Assessing Spontaneous Brain Activity by EEG and sensory probes

Andreas Kleinschmidt, NeuroSpin, France

$$y = bx_e + x_o + \varepsilon$$

Inserm

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de la santé et de la recherche médicale

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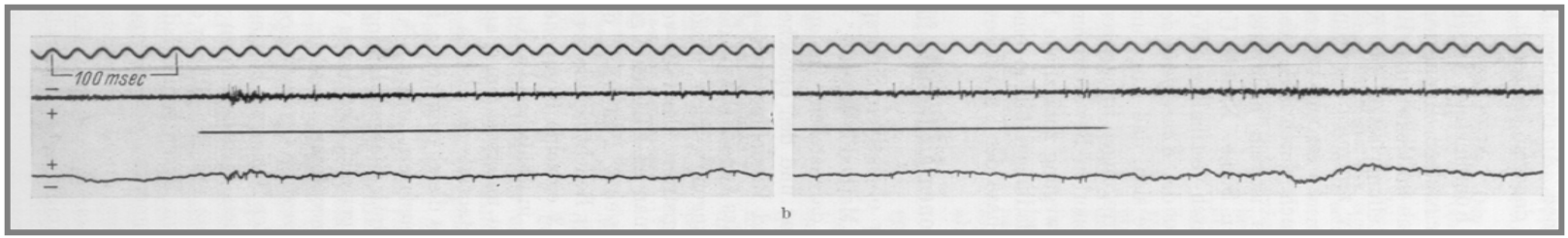
Information from Analyses of Spatial Response Patterns

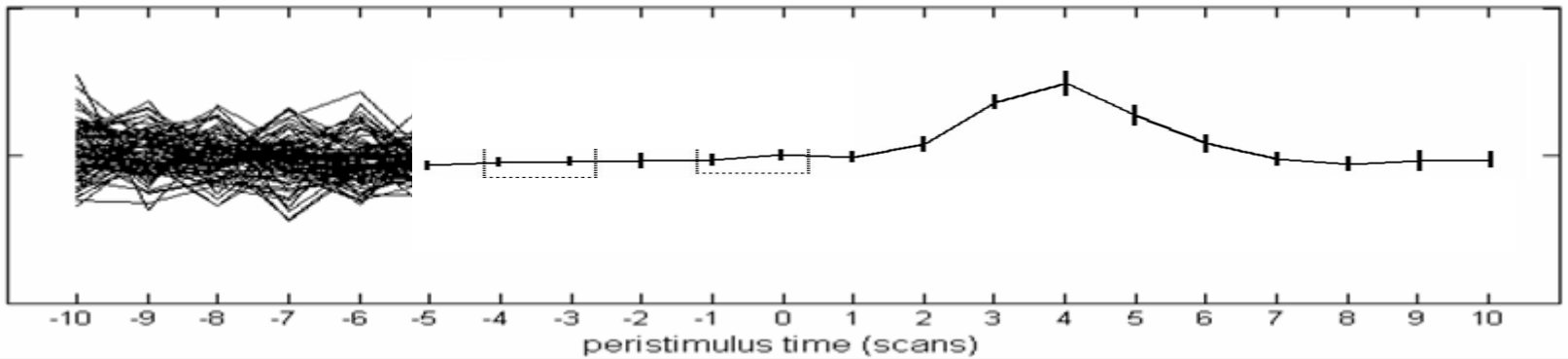
Information from Analyses of Ongoing Activity

Spontaneous brain activity is ubiquitous : across species, signals and states



Richard Jung & coll., 1952

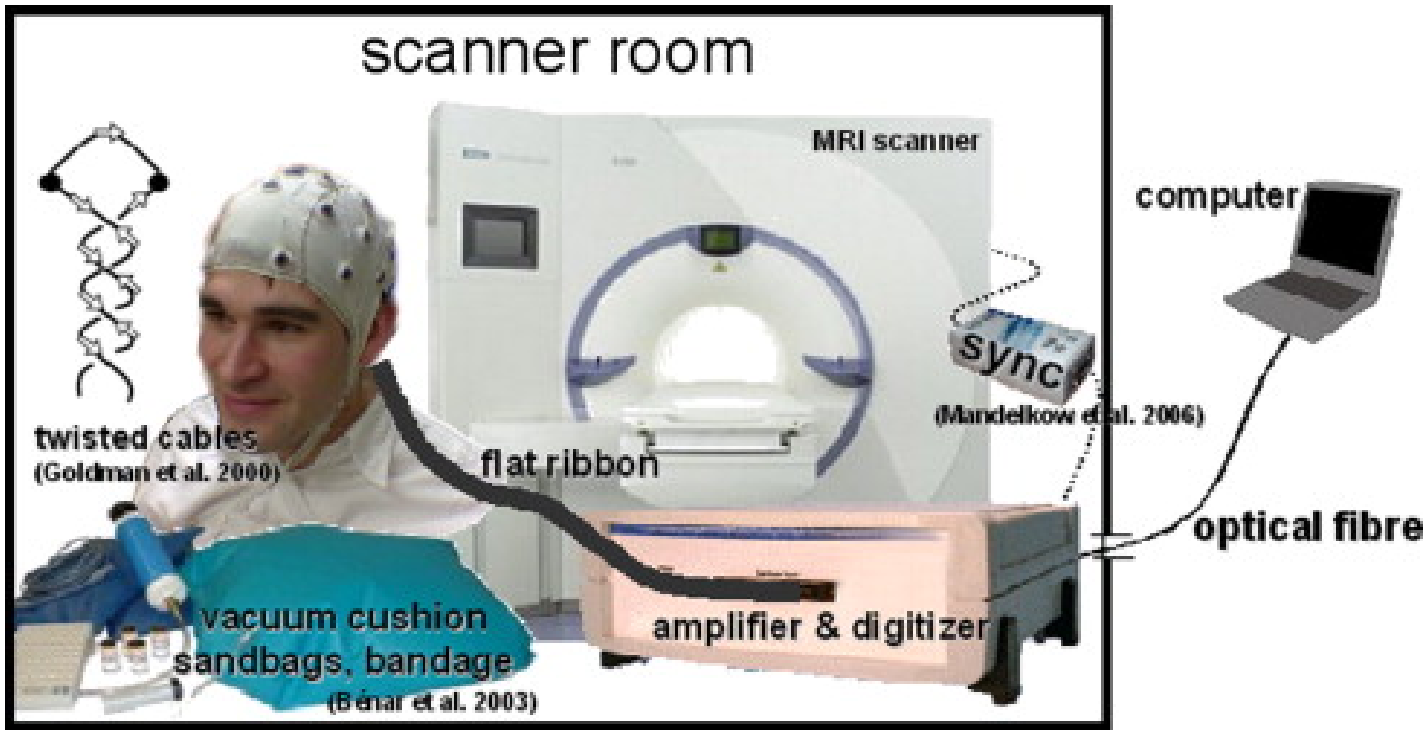
single trial responses in fMRI averaged response



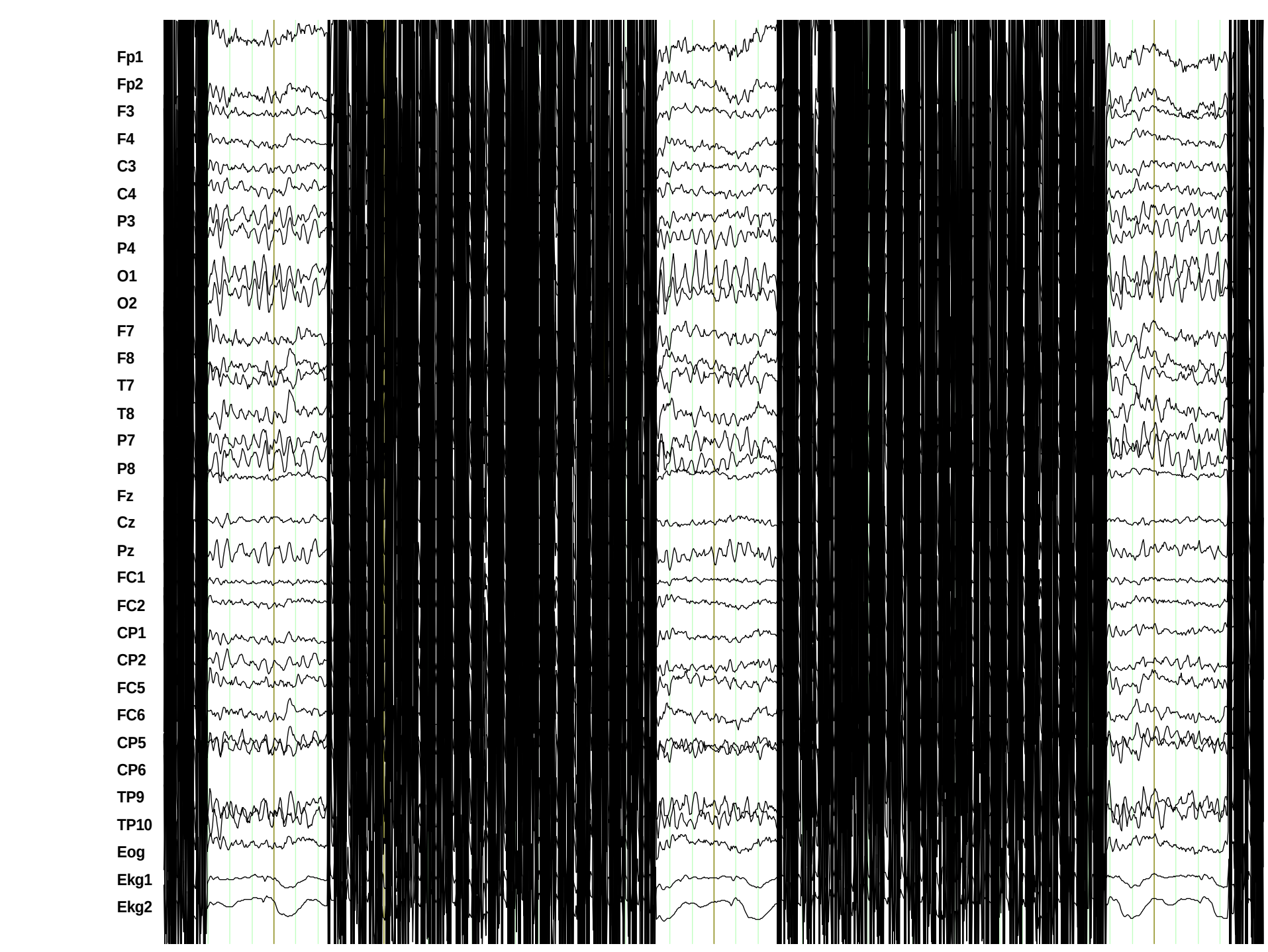
Why should spontaneous activity be important?

