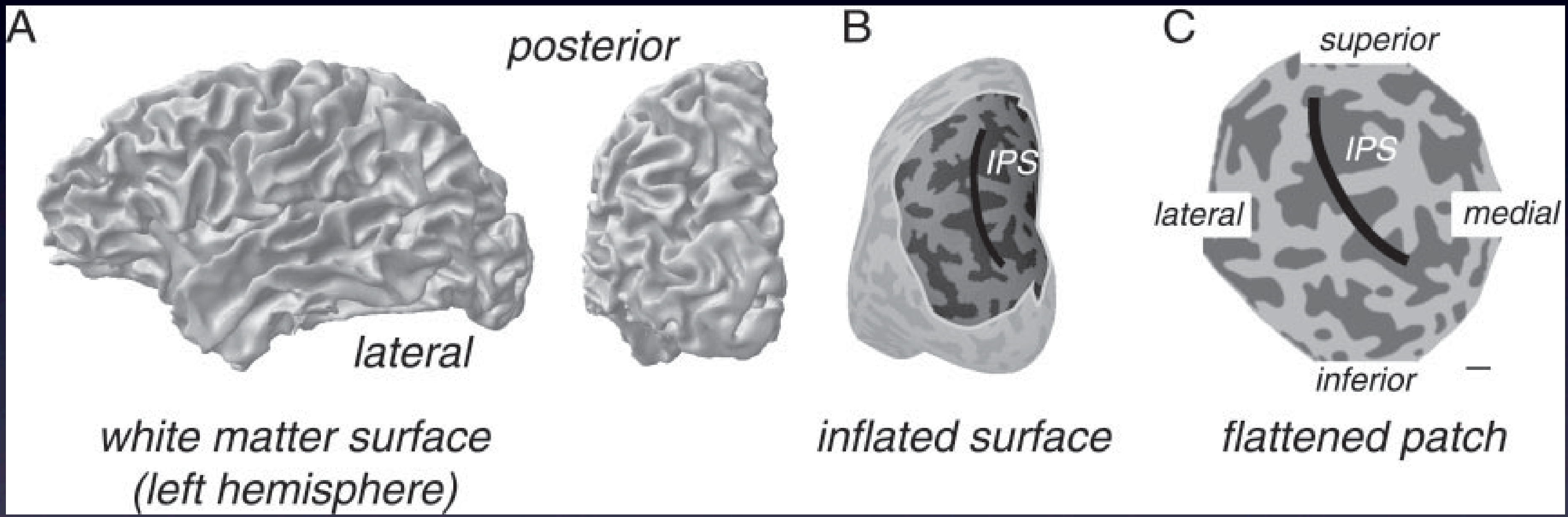


DeYoe, Carman, Bandettini, Glickman, Wieser, Cox, Miller & Neitz (1996) PNAS 92:2382-86

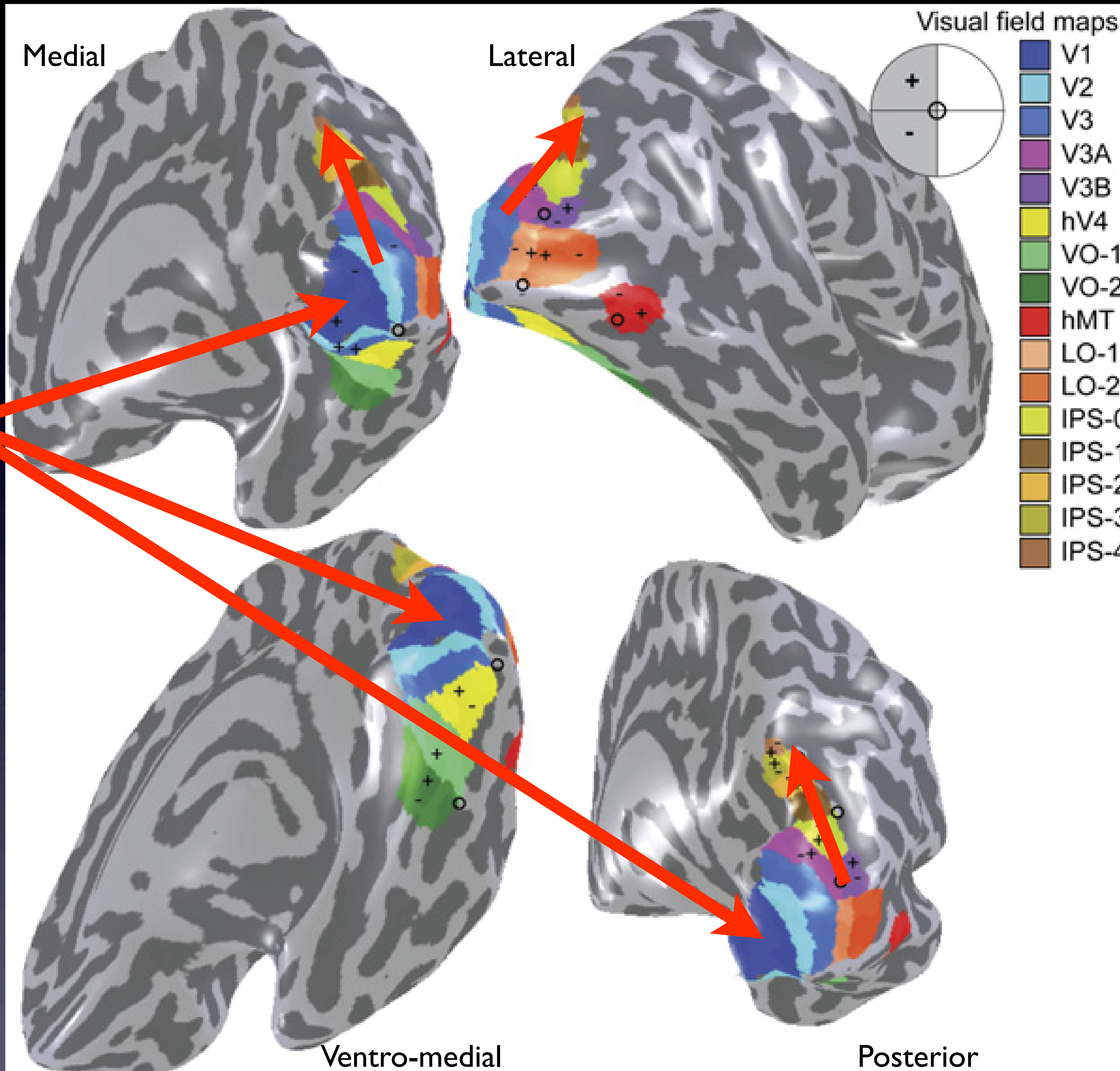


Engel, Glover & Wandell (1997) Cereb Cortex 7: 181-192

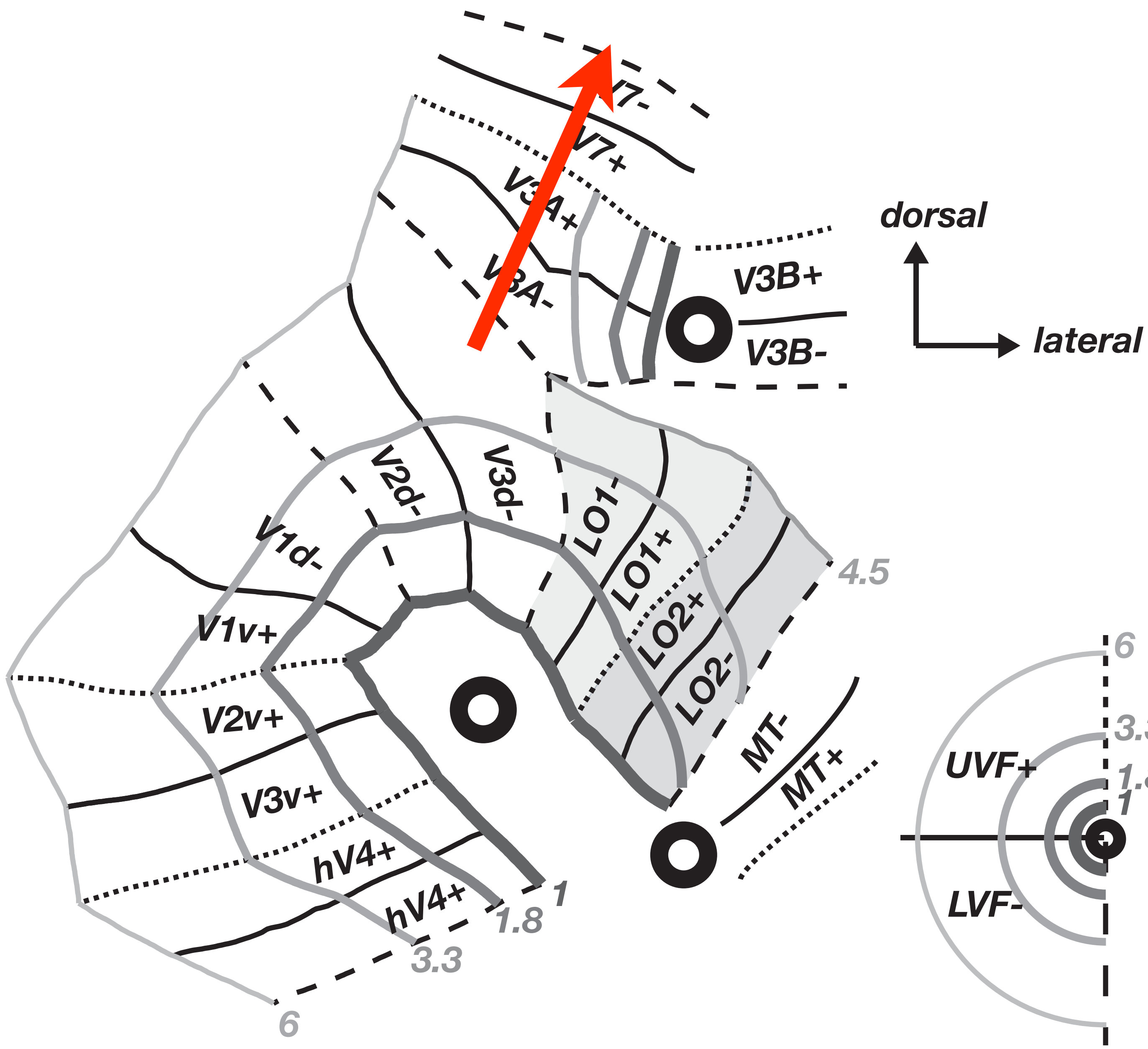
Topographic areas in the intraparietal sulcus