- Quantitatively vastly superior to any evoked increment
- Temporally fluctuating
- Spatially organized into functionally meaningful circuits

$$y = bx_e + x_o + \varepsilon$$



From Laufs et al.,2008, Neuroimage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Fp2
F3
F4
C3
C4
P3
P4
O1
O2
F7
F8
T7
T8
P7
P8
Fz
Cz
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FC1
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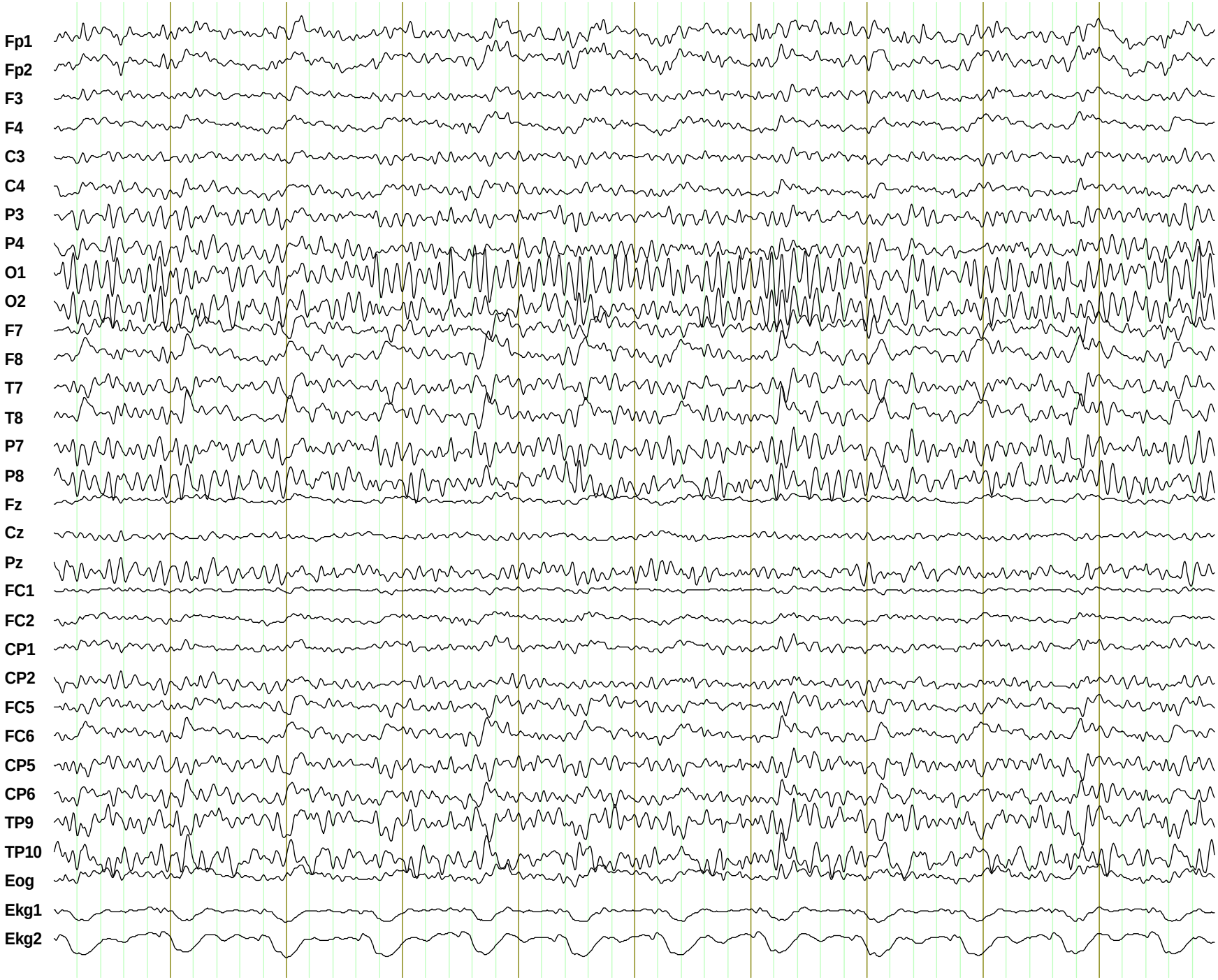
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
Eog
Ekg1
Ekg2


Fp1
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C3
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O1
O2
F7
F8
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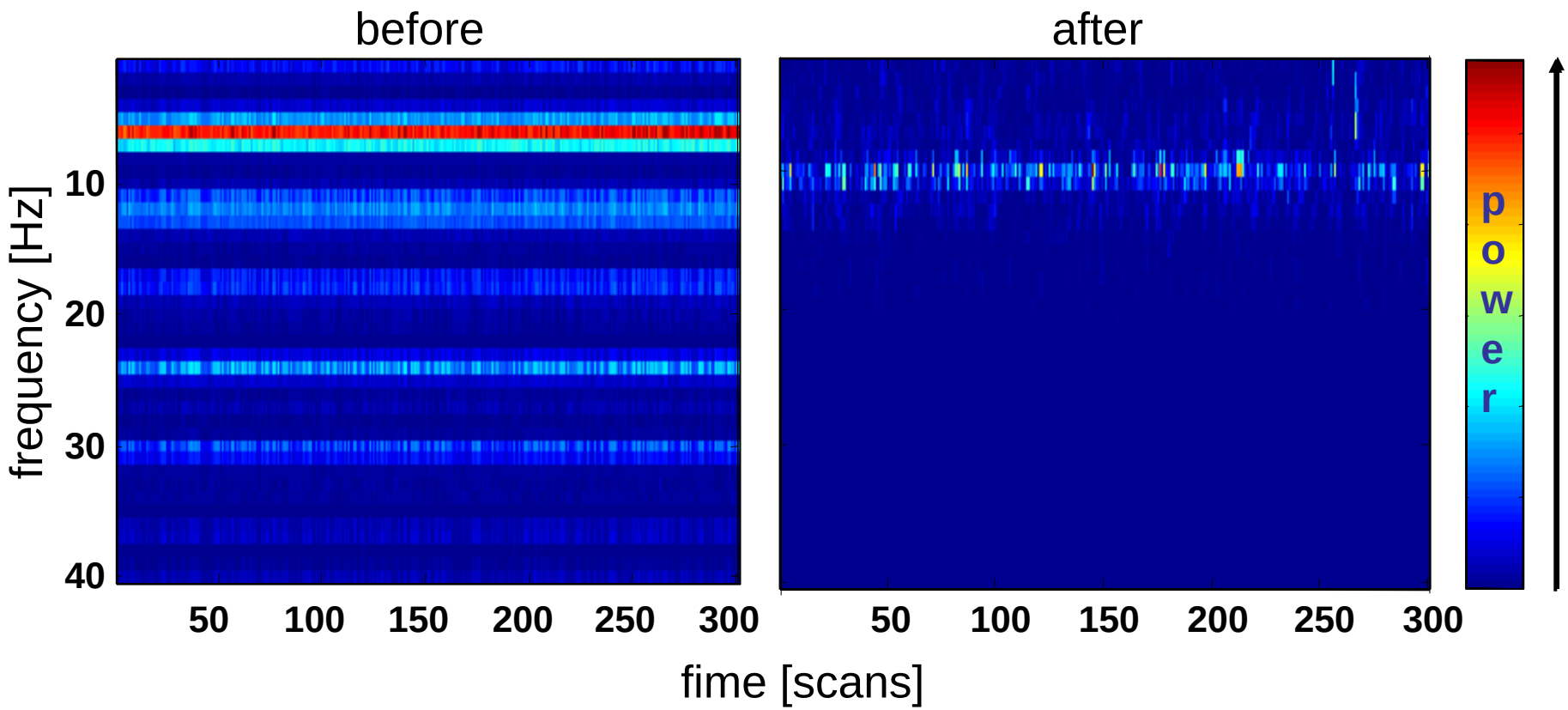
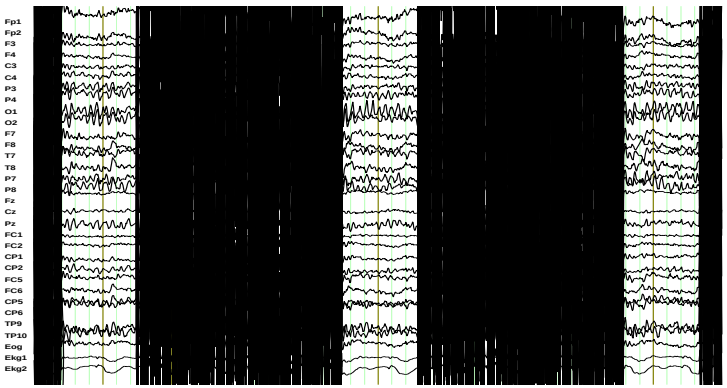
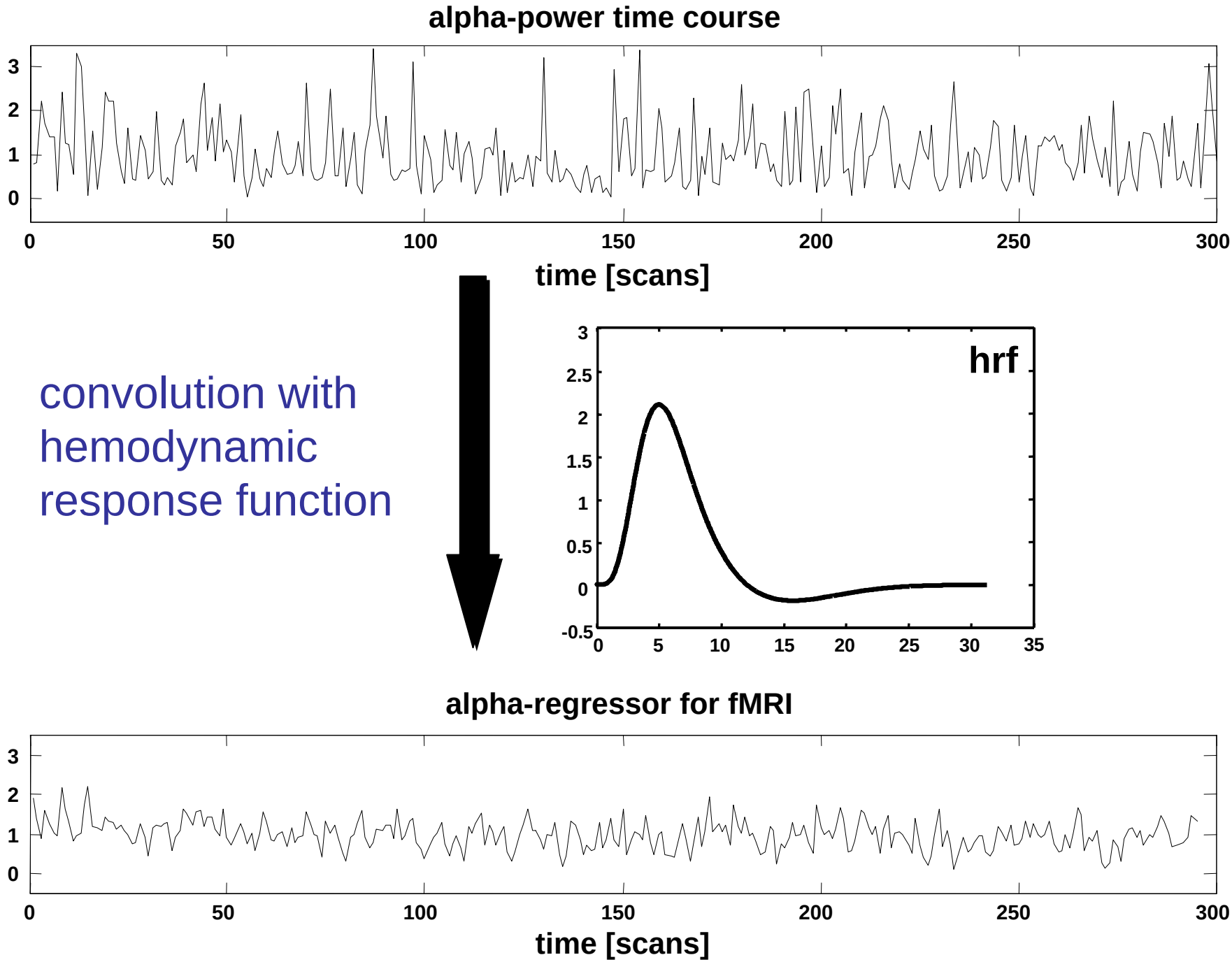
P8
Fz
Cz
Pz
FC1
FC2
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
Eog
Ekg1
Ekg2

Artefact correction and power spectra






alpha-power time course
3
2
1
0
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50
100
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200
250
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time [scans]
convolution with
hemodynamic
response function
hrf
3
2.5
2
1.5
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-0.5
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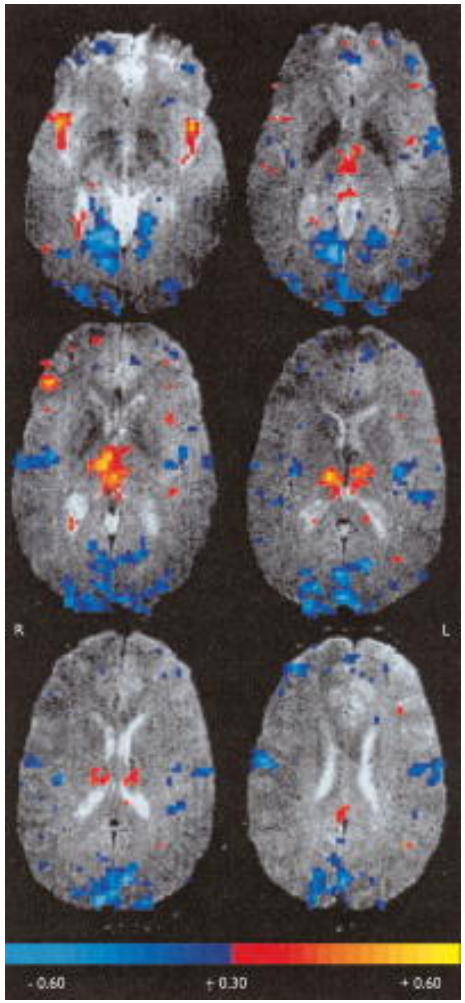
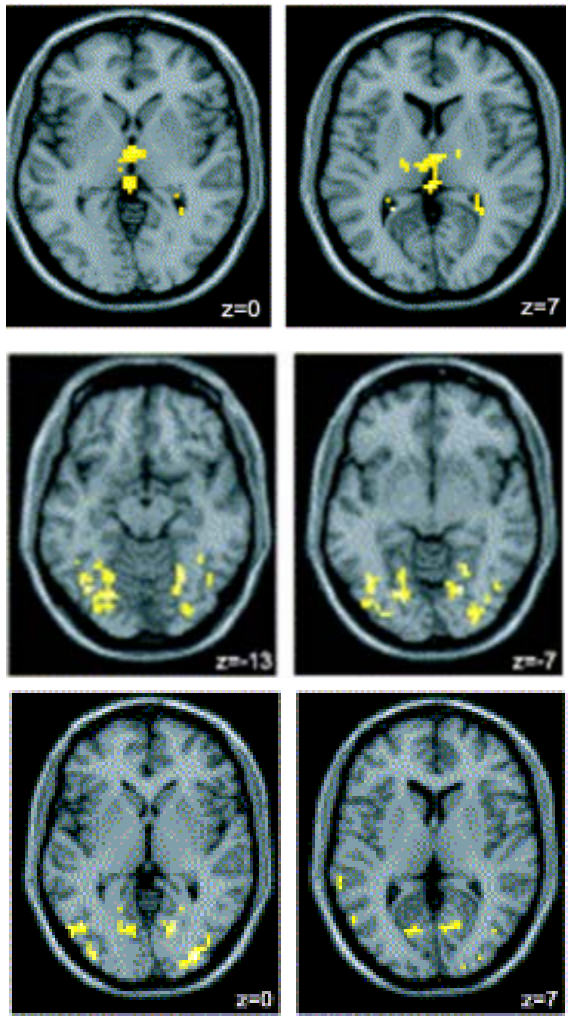
5
10
15
20
25
30
35
alpha-regressor for fMRI
3
2
1
0
0
50
100
150
200
250
300
time [scans]

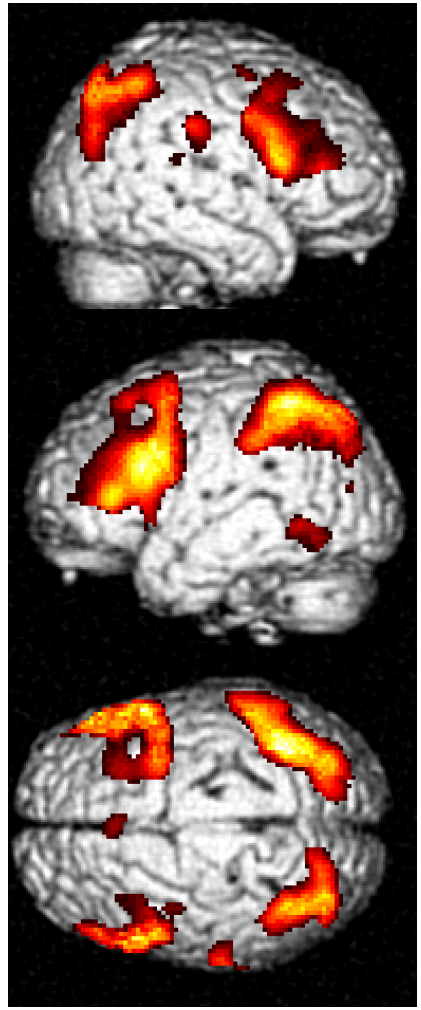
BOLD signal correlations with posterior alpha power