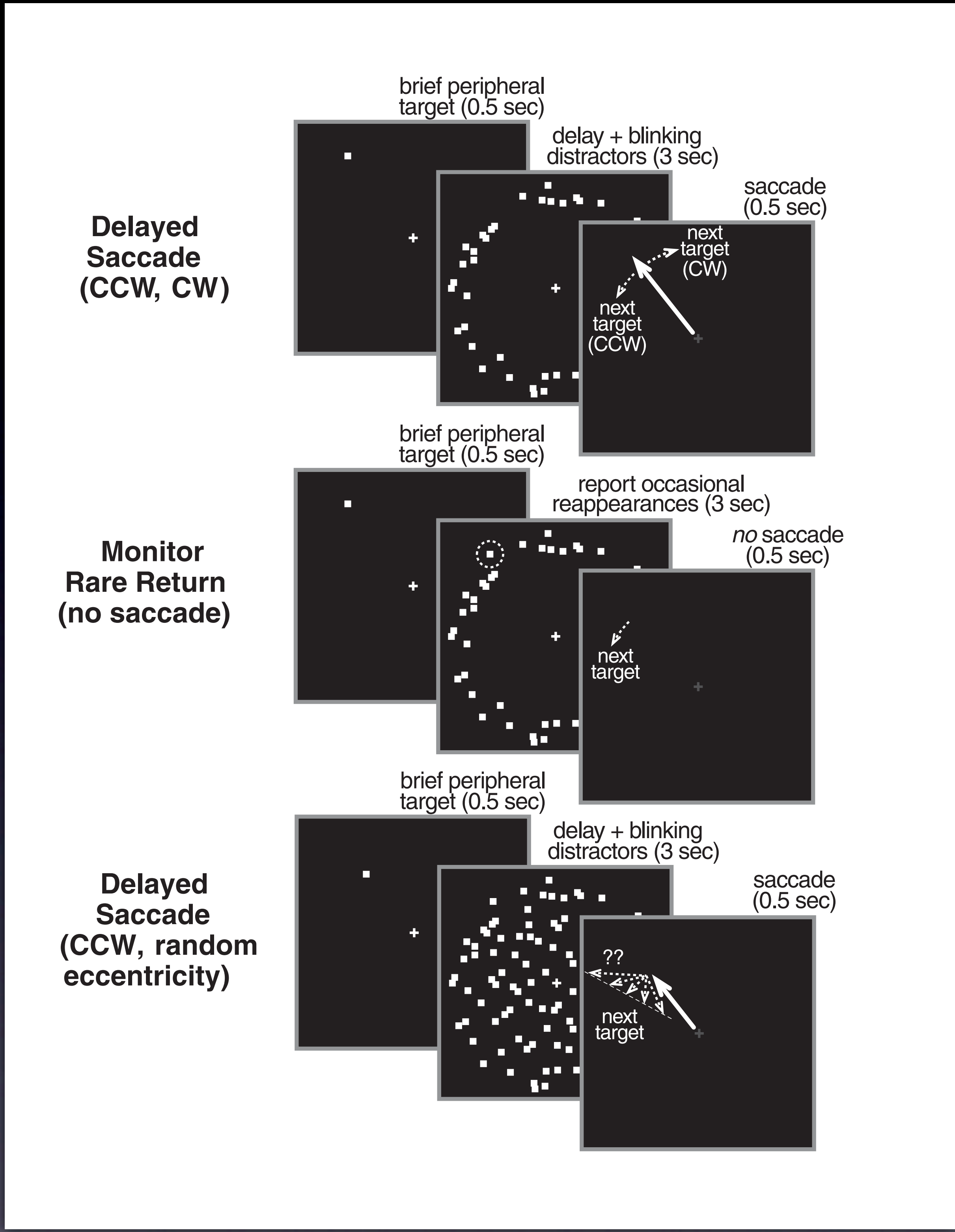
V1



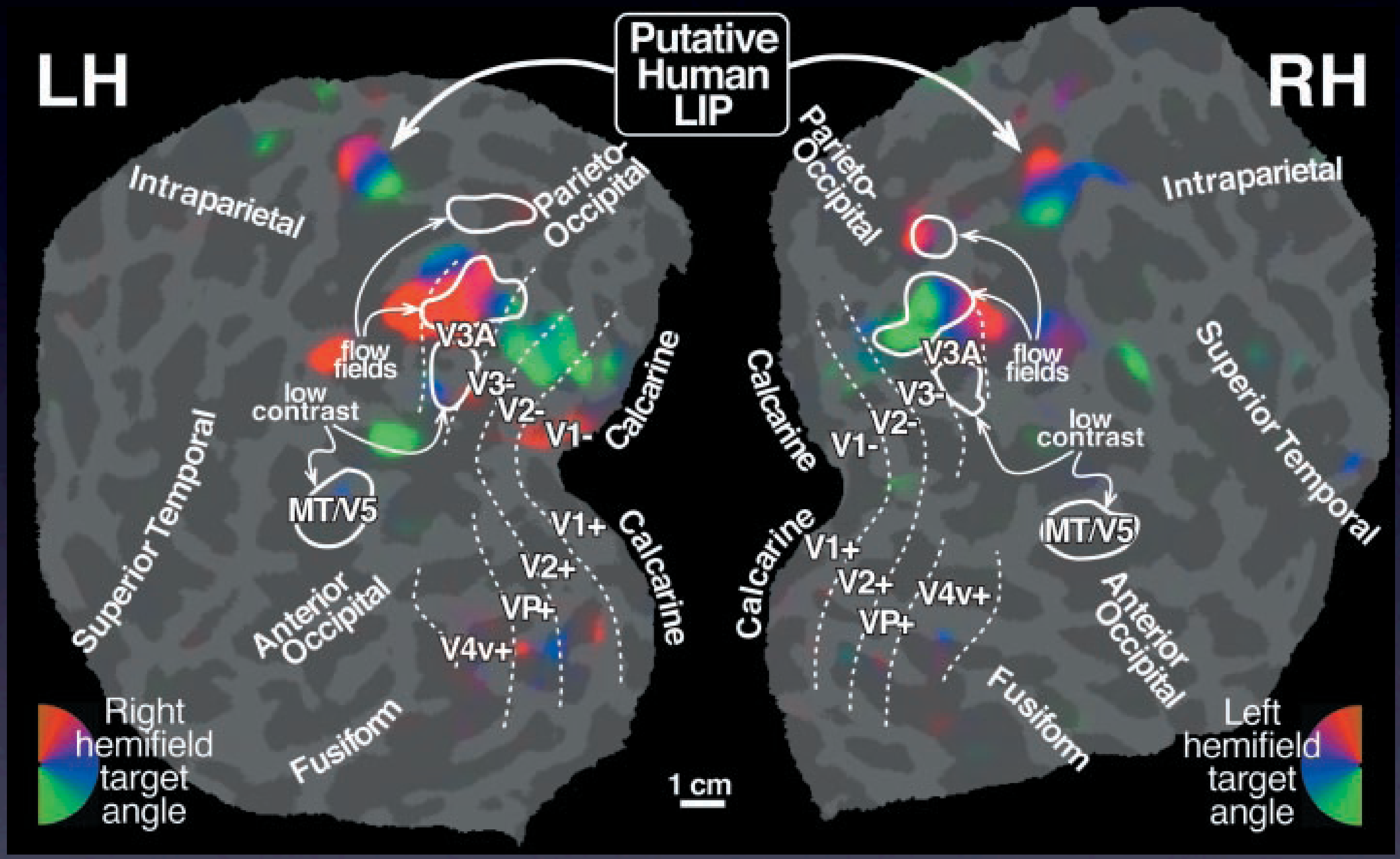
Right cortex



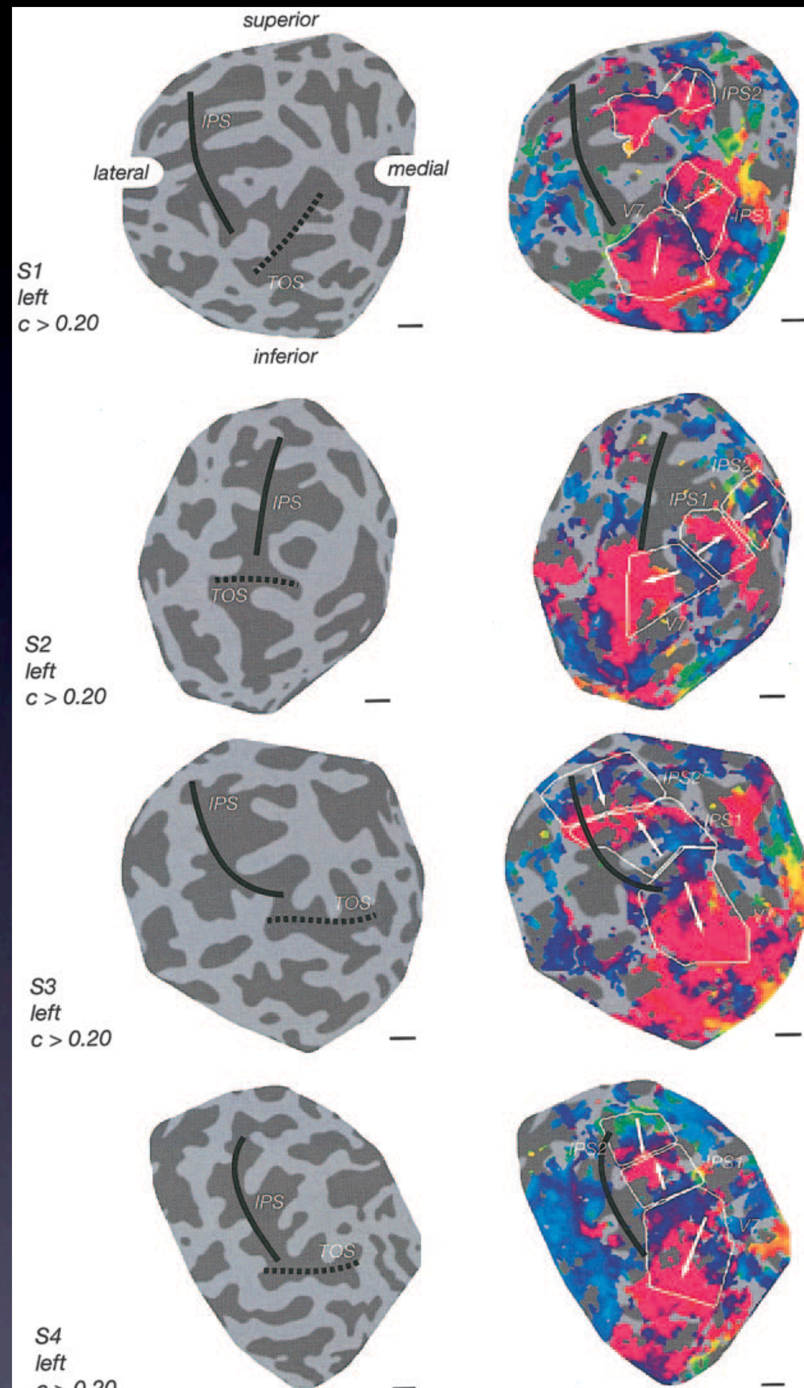
Larsson & Heeger (2006) JN 26:13128-42

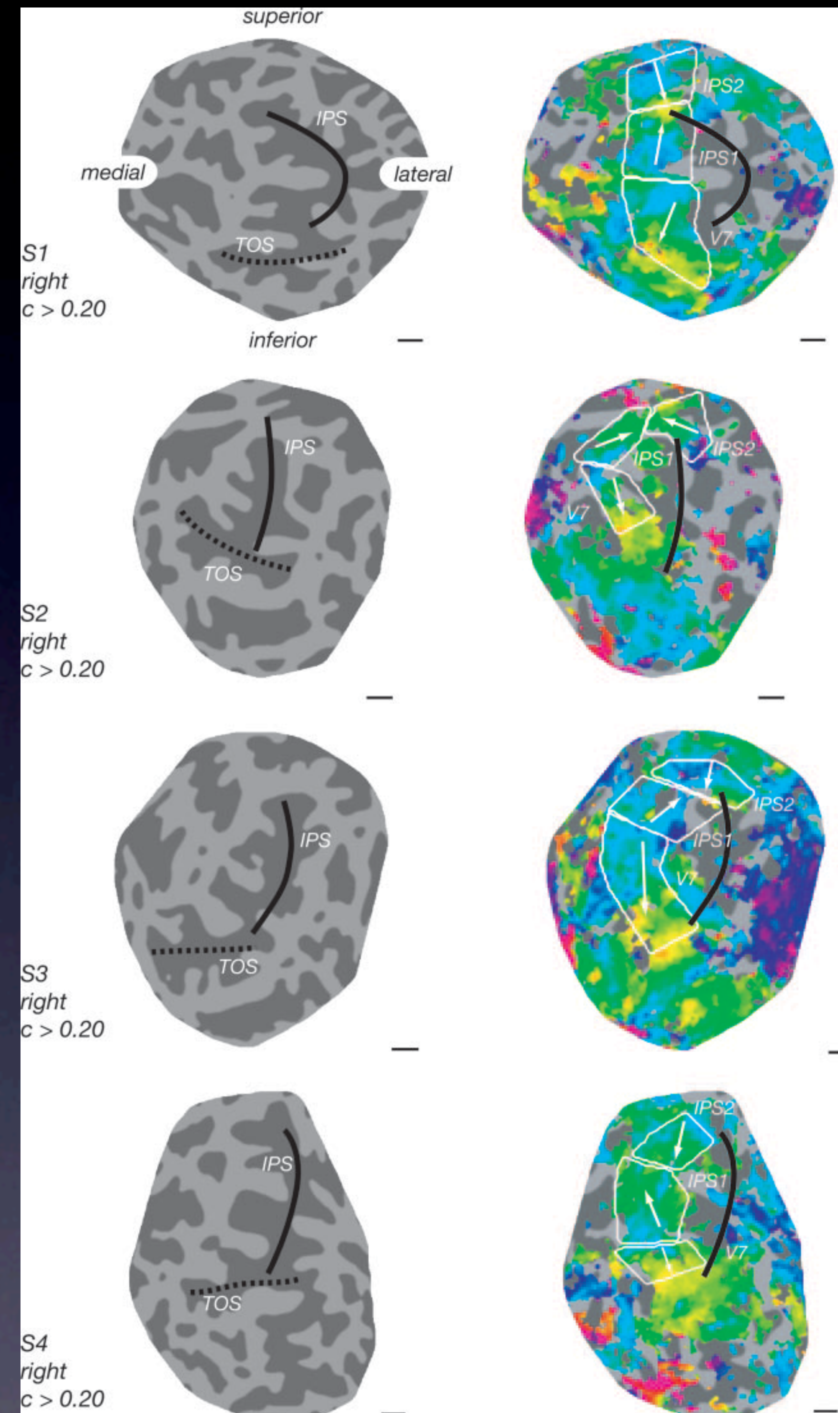


Sereno, Pitzalis & Martinez (2001) Science 294:1350-4

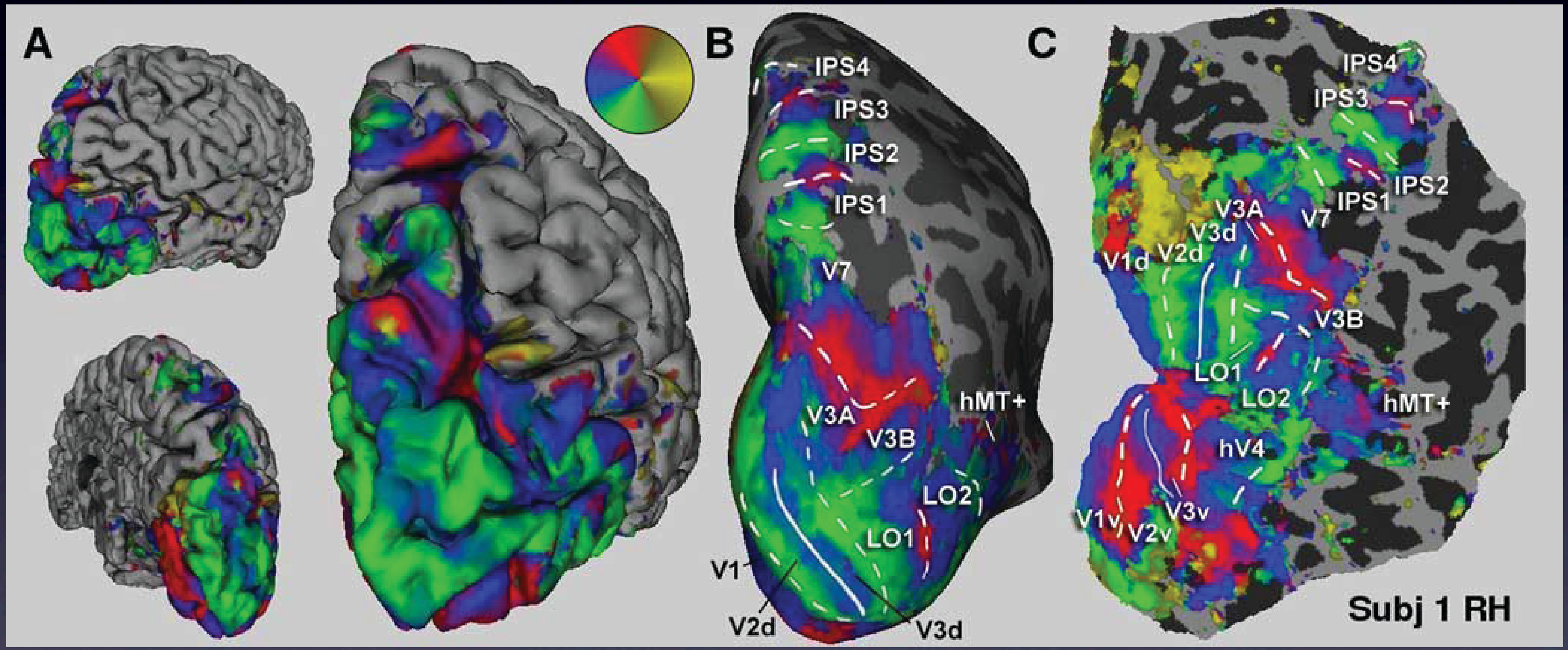


Sereno, Pitzalis & Martinez (2001) Science 294:1350-4

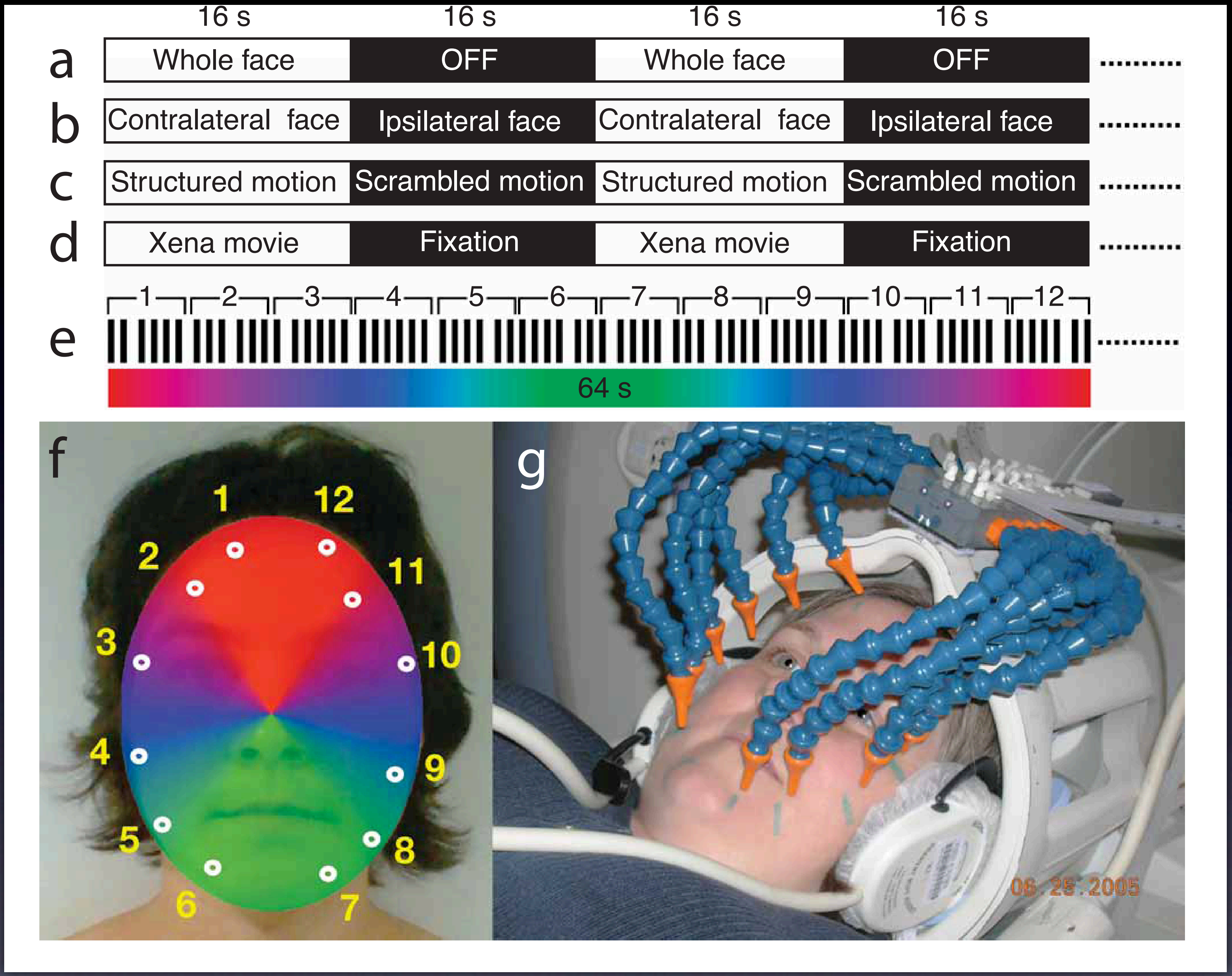




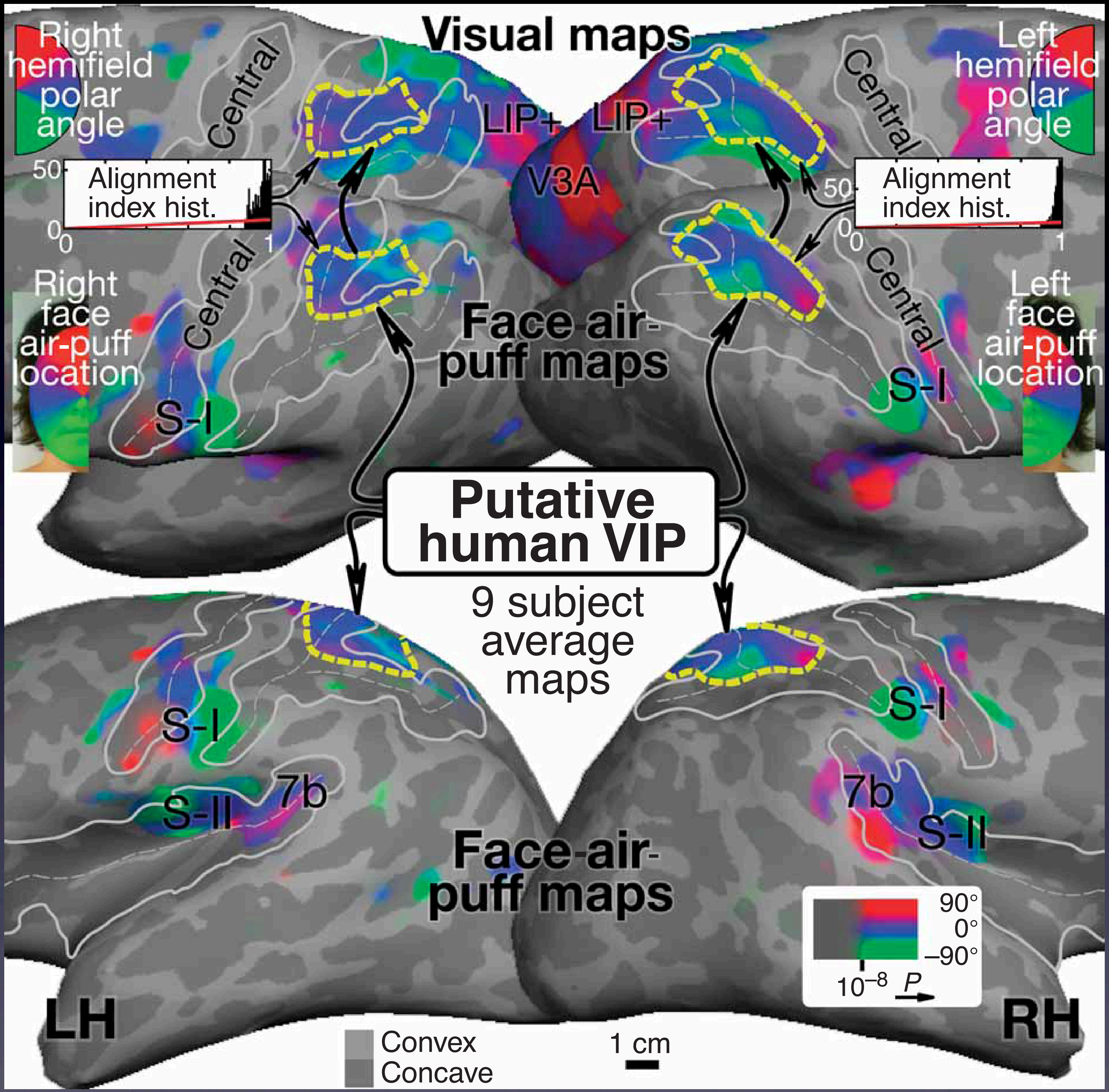
Schluppeck, Glimcher & Heeger (2005) JNP 94:1372-84