Goldman et al., 2002



Moosmann et al., 2003



Laufs et al., 2003

How Hans Berger blocked alpha activity

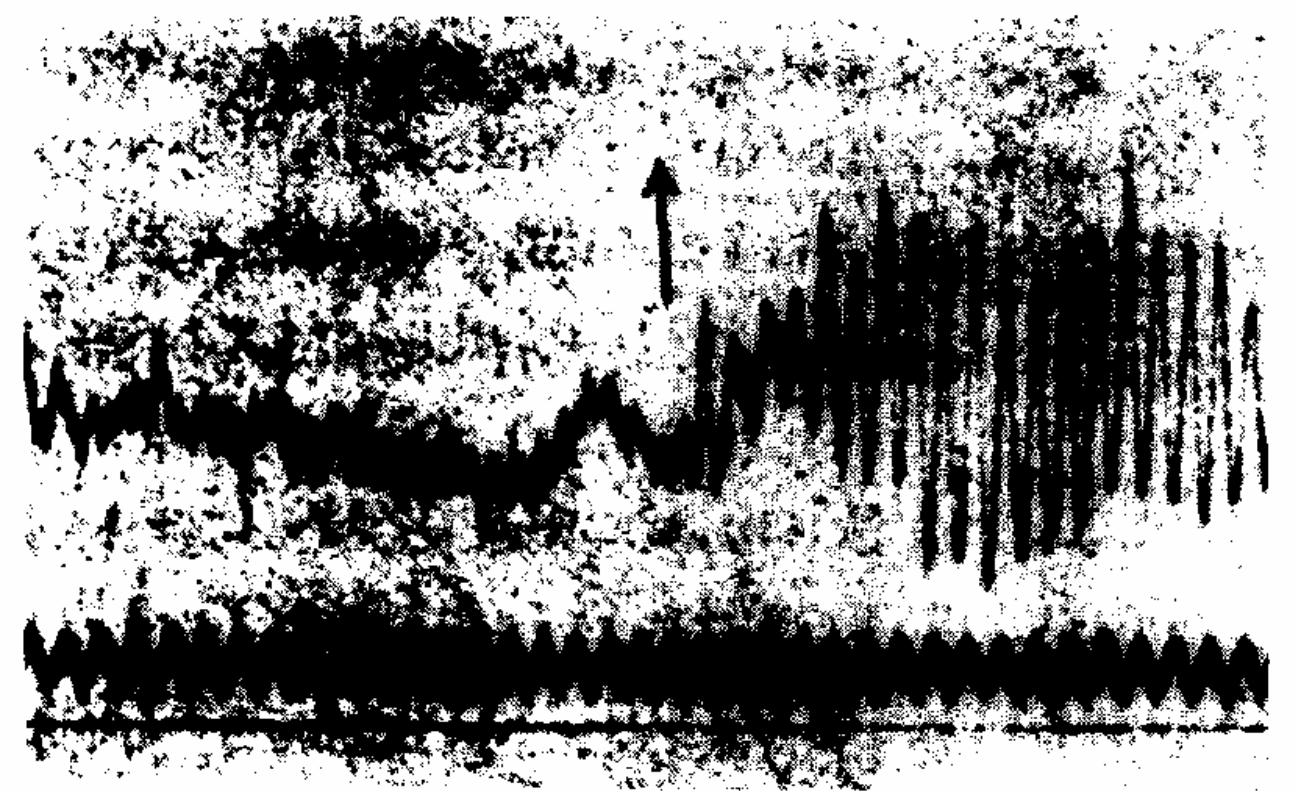
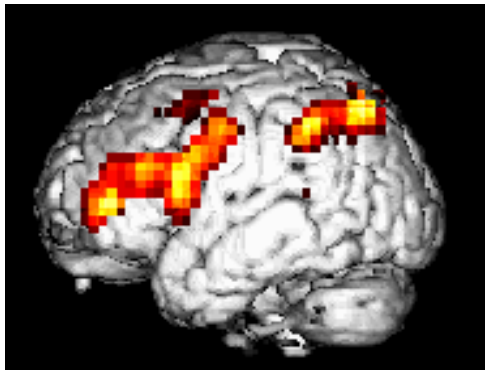
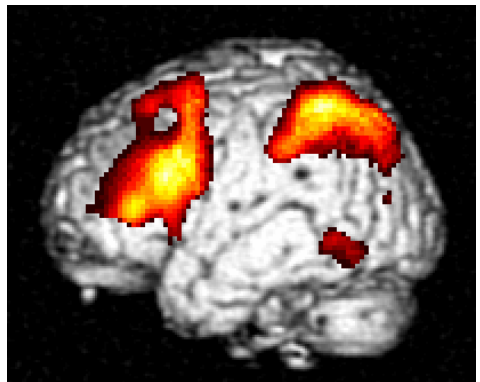


Fig. 2. Hans Berger's 14-year-old daughter Ilse calculating (196 ÷ 7). Note excellent alpha blocking and alpha return at termination of the task. The bottom trace indicates time in 0.1 s. With permission of Dr. P. Gloor and Elsevier Publishers.

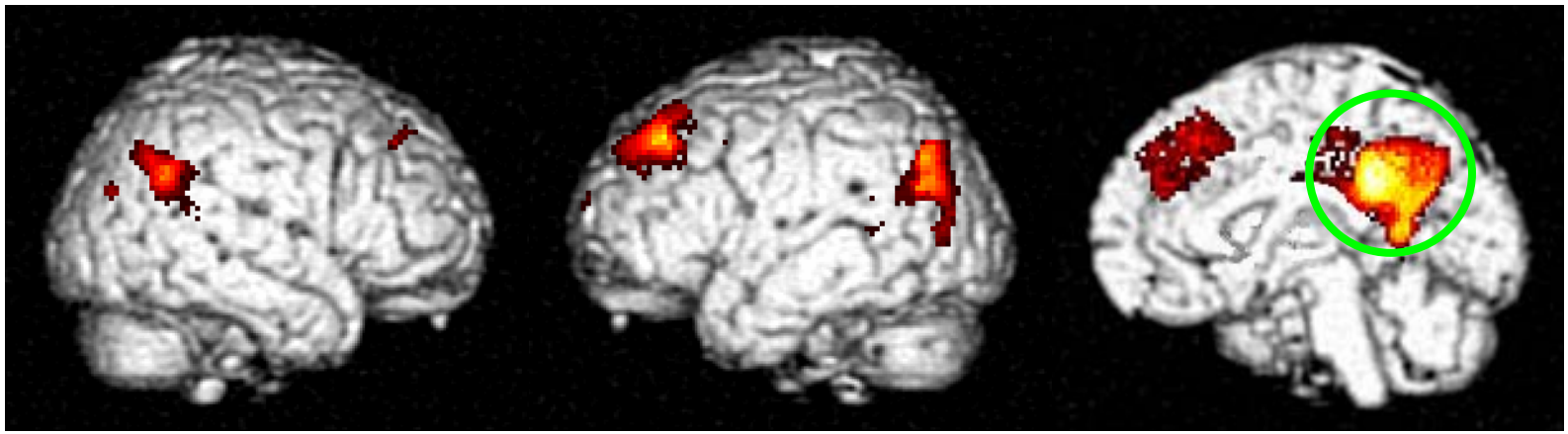


Gruber et al., Cerebral Cortex, 2001

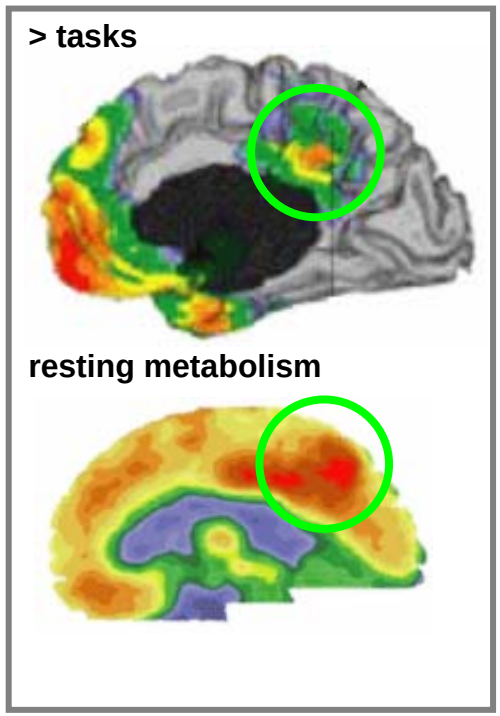


Laufs et al., NeuroImage, 2003

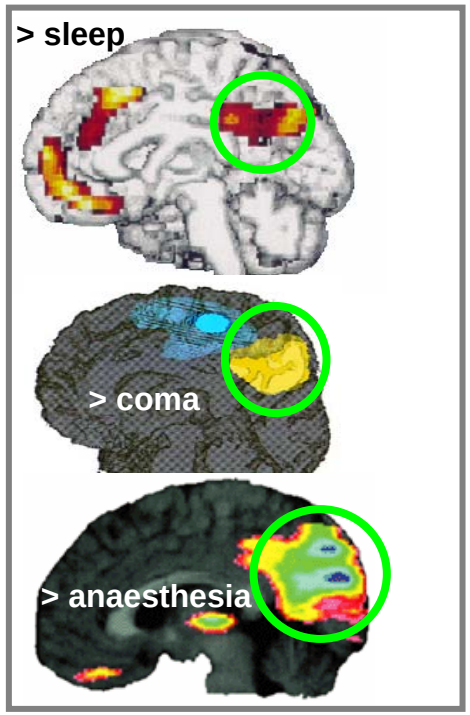
Positive correlation with beta-2 power during resting state



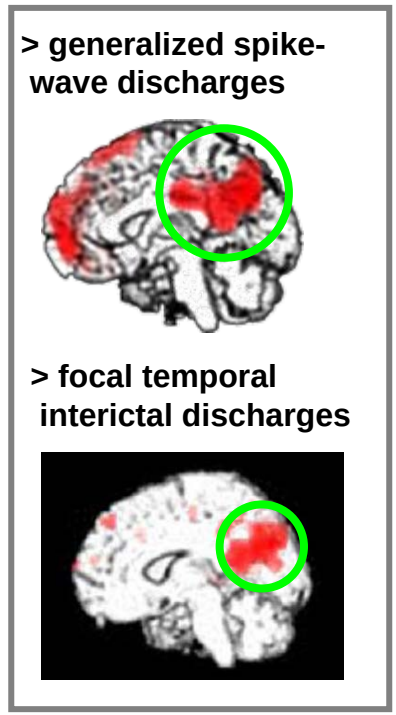
Laufs et al., PNAS, 2003



Raichle et al., ‚Nat. Rev Neurosci



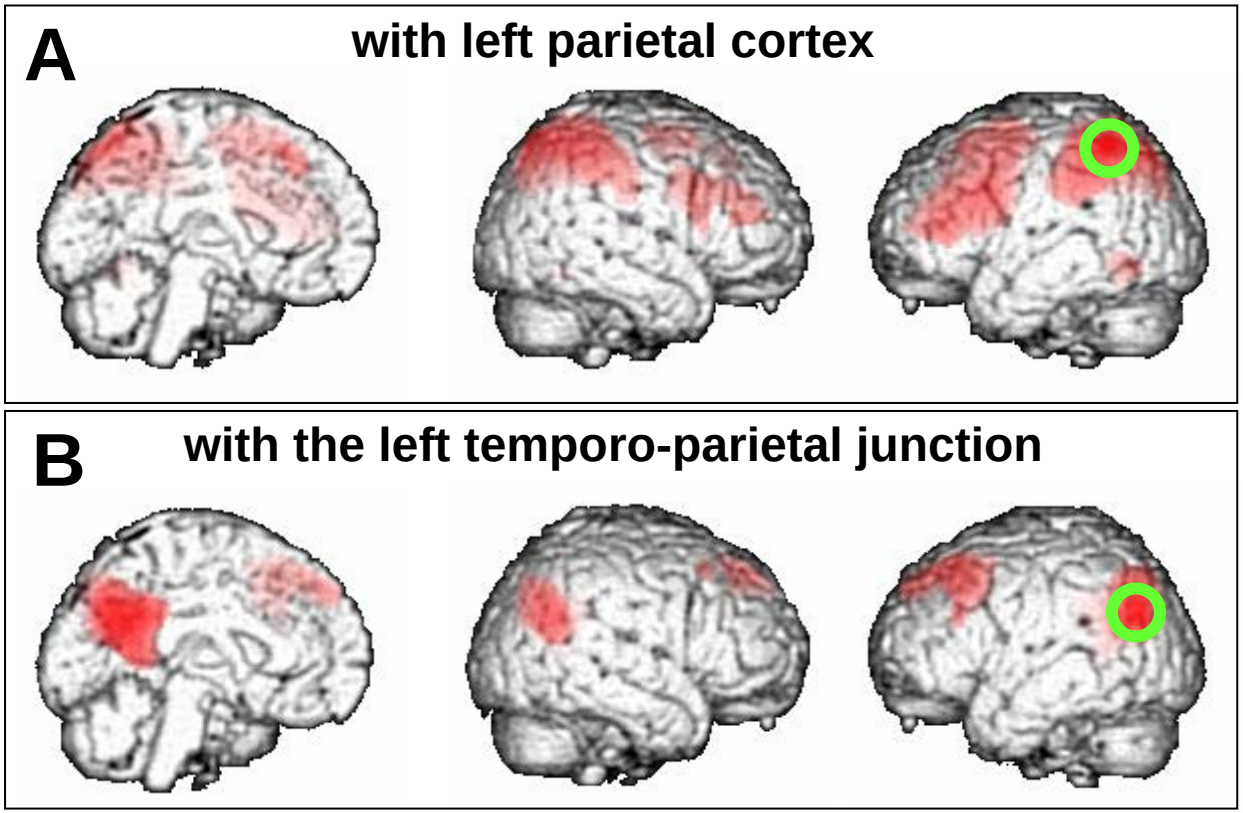
Maquet and coll., div. publ.



Laufs et al., 2005 & 2006

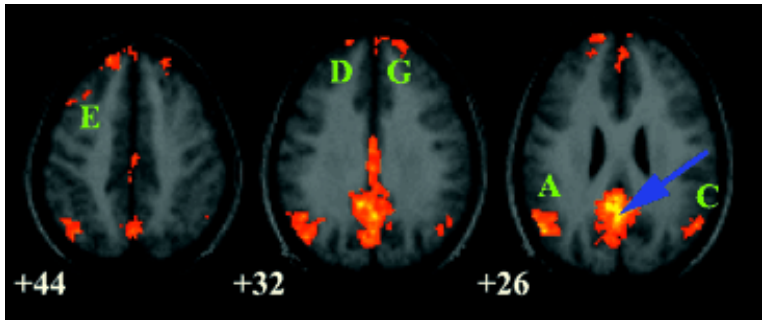
Functional connectivity during resting state

Correlation of spontaneous fMRI signal fluctuations



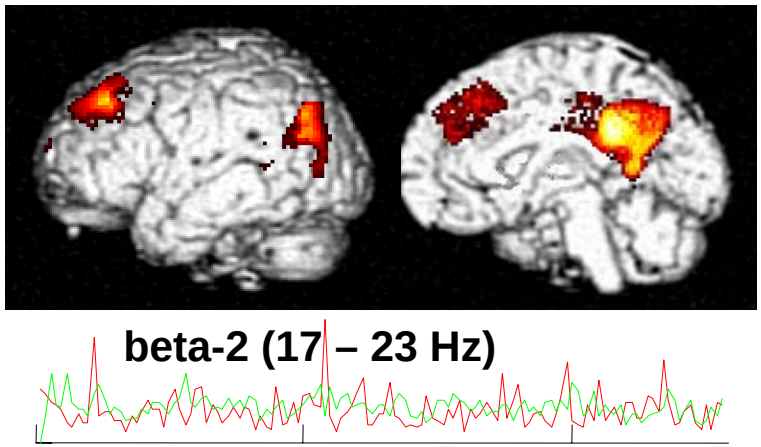
How to interrogate resting state data?