Swisher, Halko, Merabet, McMains & Somers (2007) JN 27:5326-37

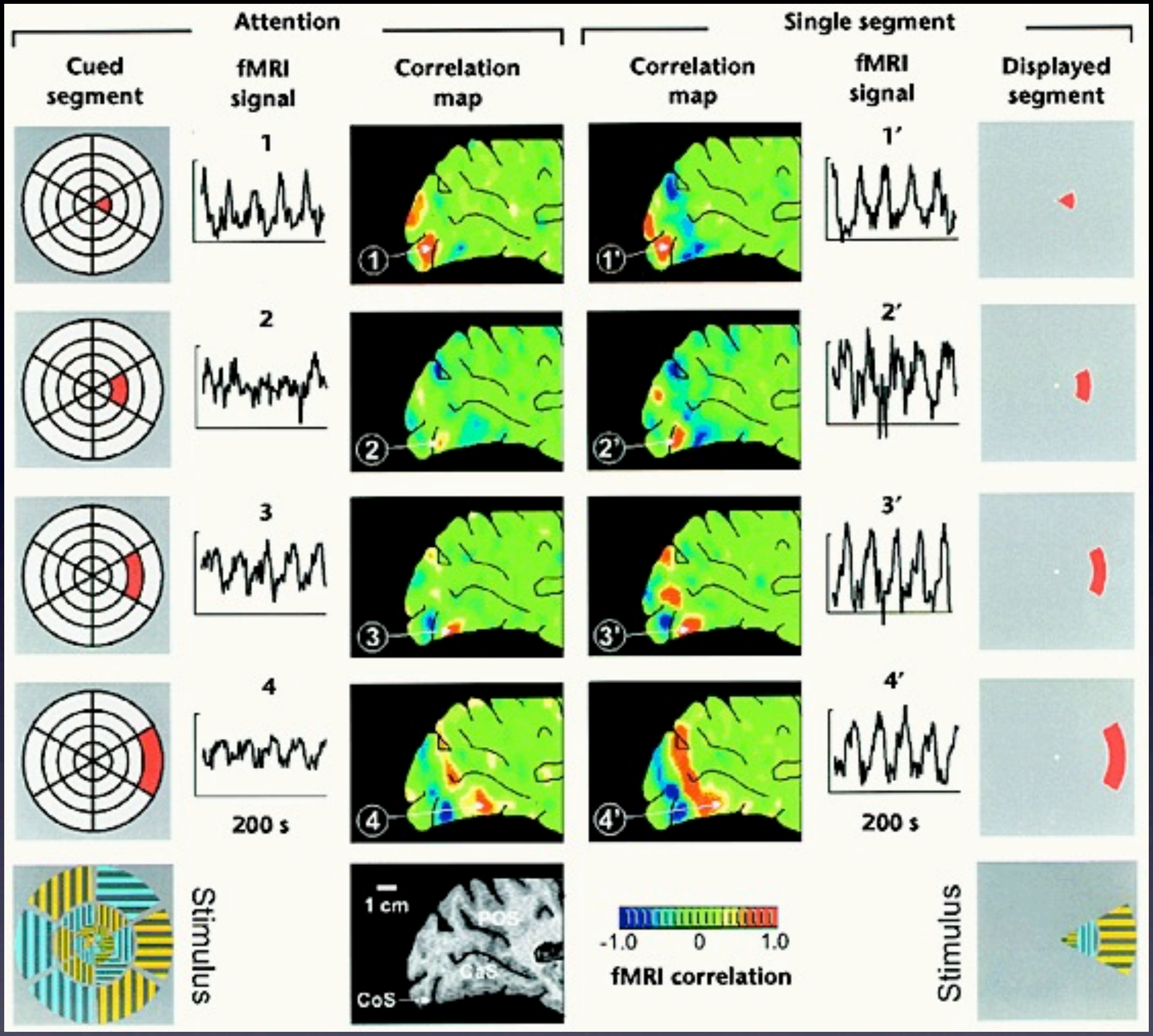


Sereno & Huang (2006) NN 9:1337-43

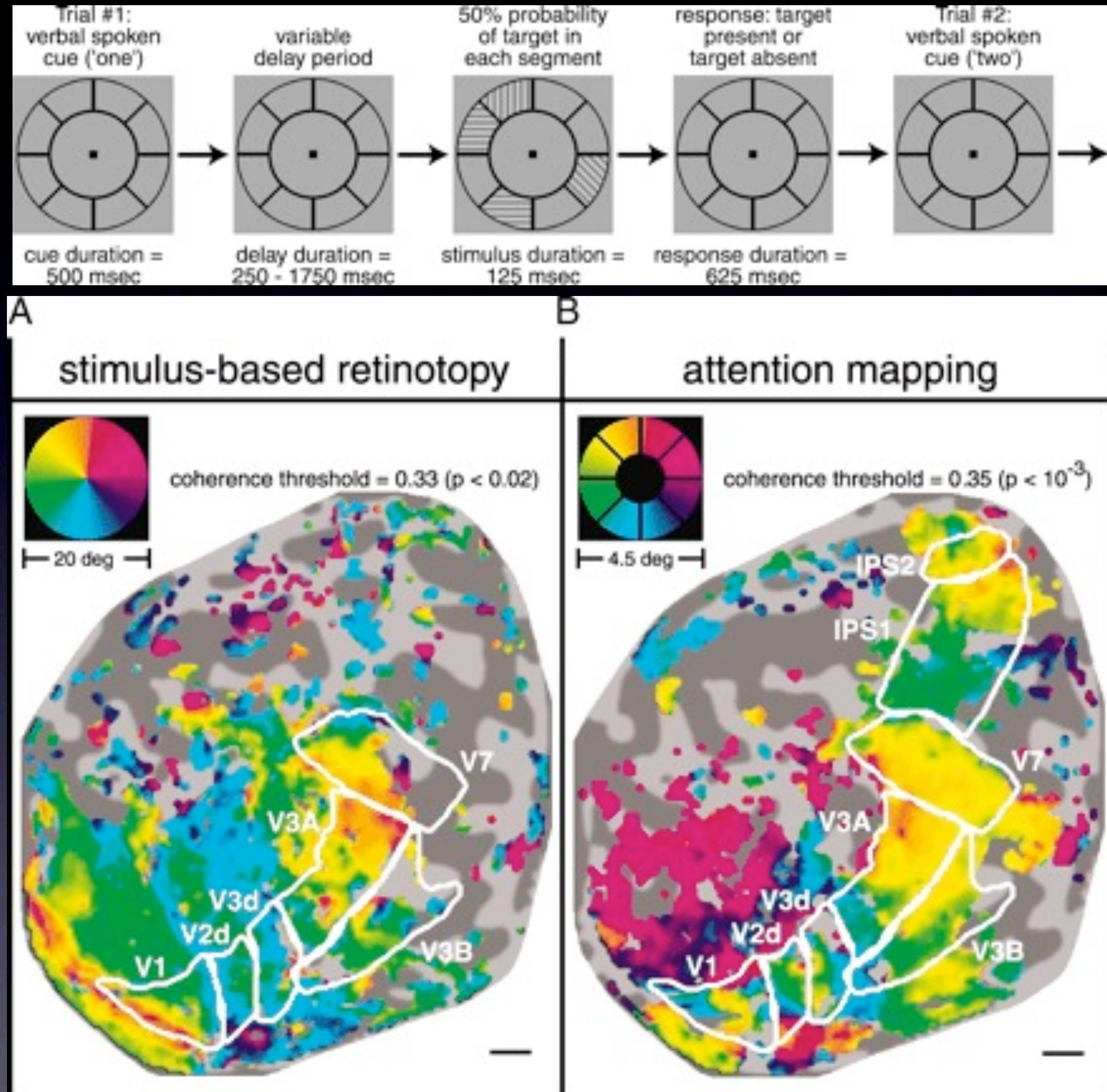


Sereno & Huang (2006) NN 9:1337-43

Spatially allocating attention alone
is enough to make topographic maps

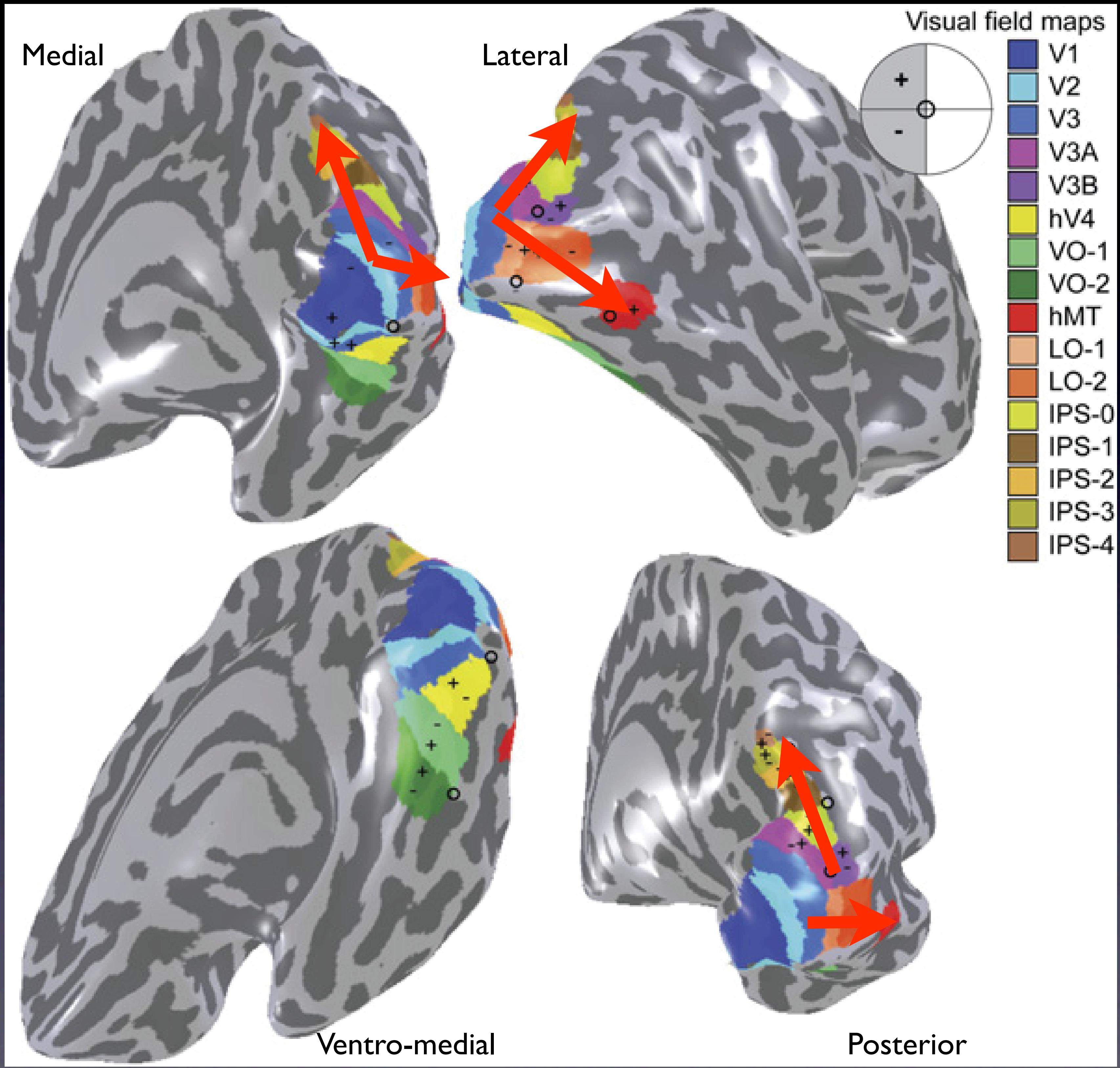


Brefczynski & DeYoe (1999) NN 2:370-4

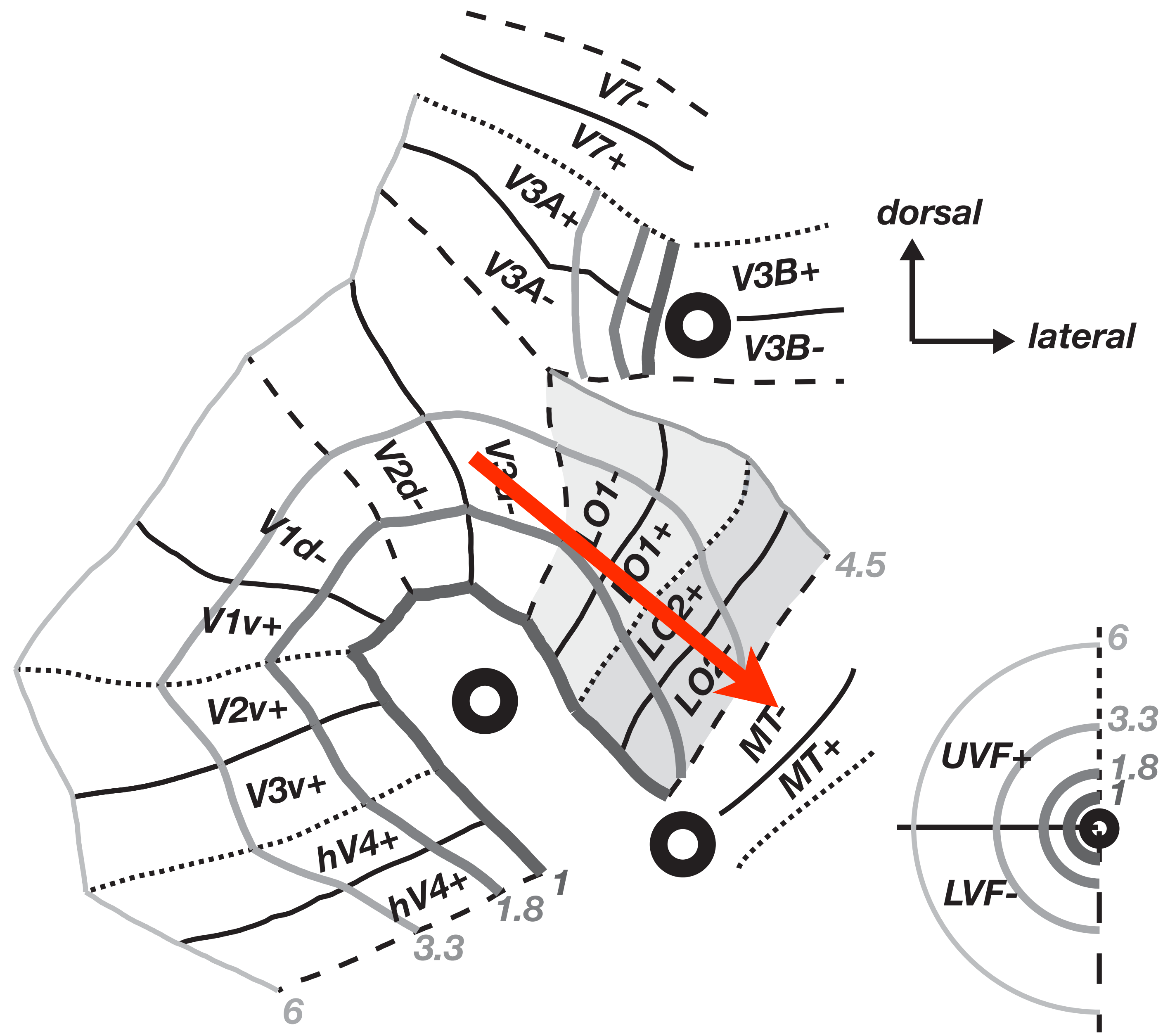