model-driven:
functional or spatial inference



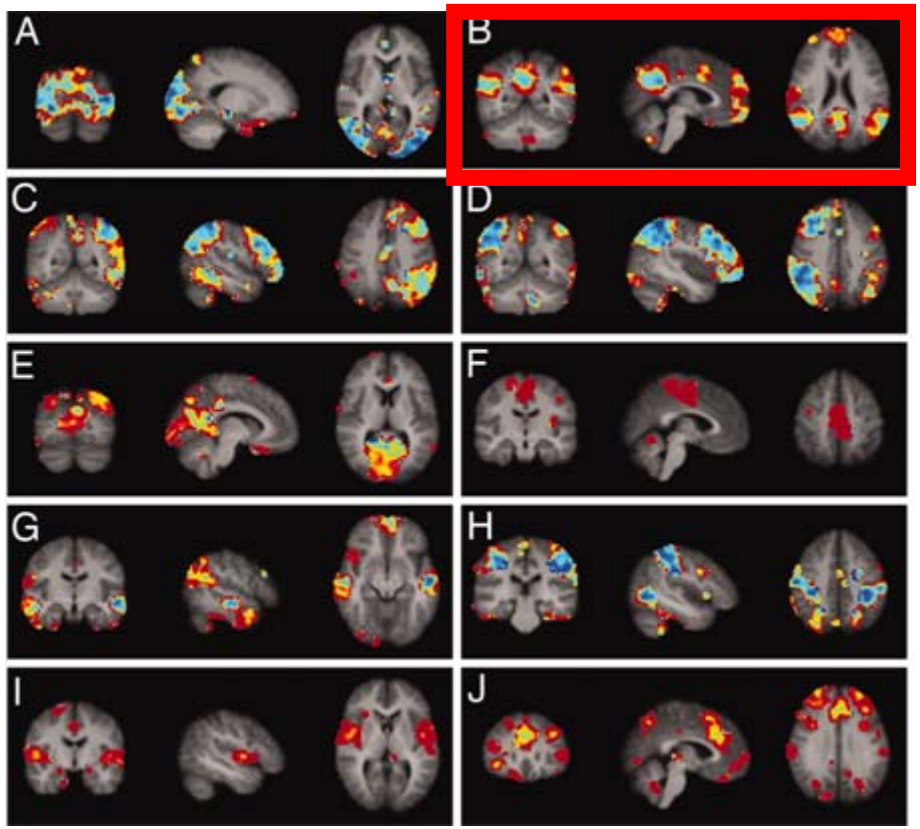
Greicius et al., PNAS, 2003

temporal inference



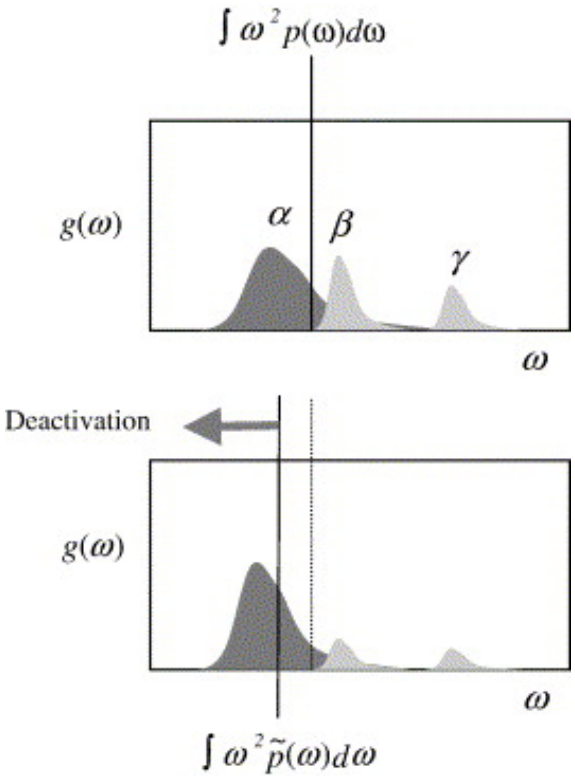
Laufs et al., PNAS, 2003

data-driven:
Independent component analysis

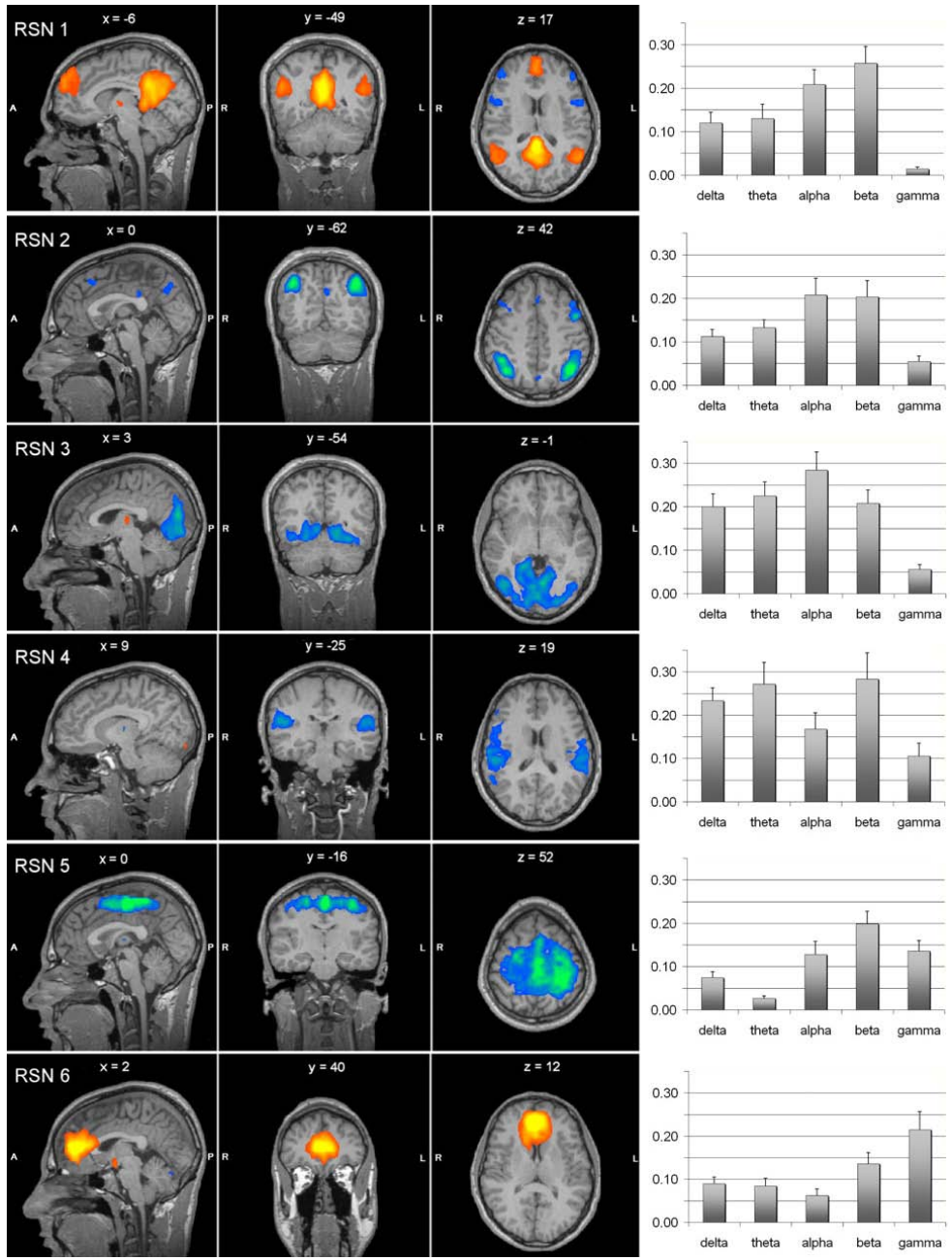


Damoiseaux et al., PNAS, 2006

Spectral EEG Signatures of Resting State Networks



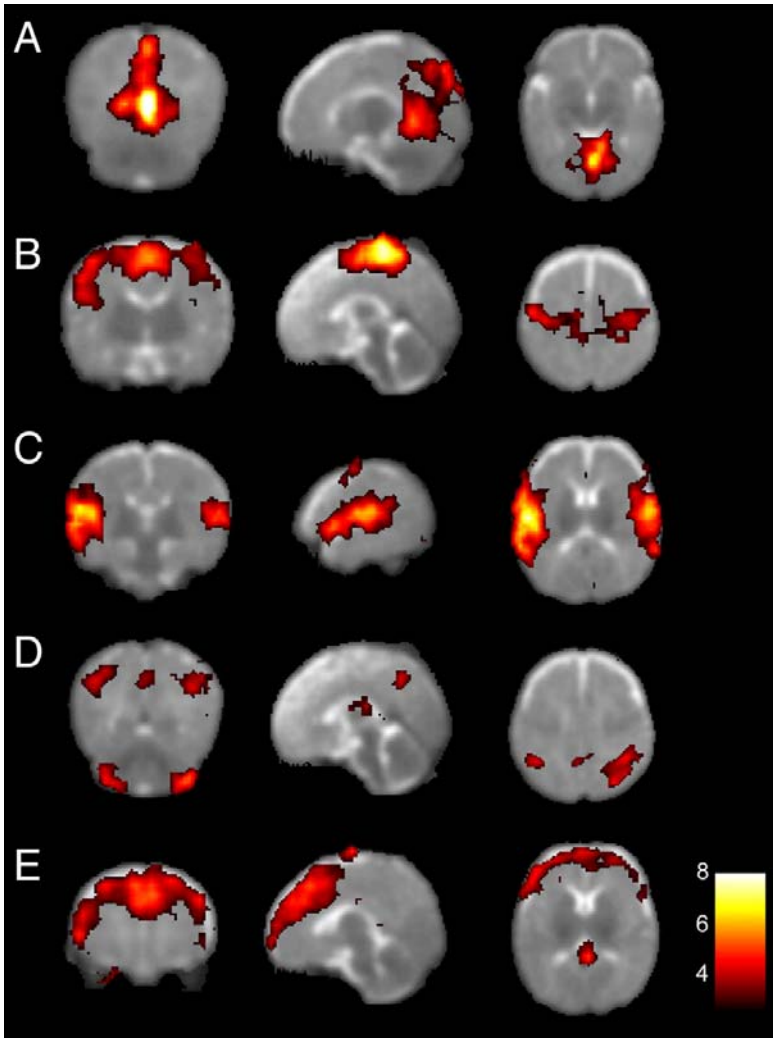
(Kilner et al., NeuroImage, 2005)



(Mantini et al., PNAS, 2007)

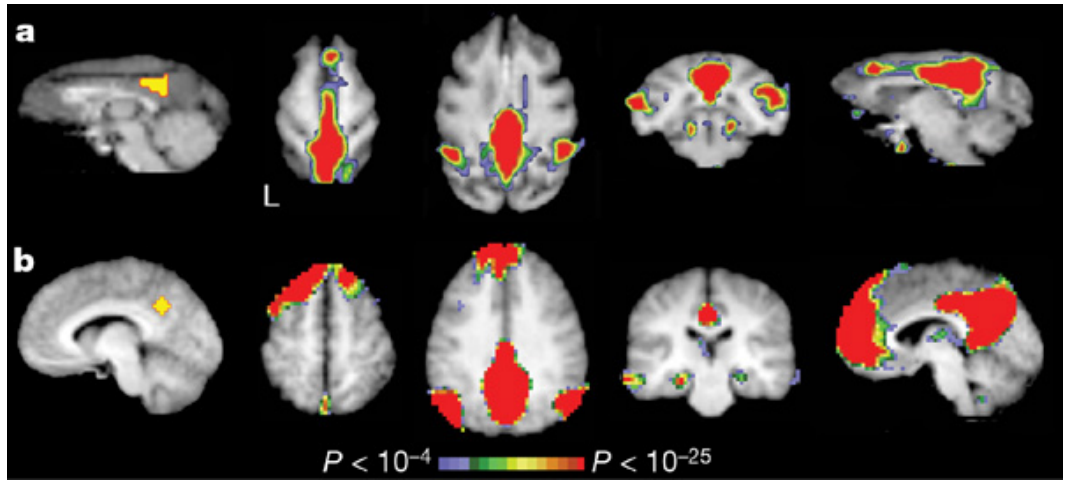
Phylo- and Ontogenesis of Intrinsic Functional Connectivity

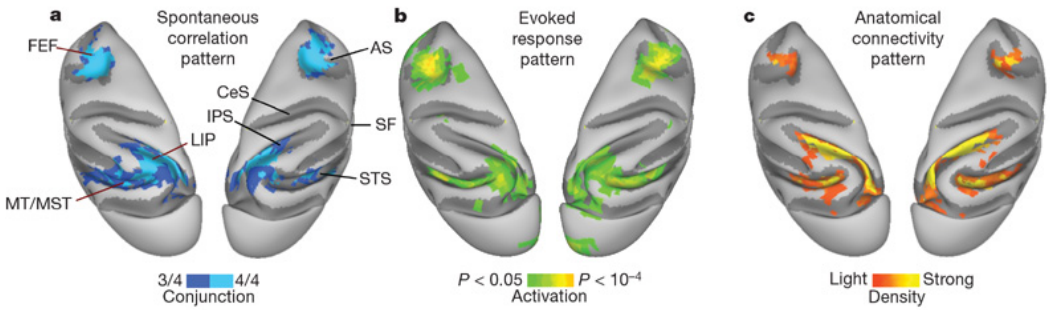
Group resting-state networks in infants



Fransson P et al. PNAS 2007;104:15531-15536

The default mode network in monkey and man



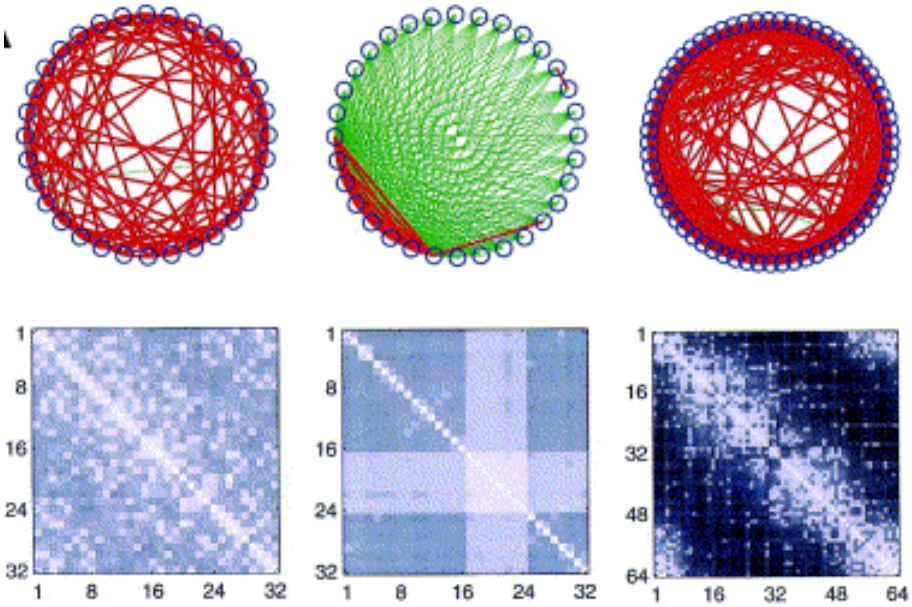


Vincent J et al., Nature, 2006

What does spontaneous activity during resting states signal? Covert cognition or functional noise replaying organized structure?