Silver, Ress & Heeger (2005) JNP 94:1358-71

Lateral occipital areas

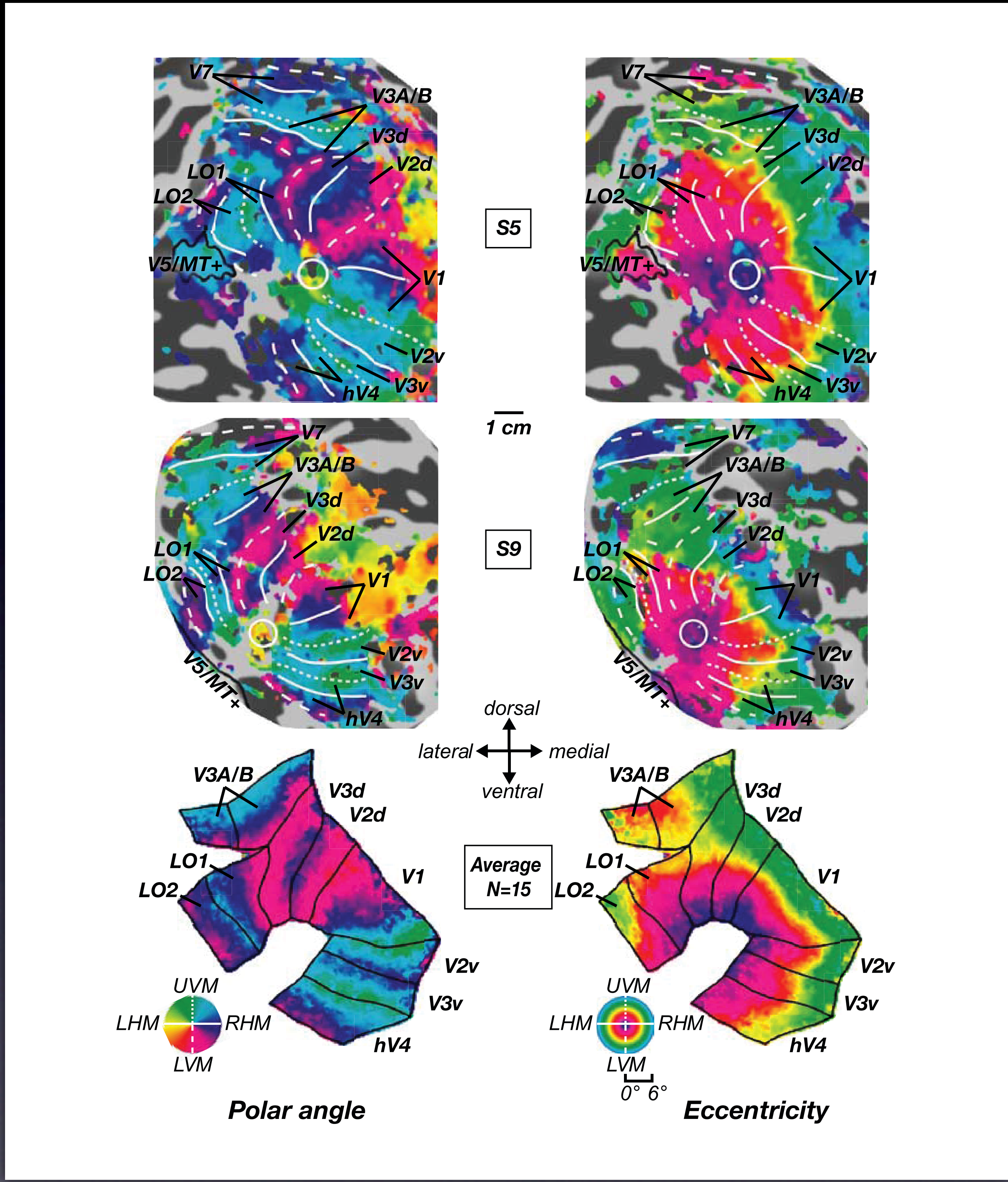


Right cortex



Larsson & Heeger (2006) JN 26:13128-42

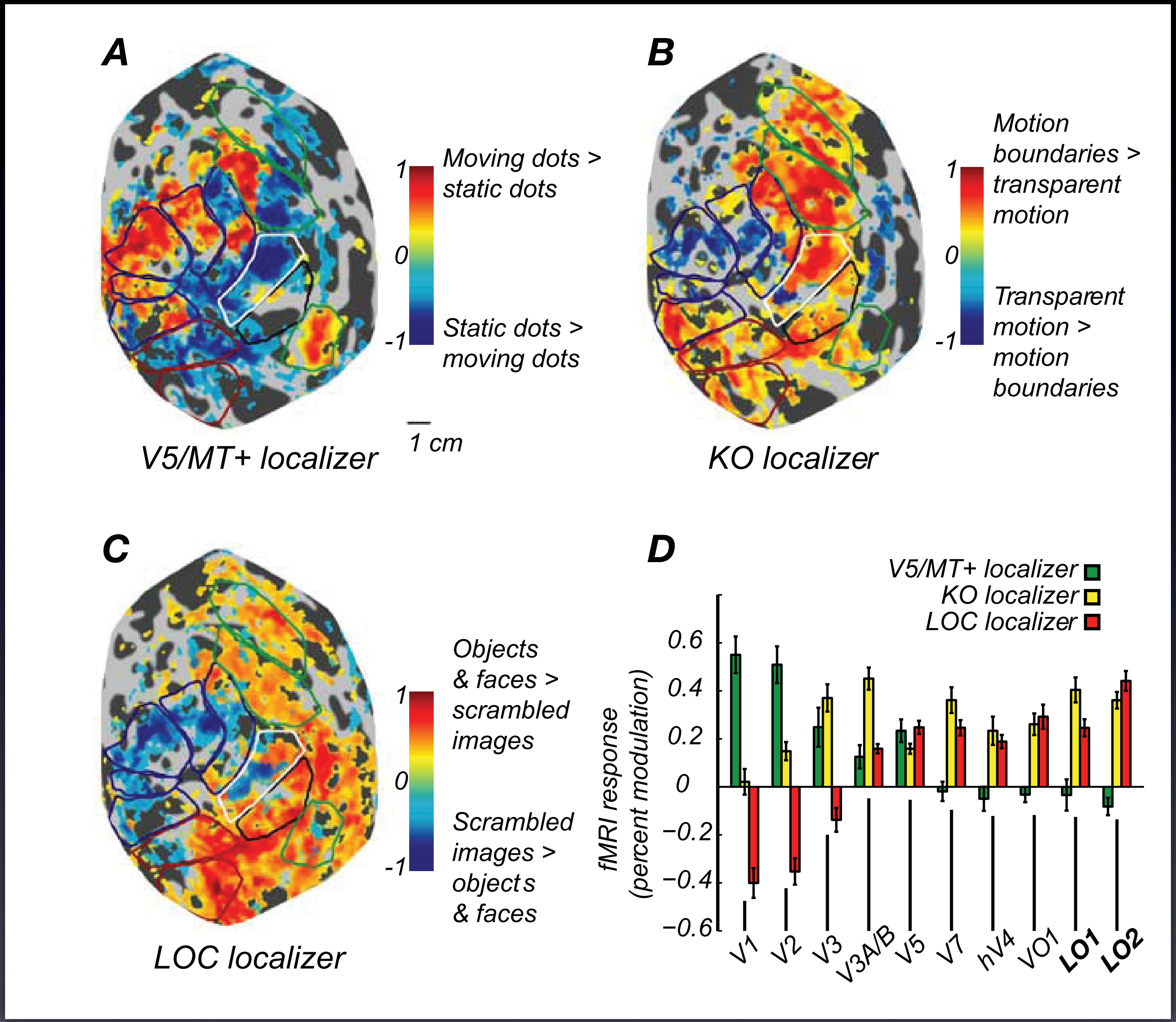
Monday, June 8, 2009



Larsson & Heeger (2006) JN 26:13128-42

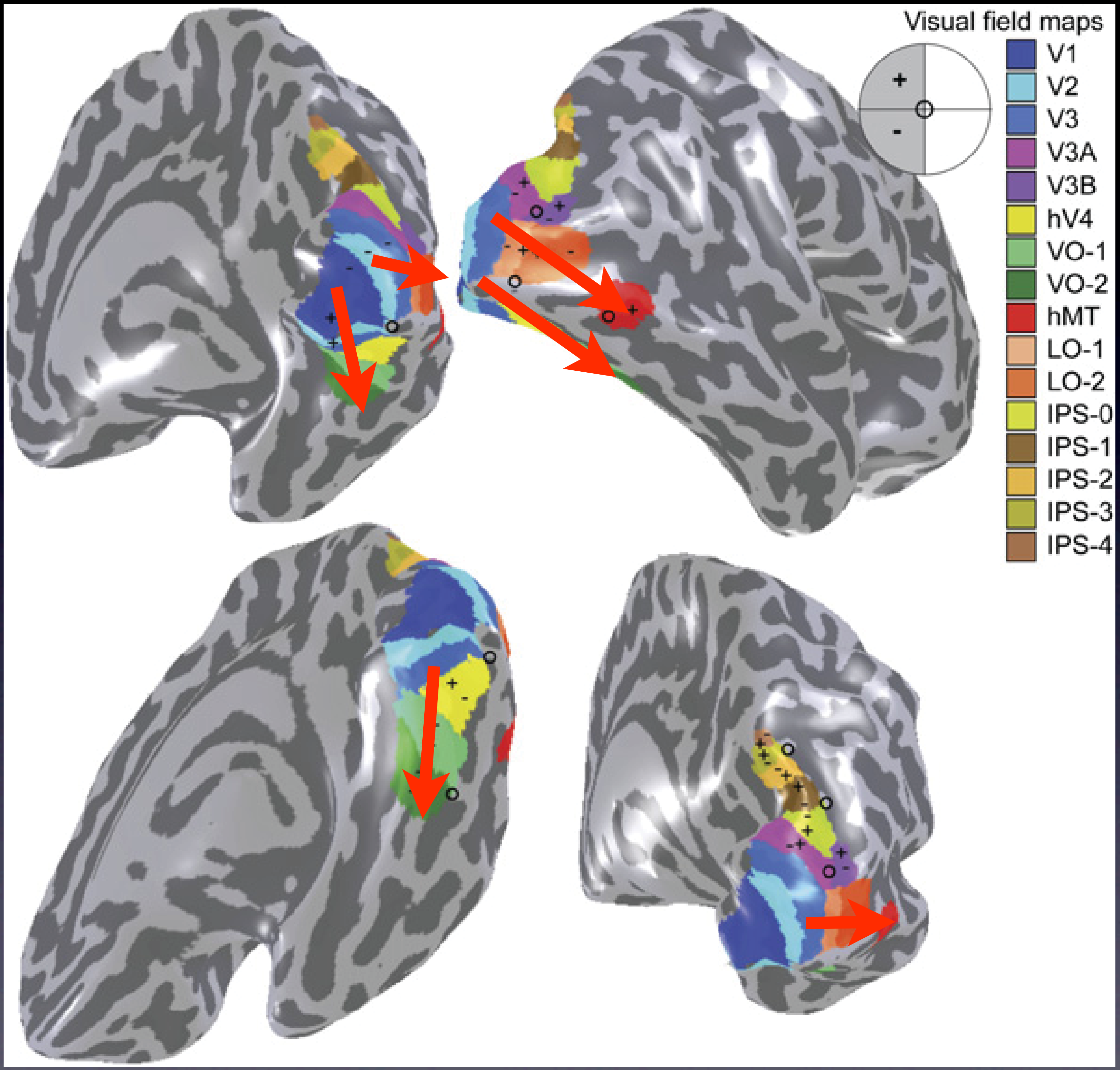
Relationship to function

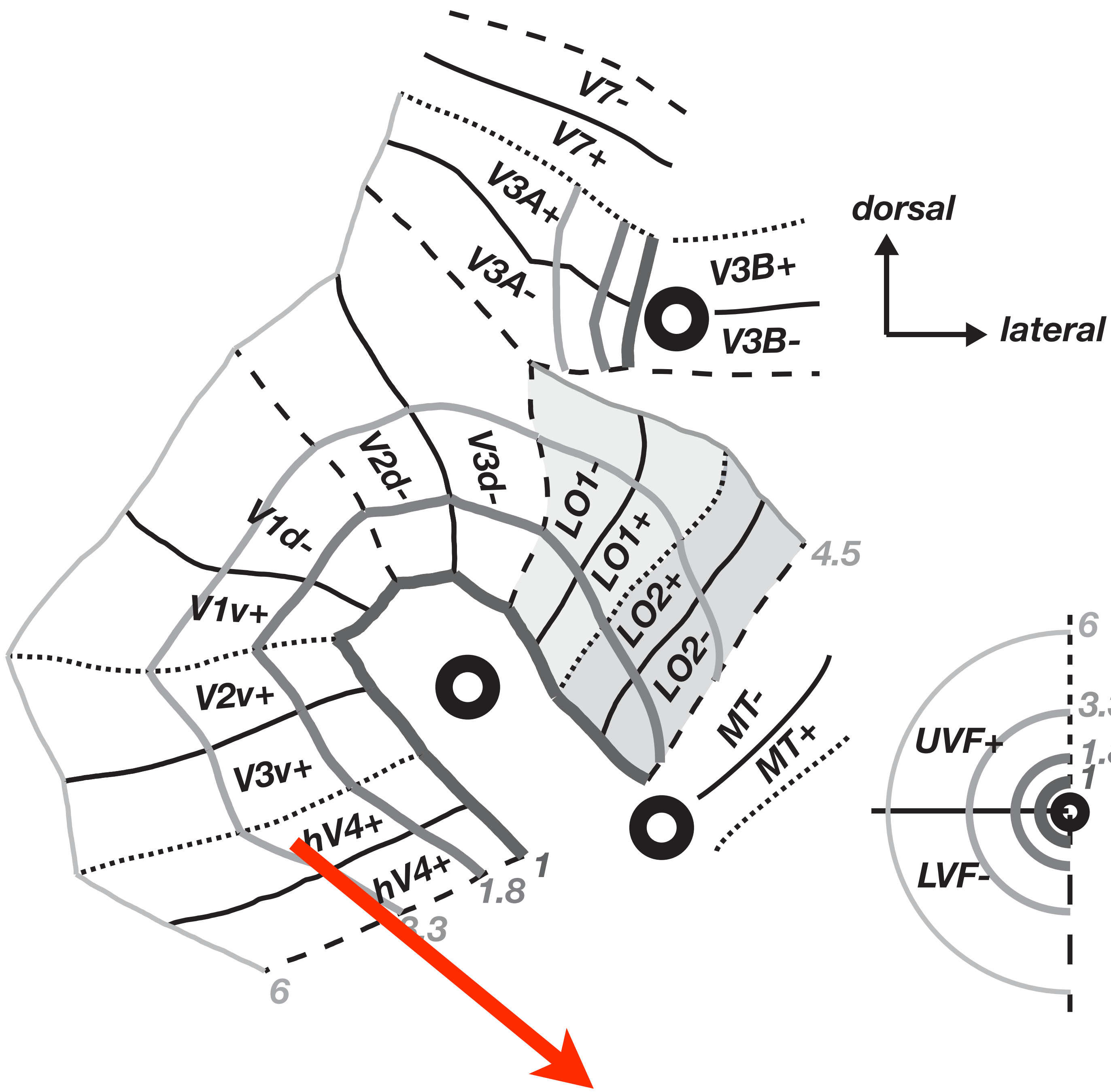
Instead of "visual areas" we should say "visual field maps"