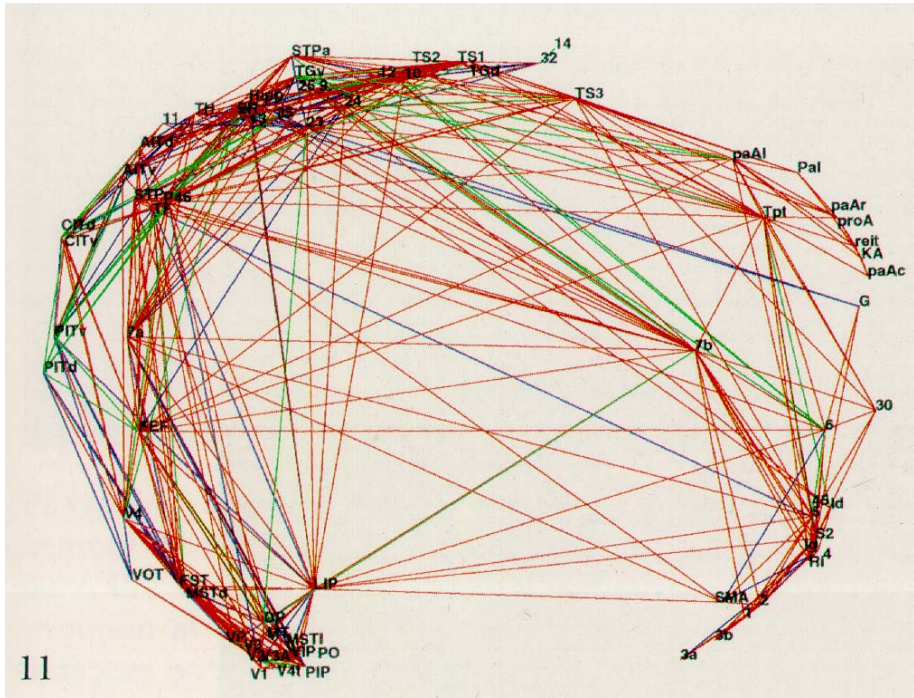
‘Theoretical neuroanatomy and the connectivity of the cerebral cortex’

‘



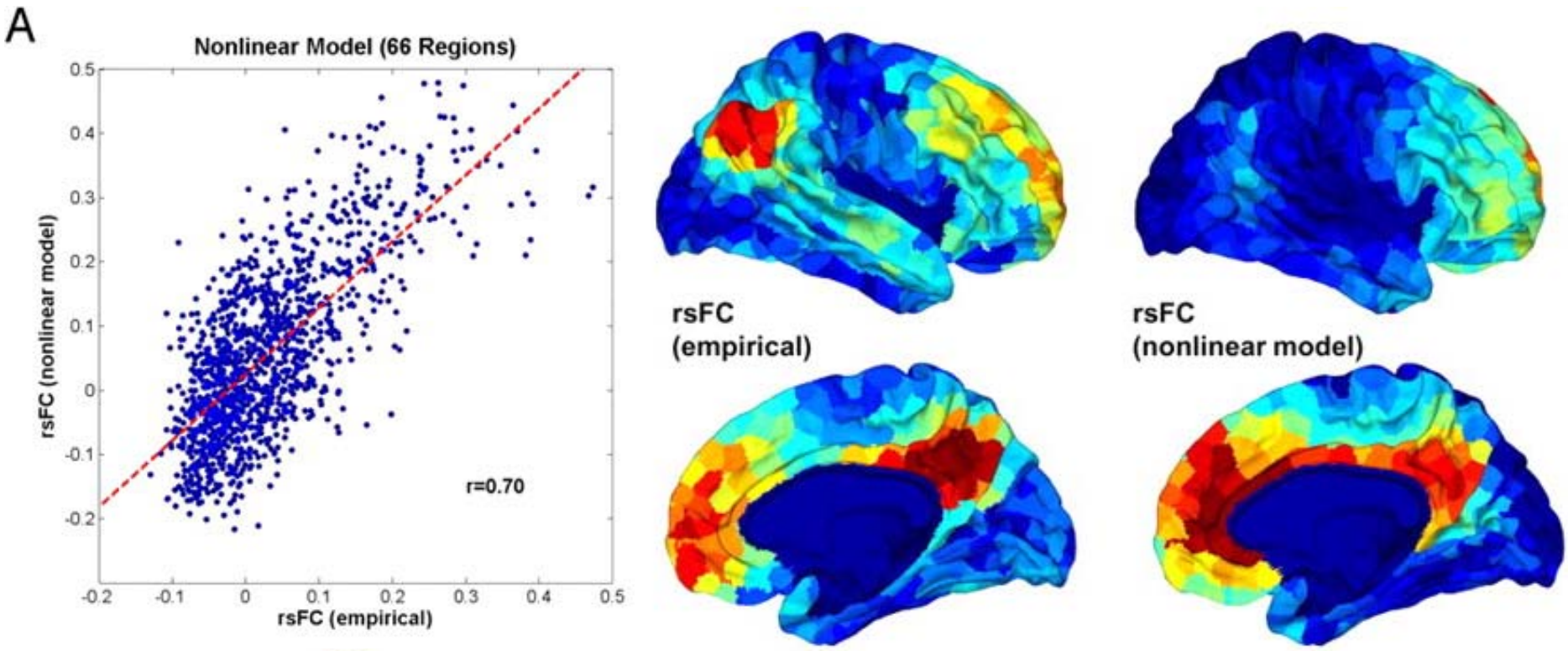
Sporns O, Tononi G, Edelman GM.
Behav Brain Res 135(1-2):69-74 (2002)

‘The organization of neural systems in the primate cerebral cortex’



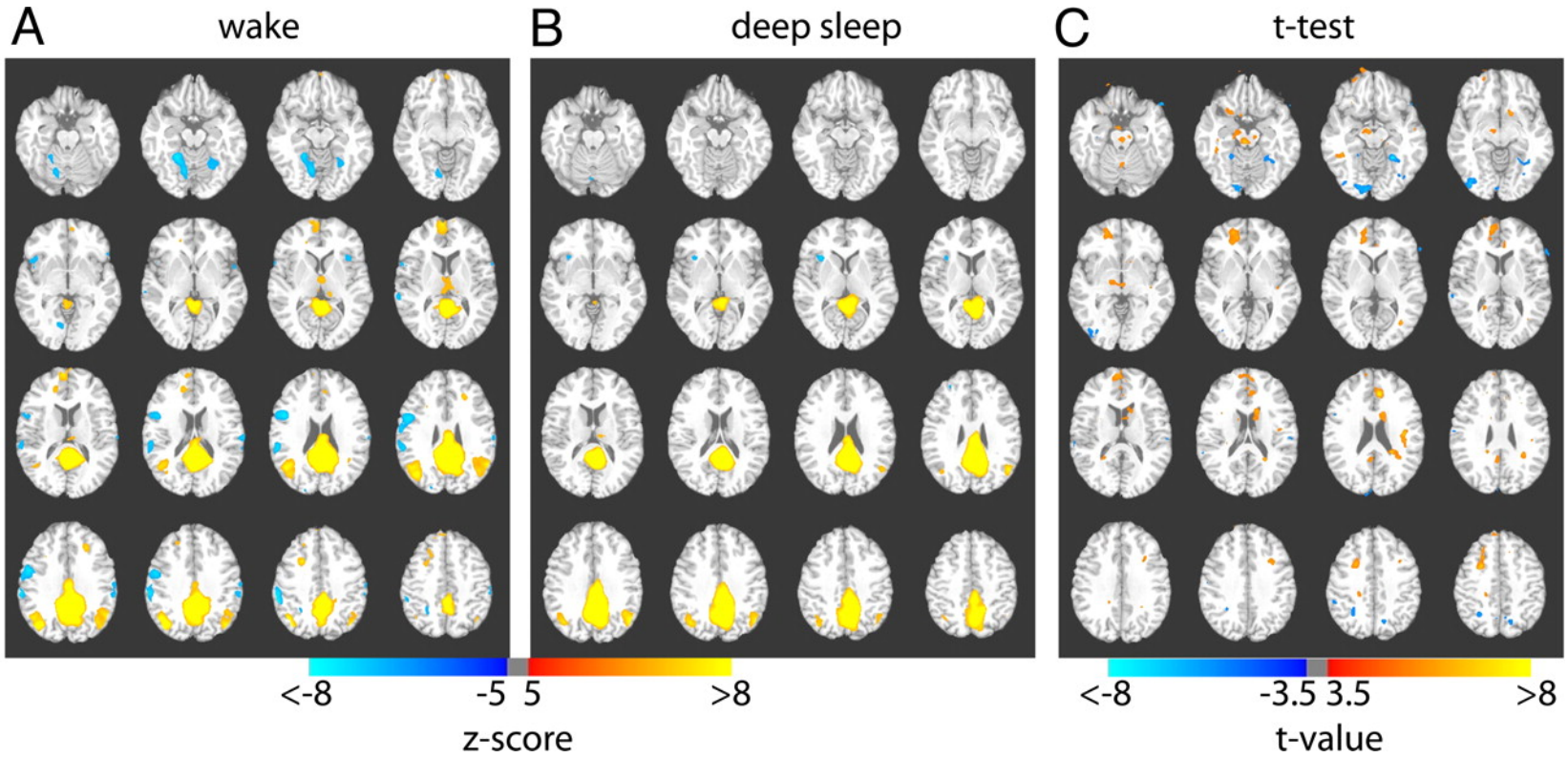
Young MP. Proc R Soc Lond
B Biol Sci 252, 13-18, 1993