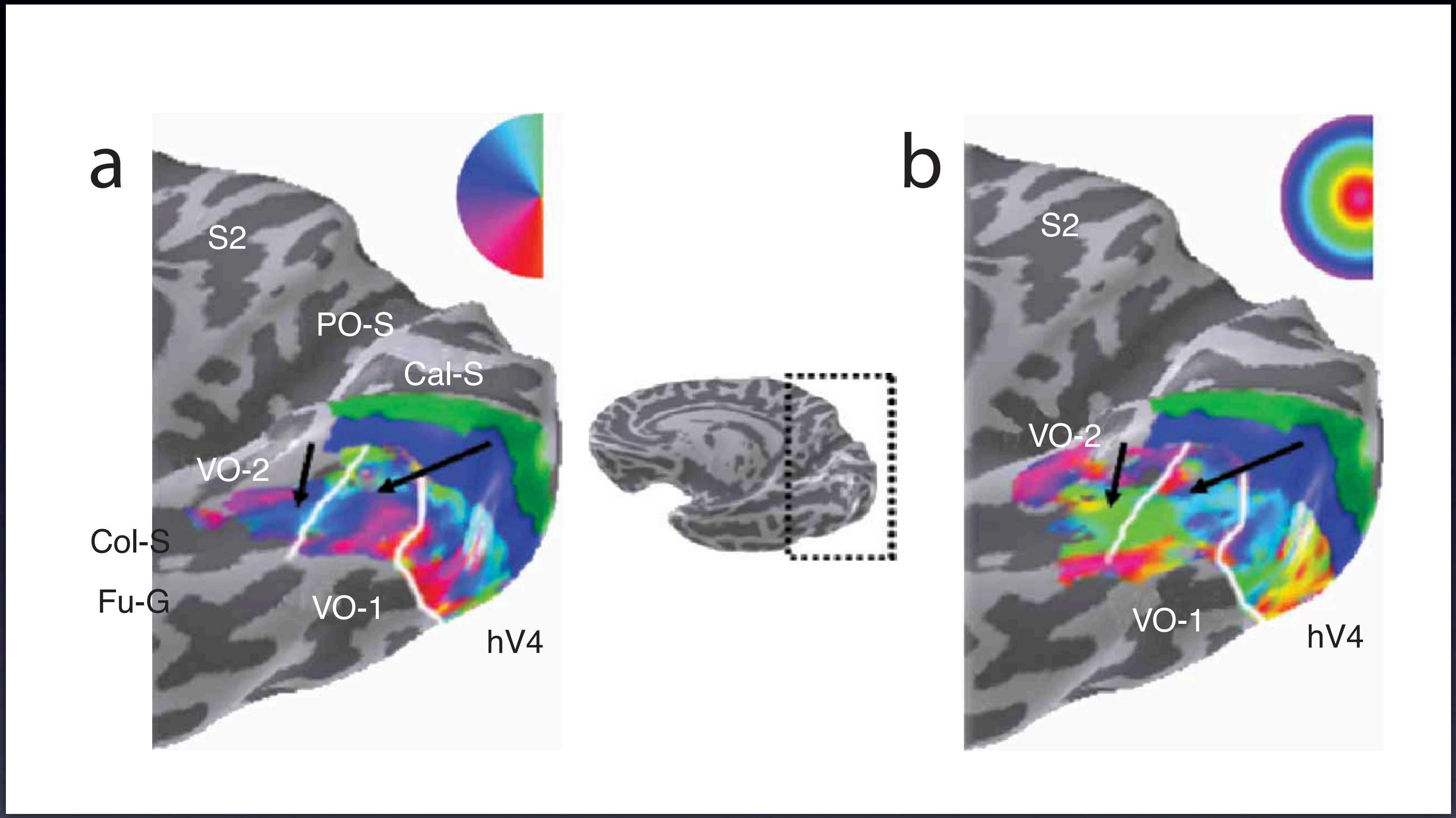
Larsson & Heeger (2006) JN 26:13128-42

Ventral occipital areas


Visual field maps
+
-
V1
V2
V3
V3A
V3B
hV4
VO-1
VO-2
hMT
LO-1
LO-2
IPS-0
IPS-1
IPS-2
IPS-3
IPS-4



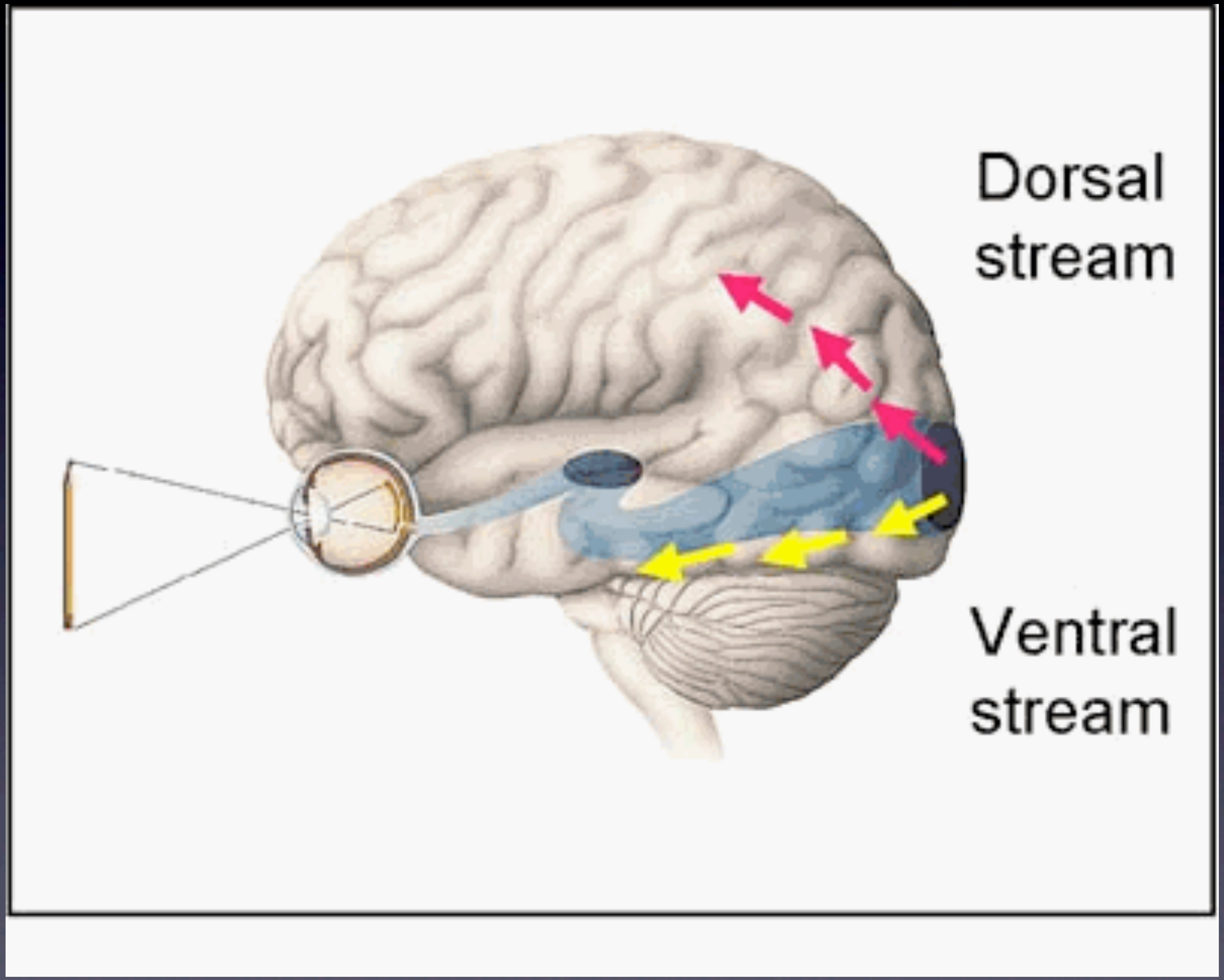
Larsson & Heeger (2006) JN 26:13128-42



Brewer, Liu, Wade & Wandell (2005) Nat Neurosci 8:1102-9

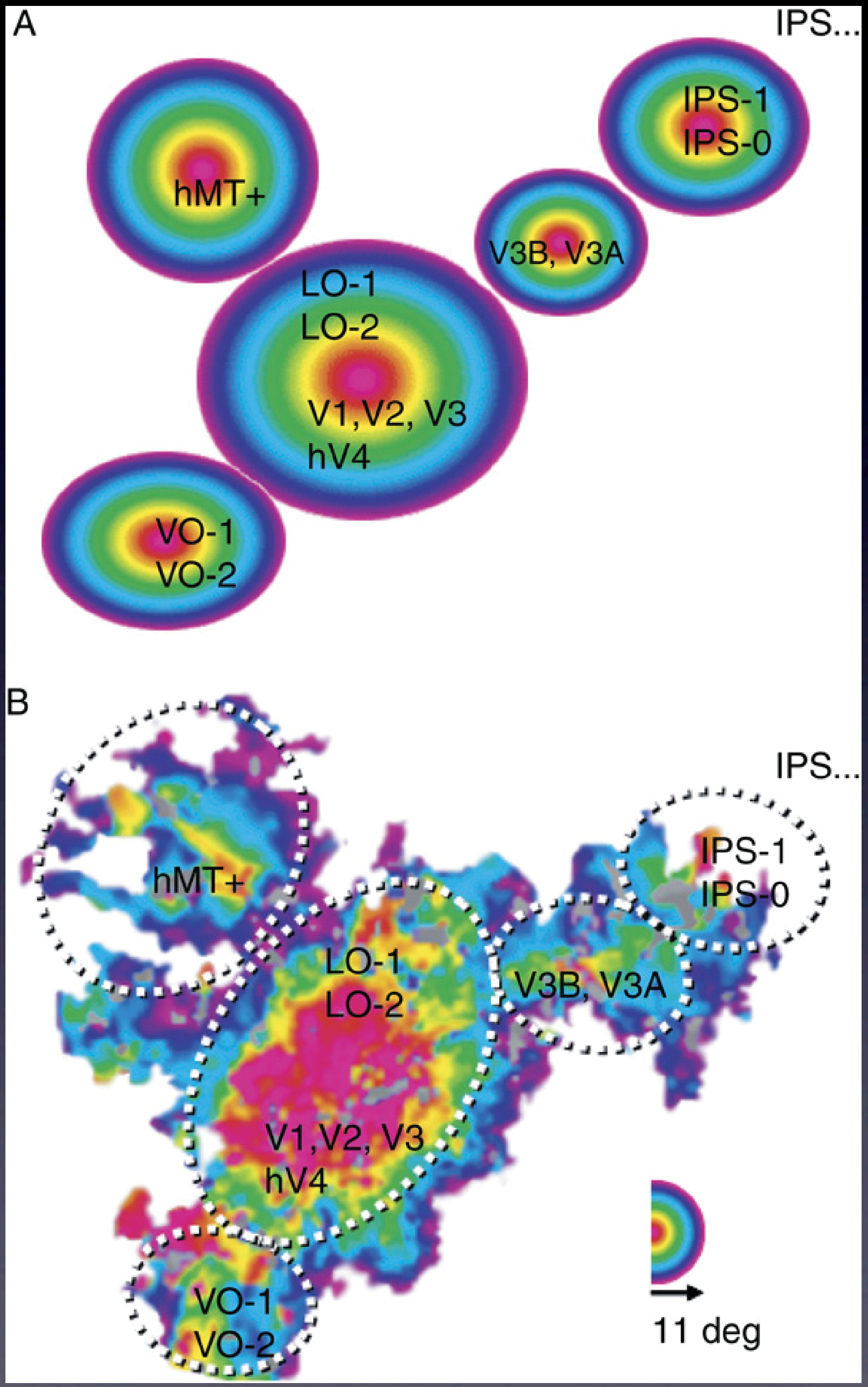
Meta-organization of visual areas

Dorsal and ventral visual streams
What & where
Action & perception



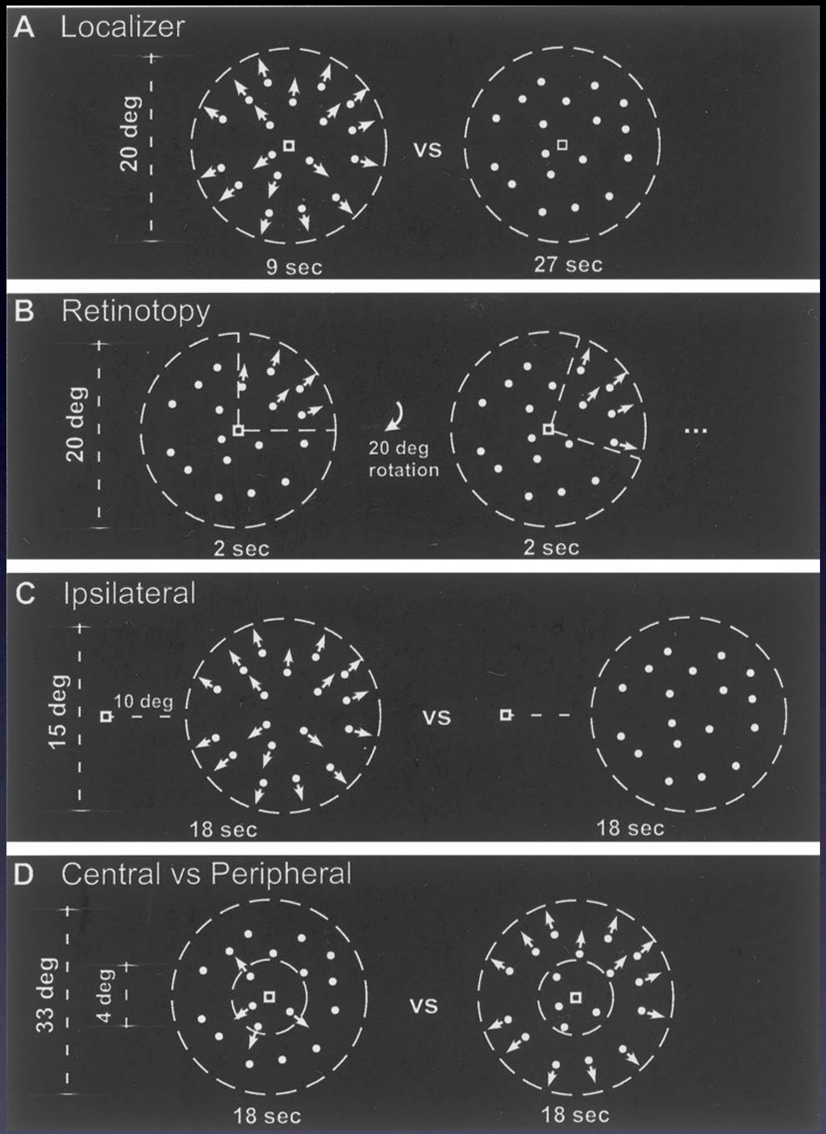
Ungerleider & Mishkin (1982)
Goodale & Milner (1992) TINS 15:20-25

Visual fields clustered around foveal representations

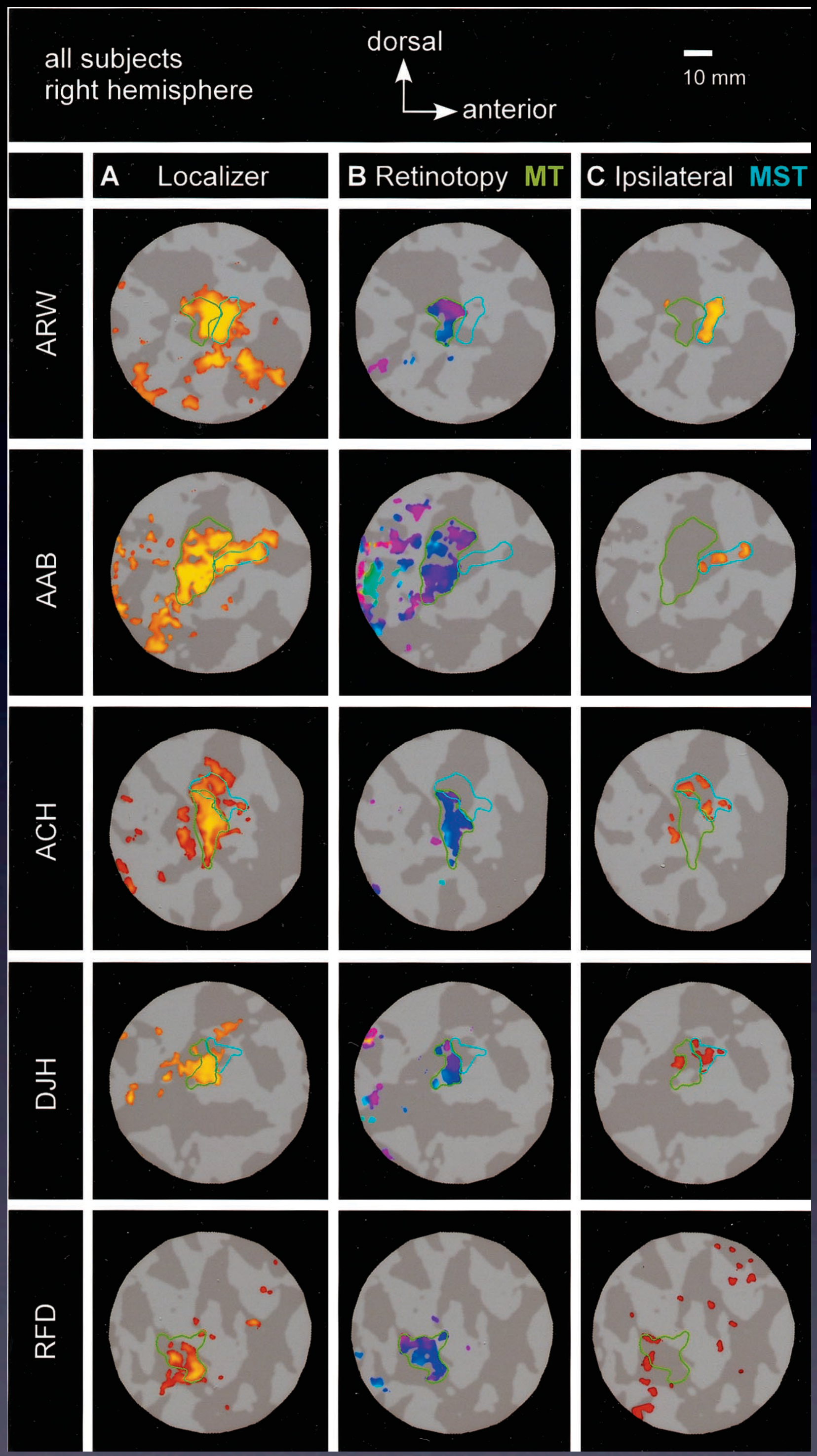


Brewer, Liu, Wade & Wandell (2005) Nat Neurosci 8:1102-9

MT and MST

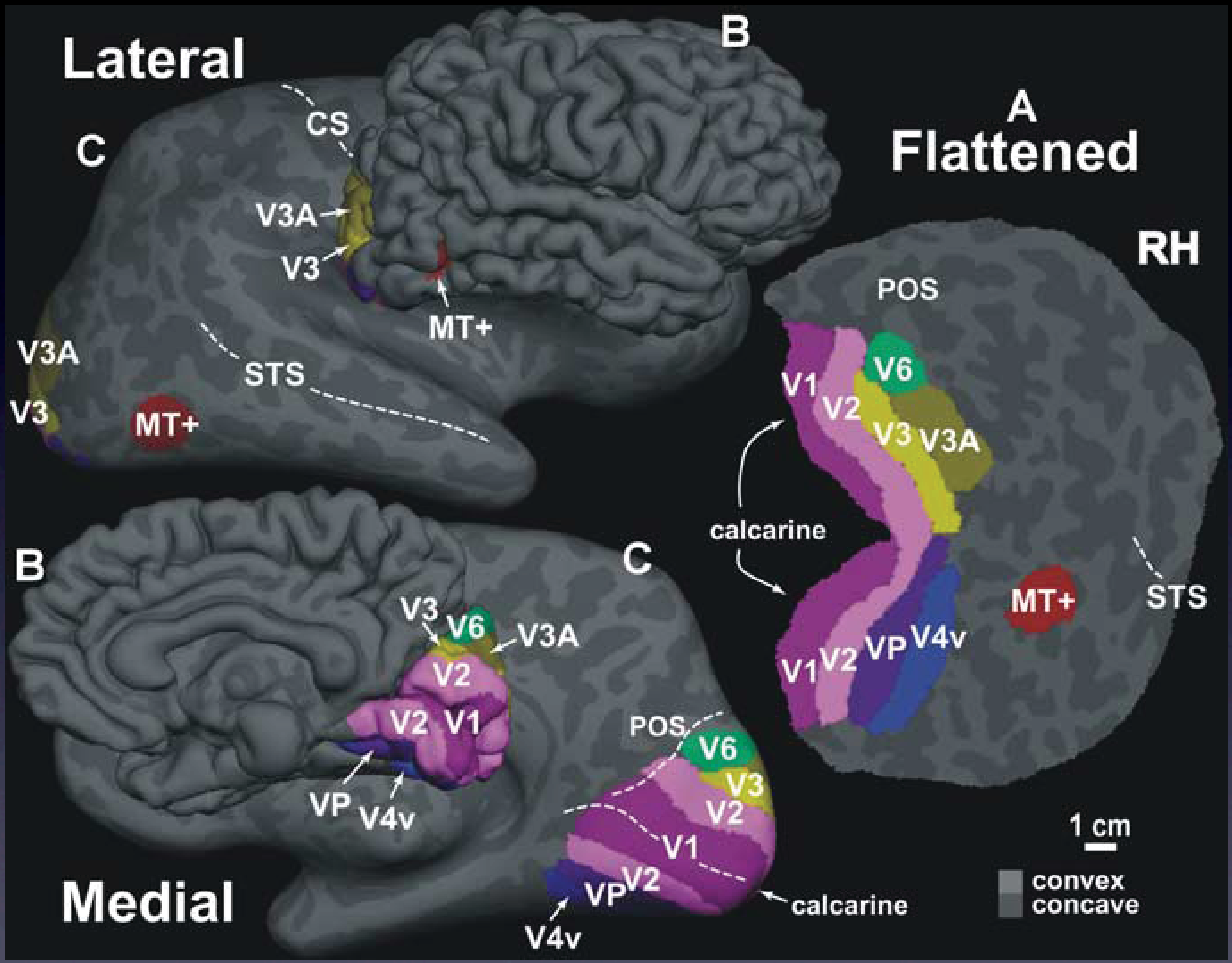


Huk, Dougherty & Heeger (2002) JN 22:7195-205



Huk, Dougherty & Heeger (2002) JN 22:7195-205

Area V6 (widefield retinotopy)



Pitzalis, Galletti, Huang, Patria, Committeri, Galati, Fattori & Sereno (2006) JN 26:7962-7973

Controversies!

Were is dorsal V4

V4d topologue

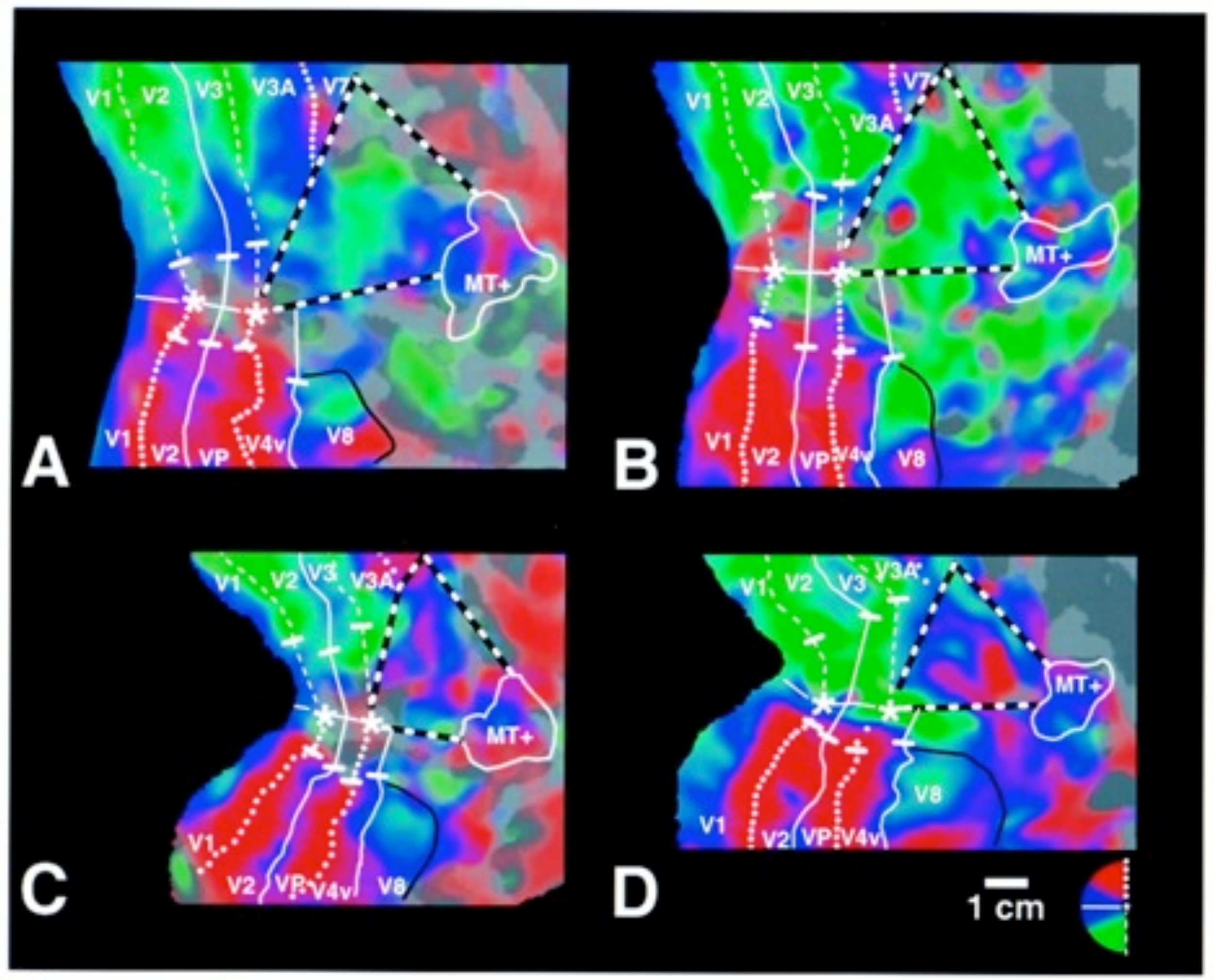
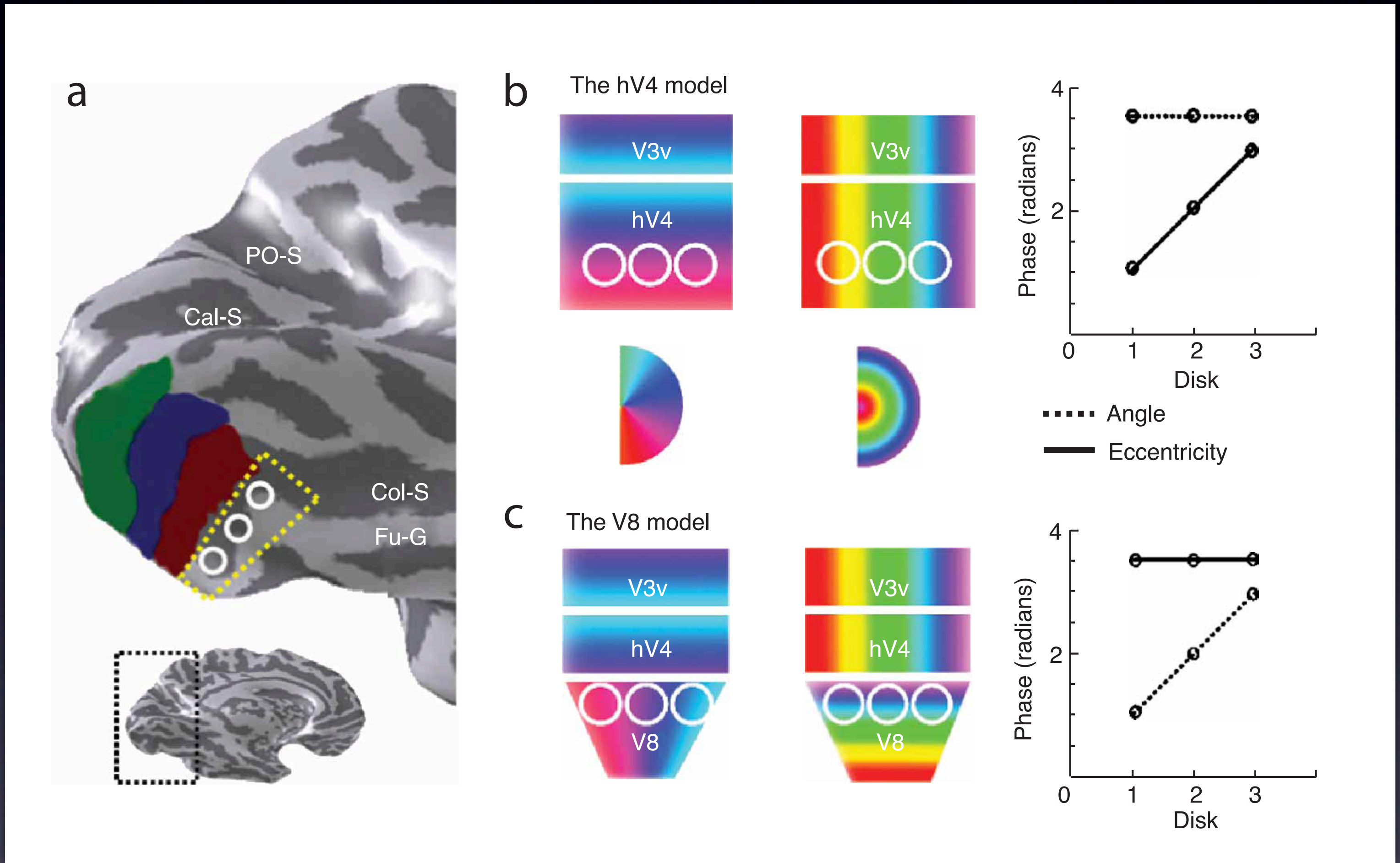
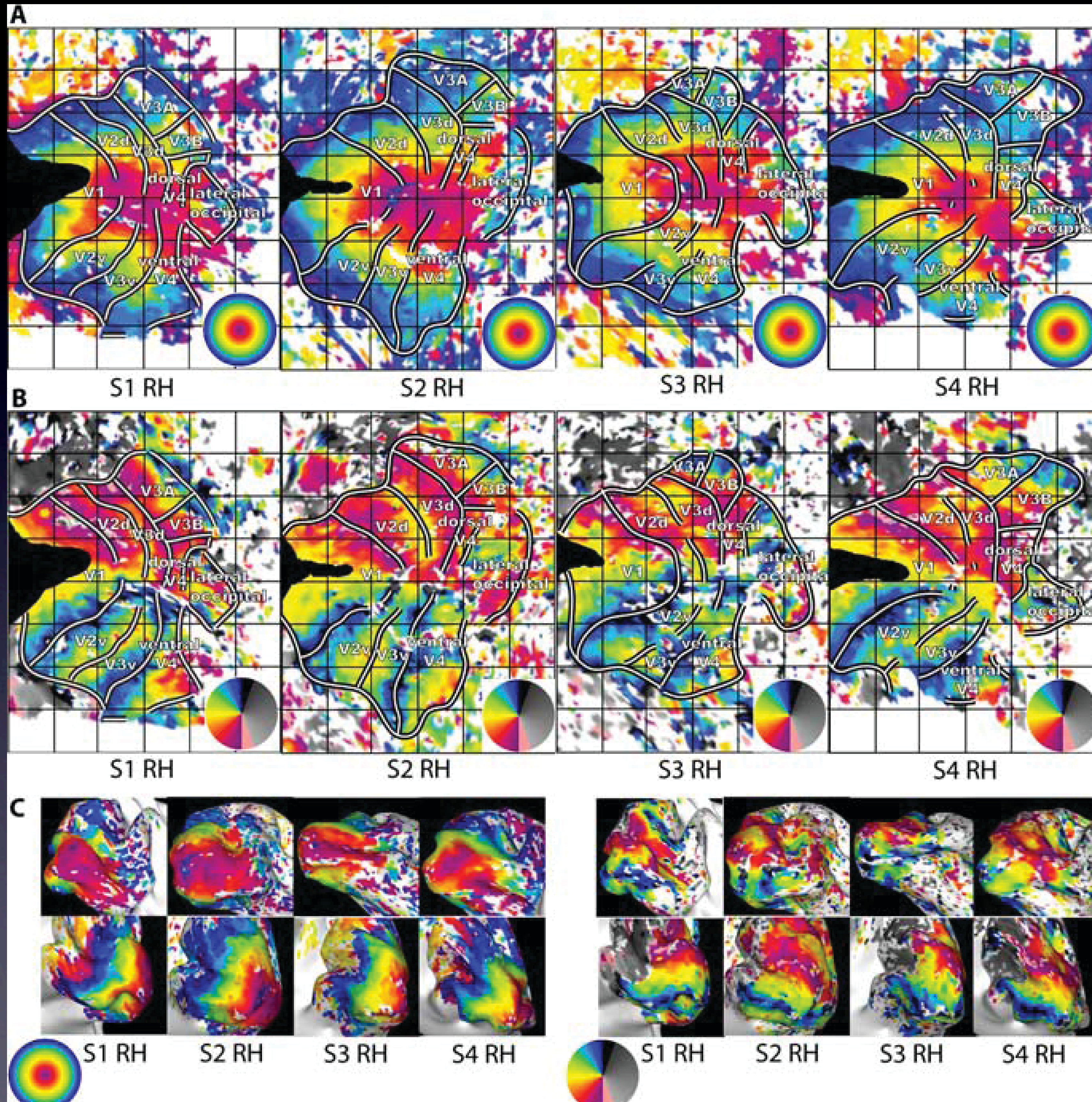


Figure 6

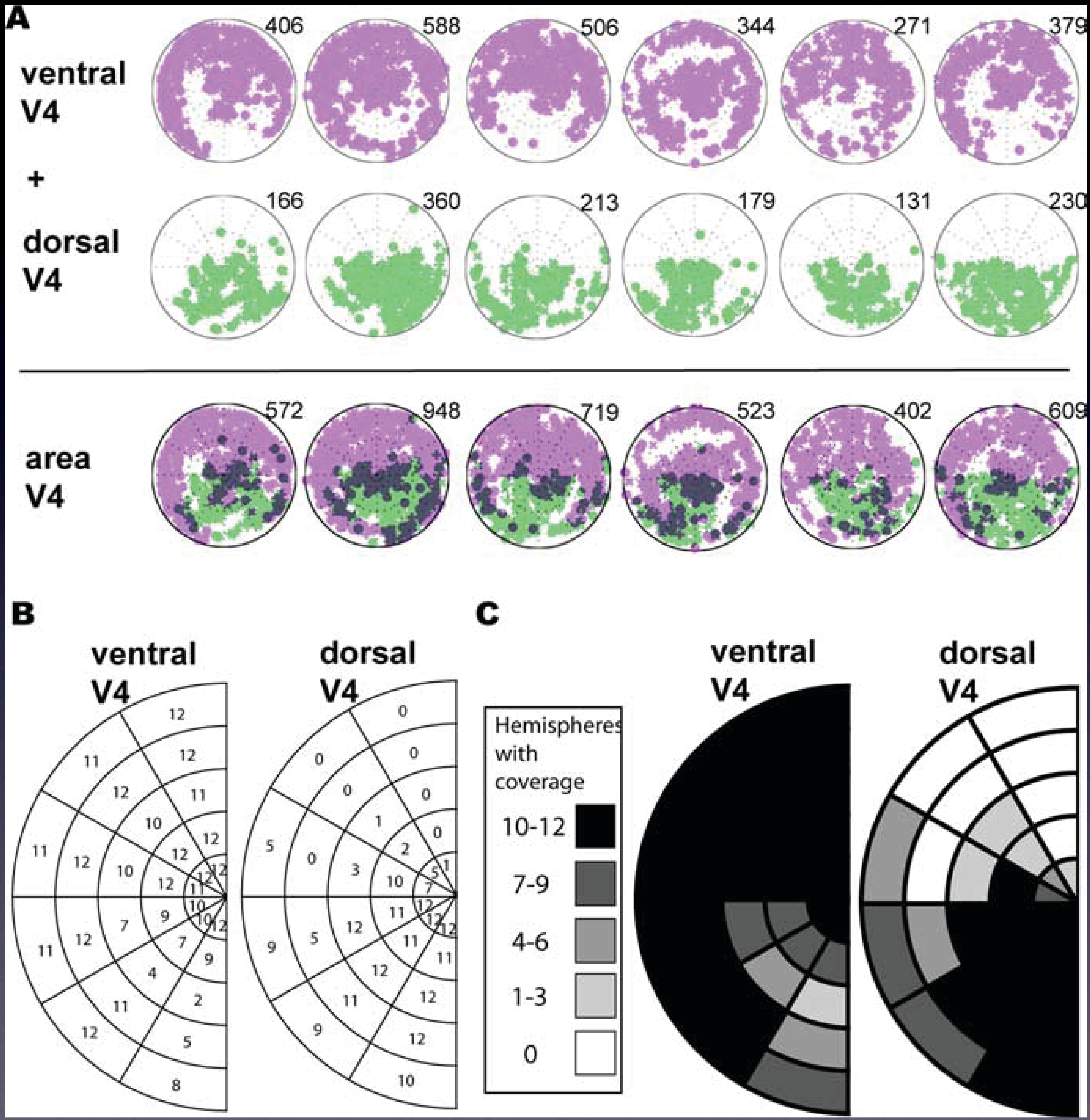
Tootell & Hadjikhani (2001) Cerebral Cortex 4:298-311



Brewer, Liu, Wade & Wandell (2005) Nat Neurosci 8:1102-9



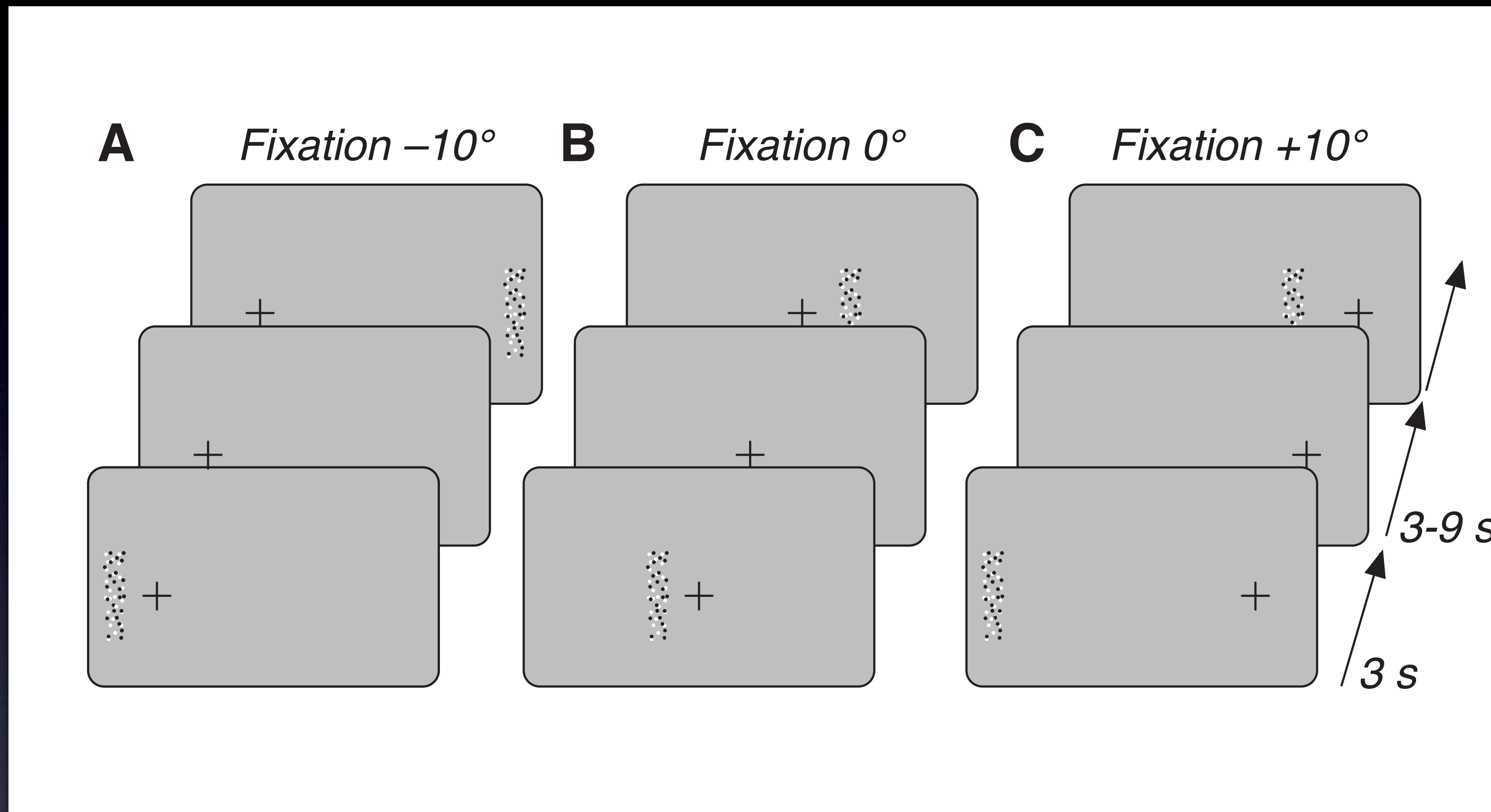
Hansen, Kay & Gallant (2007) JN 27:11896-11911

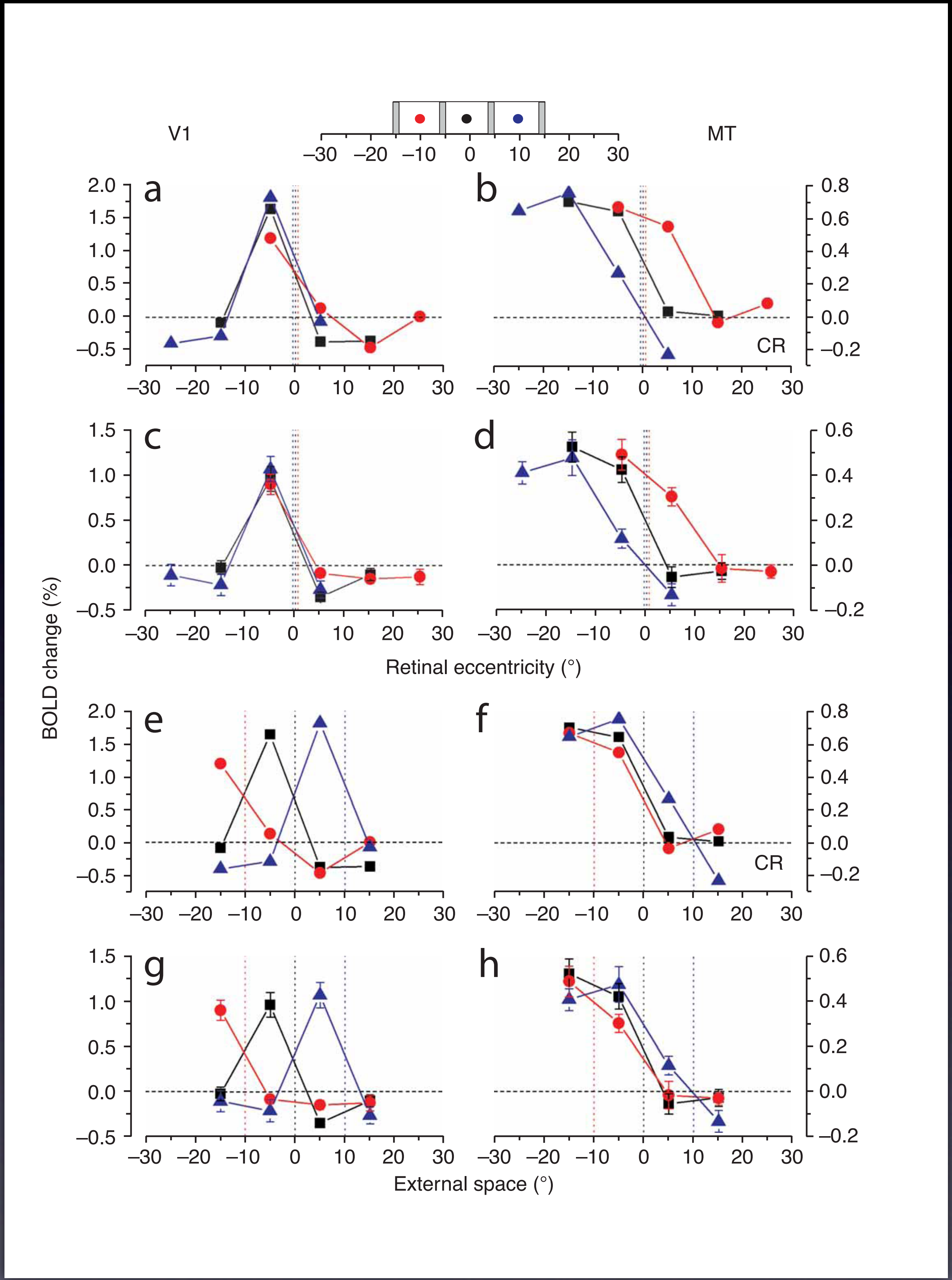


Hansen, Kay & Gallant (2007) JN 27:11896-11911

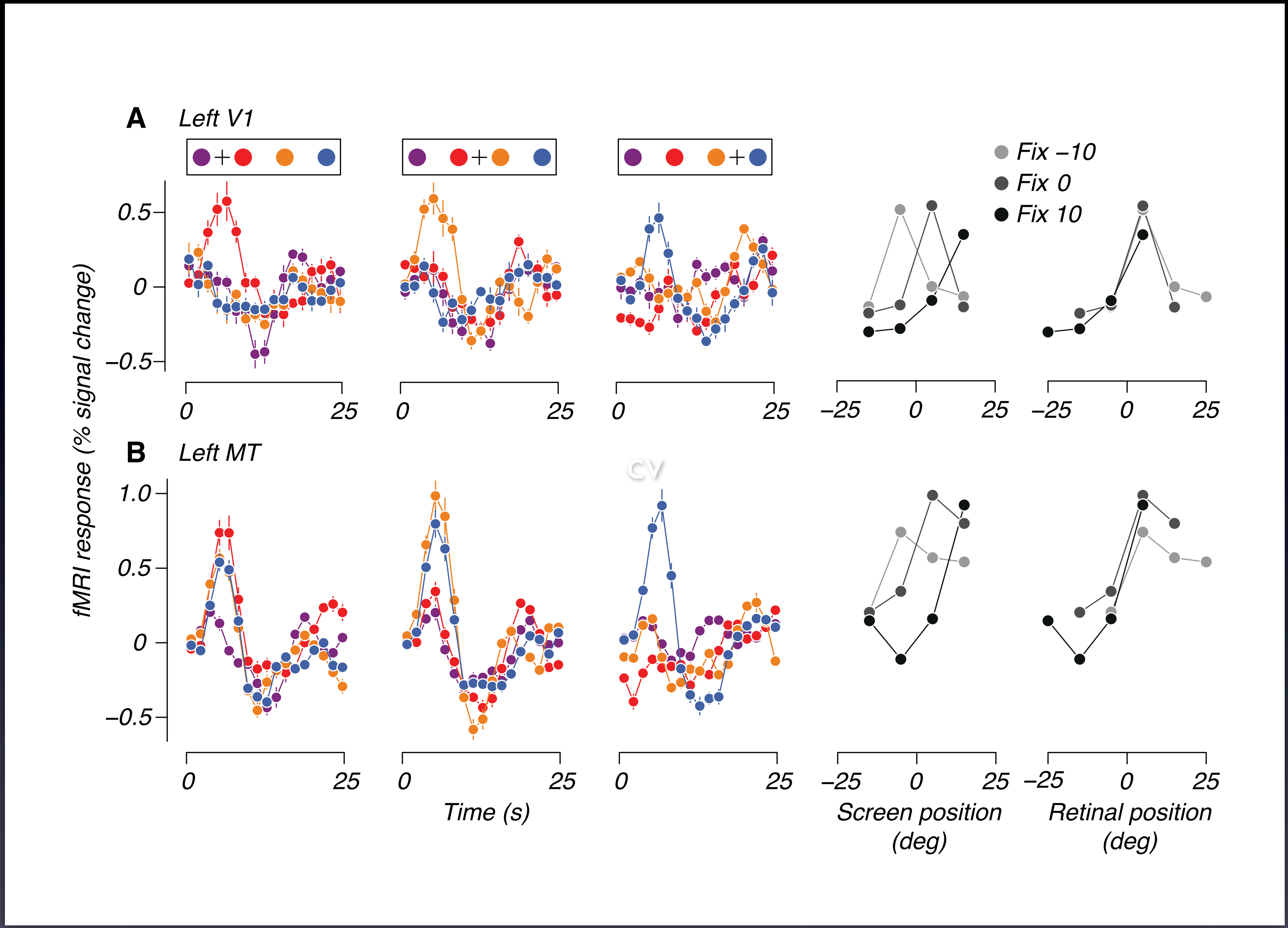
Controversies!
Reference frames of topographic maps

Retinal or space centered?


A
Fixation –10°
B
Fixation 0°
C
Fixation +10°
3-9 s
3 s



d'Avossa, Tosetti, Crespi, Biagi, Burr & Morrone (2007) Nat Neurosci, 10:249-55



Gardner, Merriam, Movshon, Heeger (2008) JN 9:3988-99

Homology between human and monkey areas

“Homology” is the wrong word!!!!

J. Neurosci. -- eLetters for Larsson and Heeger, 26 (51) 13128-13142

http://www.jneurosci.org/cgi/eletters/26/51/13128

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The concept of homology applied to extrastriate cortical areas

24 January 2007

Marcello G Rosa,
Professor
Monash University, Melbourne, VIC 3800, Australia

Send letter to journal:
Re: The concept of homology applied to extrastriate cortical areas

Email Marcello G Rosa

One of the key findings of the paper by Larsson and Heeger is that the human lateral occipital cortex contains representation(s) of the central portion of the upper visual field in the dorsolateral cortex caudal to MT, and rostral to "dorsal V3". These representations would seem to occupy part of the region that corresponds to dorsal (lower quadrant) V4 in the macaque. Based on the fact that the visuotopic organization of this part of the brain appears to be different in humans and monkeys, the authors proceed to suggest the existence of two new visual areas of the human cortex (LO1 and LO2), which would have no simian homologues. This conclusion is unwarranted, as it reflects an erroneous expectation that homologue structures will look identical in different species.

Homologous structures in nature can, and often are, quite different. The concept of homology is based not on morphology or function, but rather on a common evolutionary origin (i.e., whether or not the structure in question was present in a common ancestor). This common origin is, in turn, often (if not always) reflected in a common embryological origin.

Larsson and Heeger report that the lateral occipital areas LO1 and LO2 show marked interindividual variability, with fewer than half of the examined hemispheres (14/ 30) showing a complete representation of polar angles in the upper quadrant, and a substantial proportion of the sample (7/ 30) showing no clear topographic order assessable via fMRI. This high degree of variability (which may also explain conflicting reports from other laboratories) is compatible with a developmental model based on activity-dependent formation of topographic maps, which would translate into multistable solutions for adult visual topography. We have proposed one such model, which specifically predicts a high degree of variability in topographic organization of the region of "fourth visual complex" as a result of its markedly delayed maturation relative to areas such as V1 and MT (Rosa and Tweedale, 2005). This variability is expected not only across primate species, but also between individuals of the same species. Critically, the final configuration of the maps is linked not only to phylogeny, but is the result of an epigenetic process that is strongly influenced by overall brain size (hence, length of corticogenesis). For example, New World and Old World monkeys of similar size have similar visual topographies in this region. Given that a pool of cells with similar embryological identity may form different maps in different individuals and/ or species, visuotopy alone constitutes a weak criterion for establishing homologies in high-order (or late-maturing) visual areas.

Whether the observed variability ultimately proves to be the result of variable visual topographies within areas, or variable topological relationships between areas, the rich data set and excellent analysis provided by Larsson and Heeger will provide a strong basis for further exploration of this question.

Reference: Rosa MGP, Tweedale R (2005) Brain maps, great and small: lessons from comparative studies of primate visual cortical organization. Philos Trans R Soc Lond B Biol Sci. 360: 665-691.

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homology

Pronunciation: \hō-ˈmä-lə-jē, hə-\
Function: noun
Inflected Form(s): *plural* ho·mol·o·gies
Date: circa 1656

2 a: likeness in structure between parts of different organisms (as the wing of a bat and the human arm) due to evolutionary differentiation from a corresponding part in a common ancestor — compare **analogy**

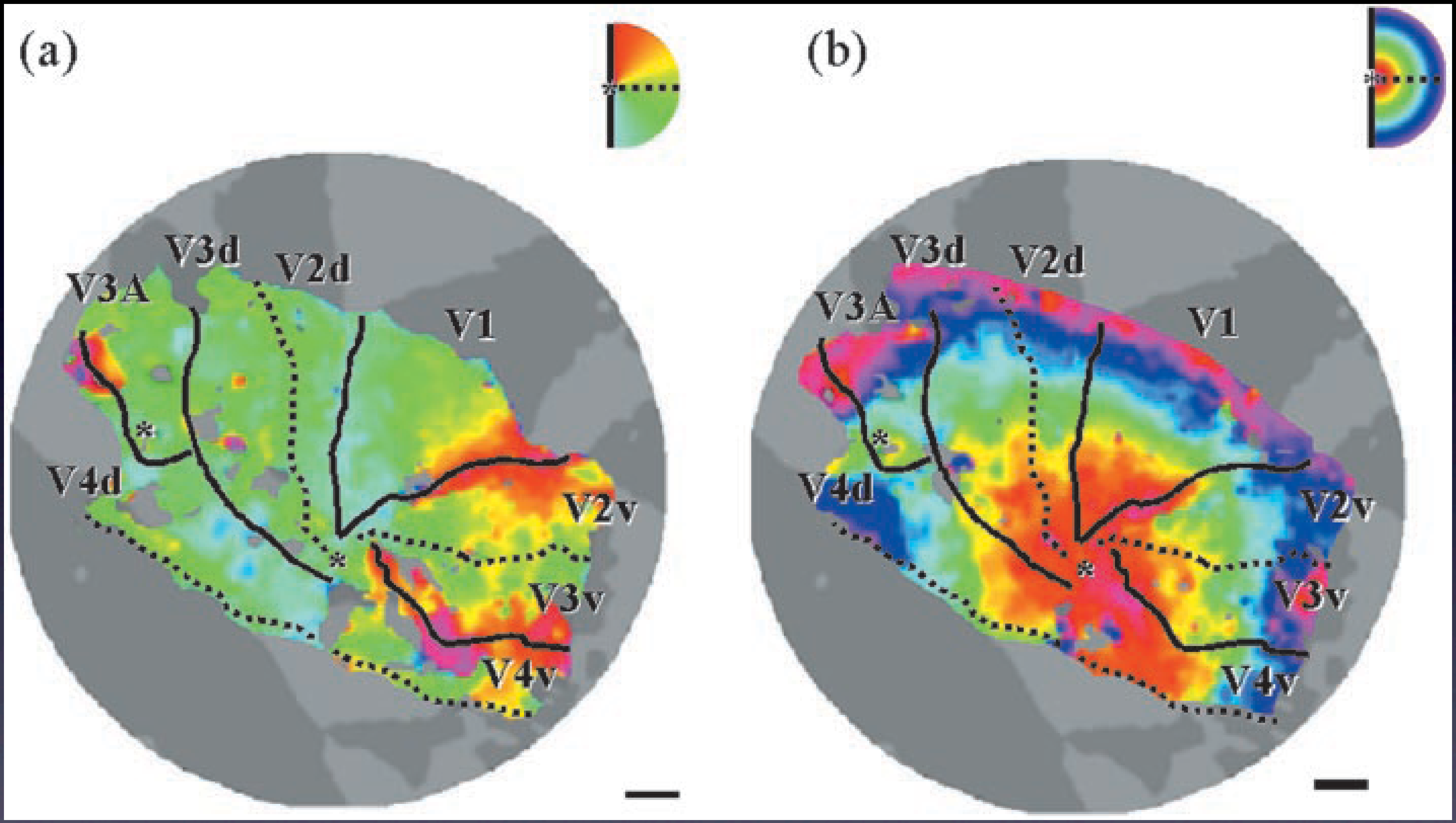
analogy

Pronunciation: \ə-ˈna-lə-jē\
Function: noun
Inflected Form(s): *plural* anal·o·gies
Date:15th century

4: correspondence in function between anatomical parts of different structure and origin — compare **homology**

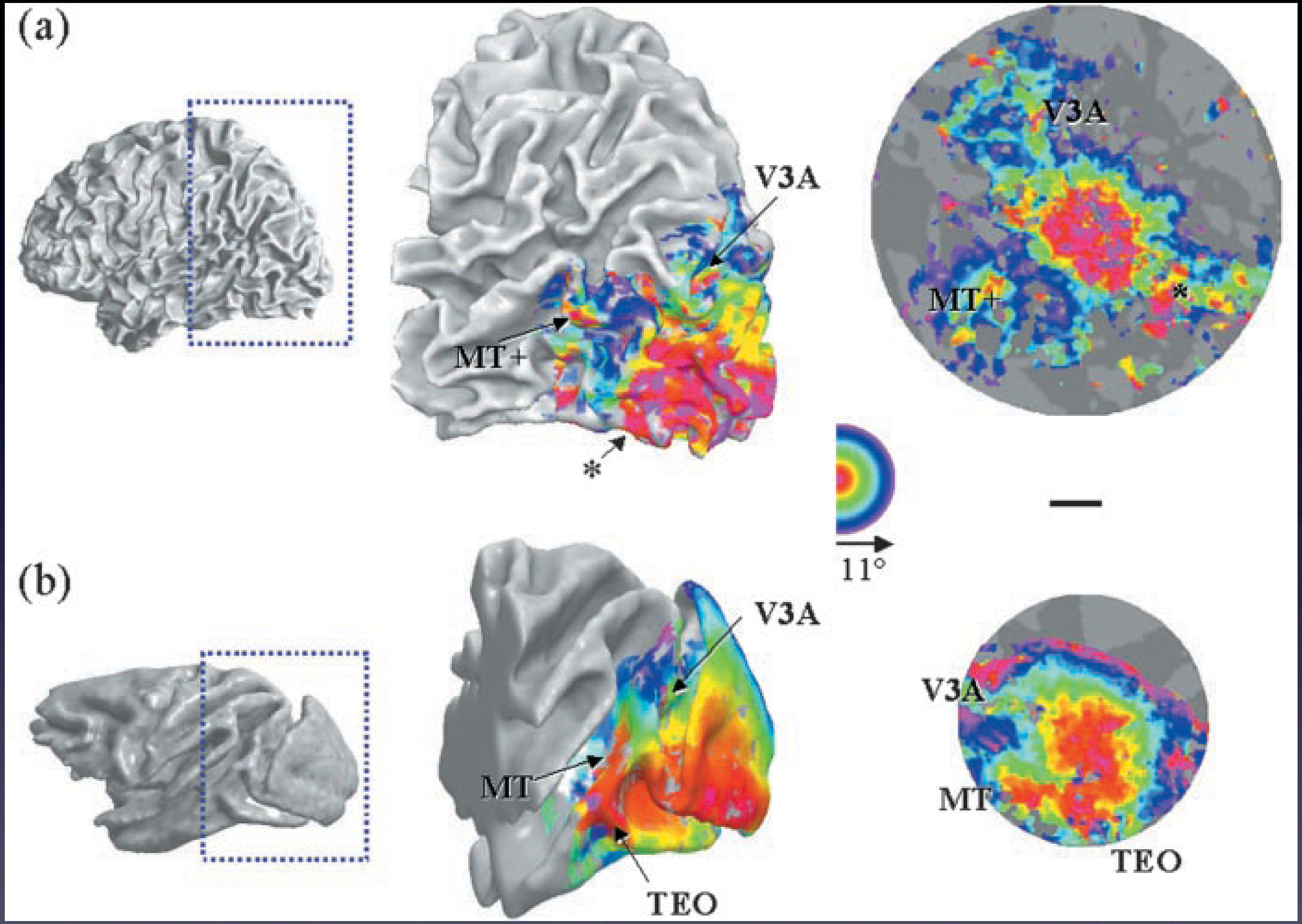
“Functionally corresponding”
or “Functionally equivalent”
areas???

Monkey retinotopy

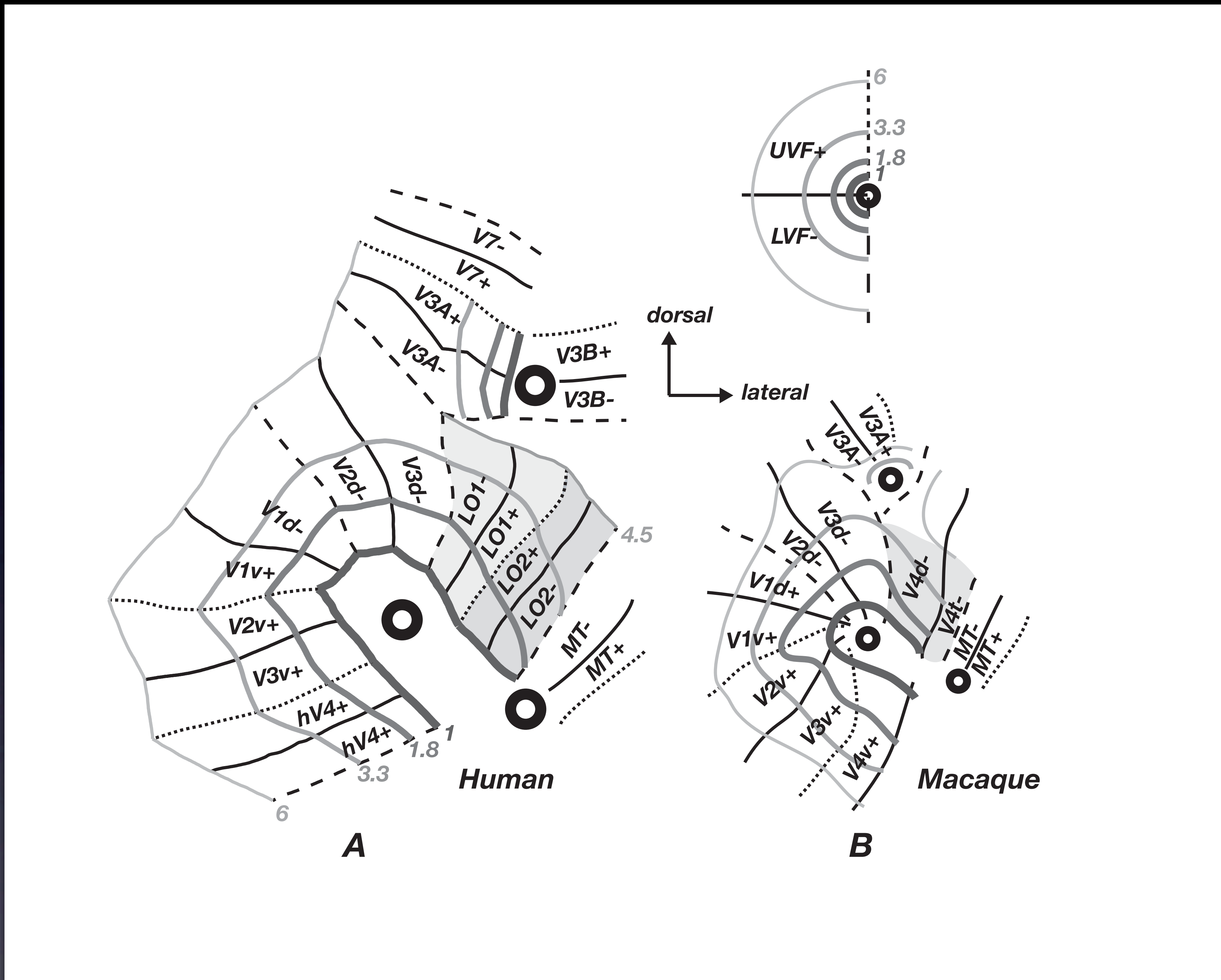


Brewer, Press, Logothetis, Wandell (2002) JN 22:10416-26

Much similarity between monkey & human



Brewer, Press, Logothetis, Wandell (2002) JN 22:10416-26



Some areas in the human have no topographical eqivalent in the monkey (e.g. V7, LO1, LO2)

Some areas are in the same location but have very different function (e.g. V3a is very sensitive to motion only in humans)

Larsson & Heeger (2006) JN 26:13128-42

To really establish equivalencies between human and monkey, we need FACTs!!!

Critically, after establishing topography,
we need to understand function!