Computational model of functional connectivity



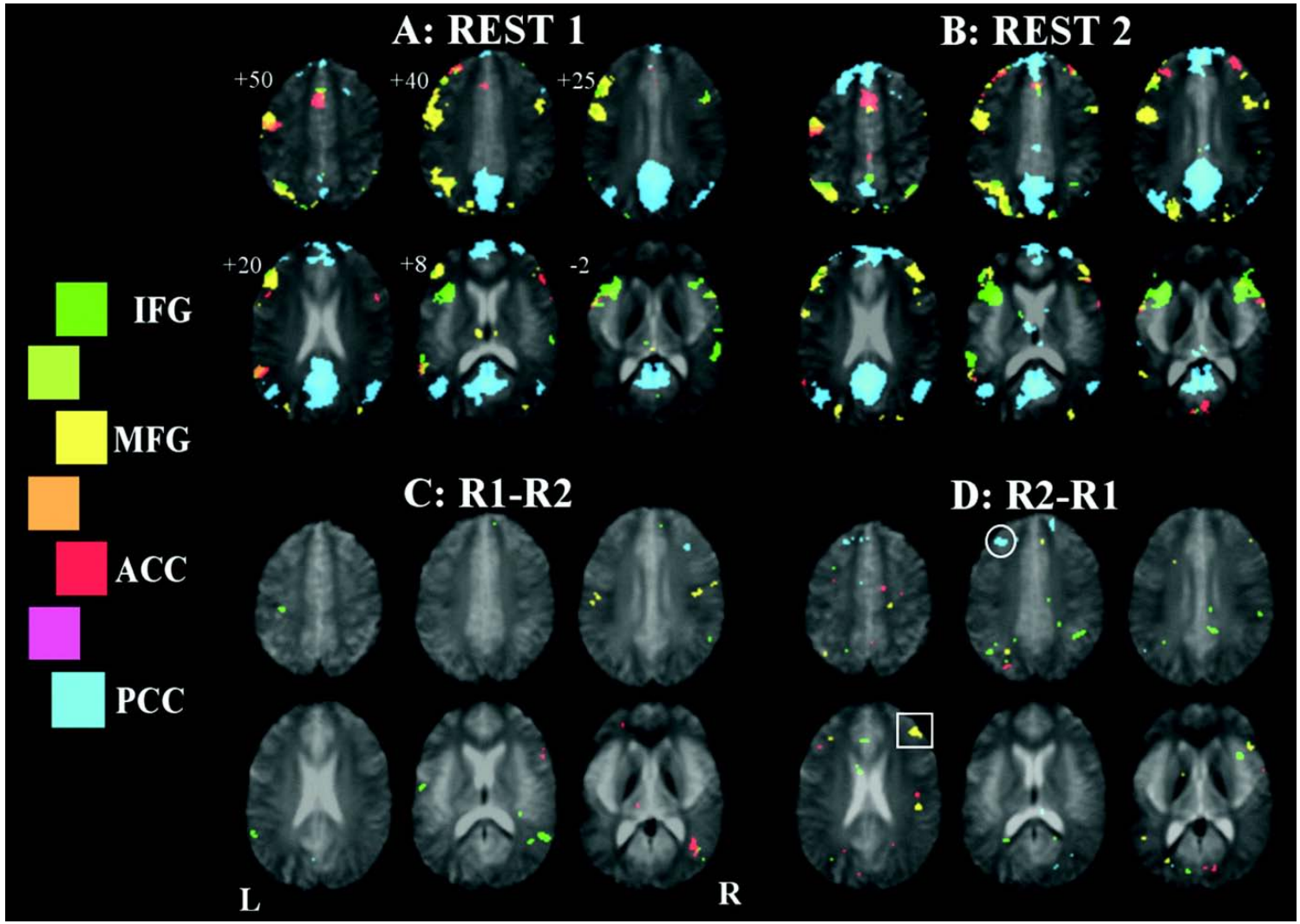
Honey C J et al. PNAS 2009;106:2035-2040

The default mode network during wake and sleep



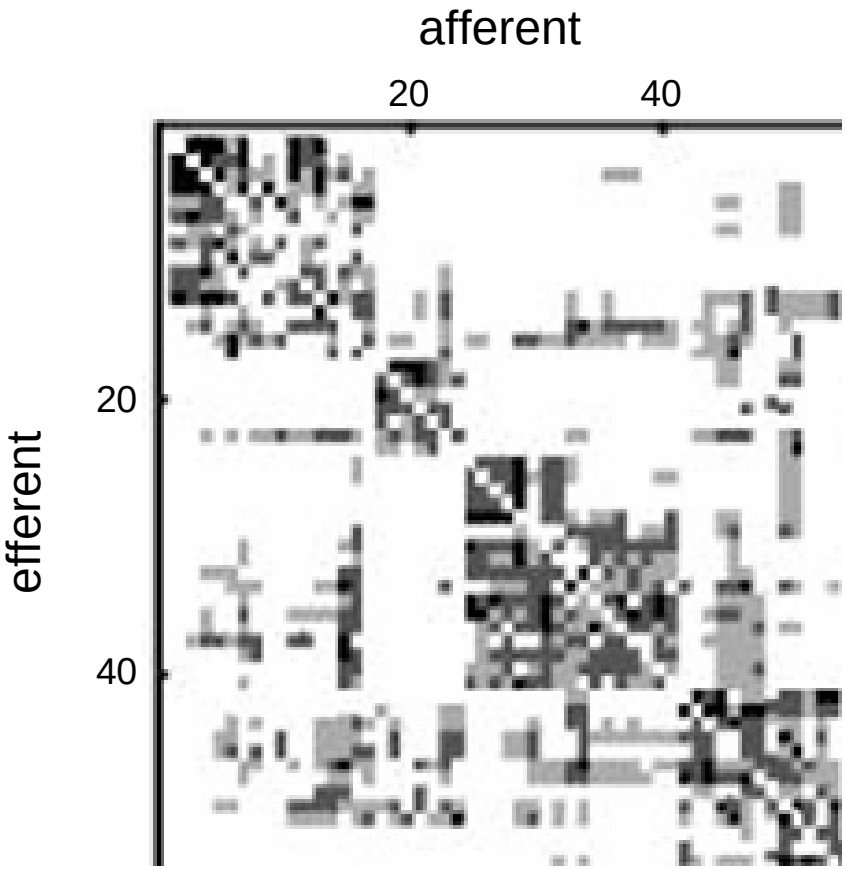
Horovitz S G et al. PNAS 2009;106:11376-11381

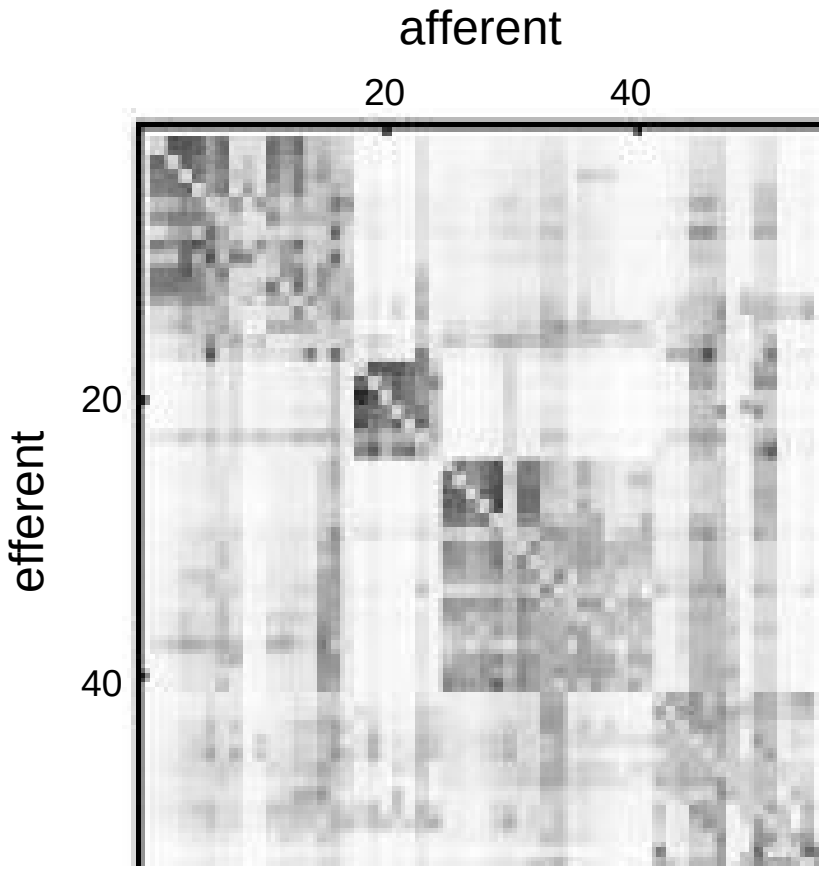
Short-term changes in intrinsic functional connectivity



(Waites et al., Human Brain Mapp, 2005)

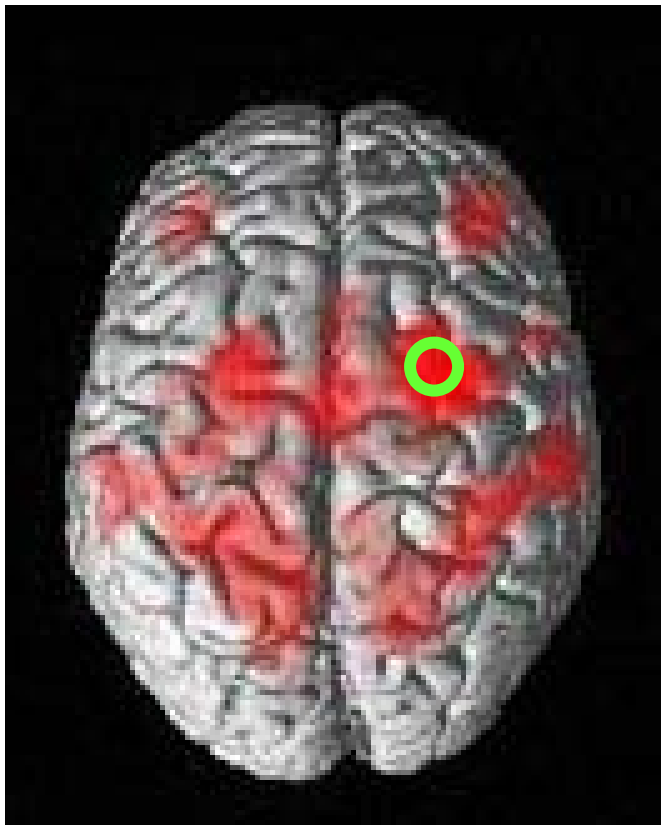
‘On imputing function to structure from the behavioural effects of brain lesions‘



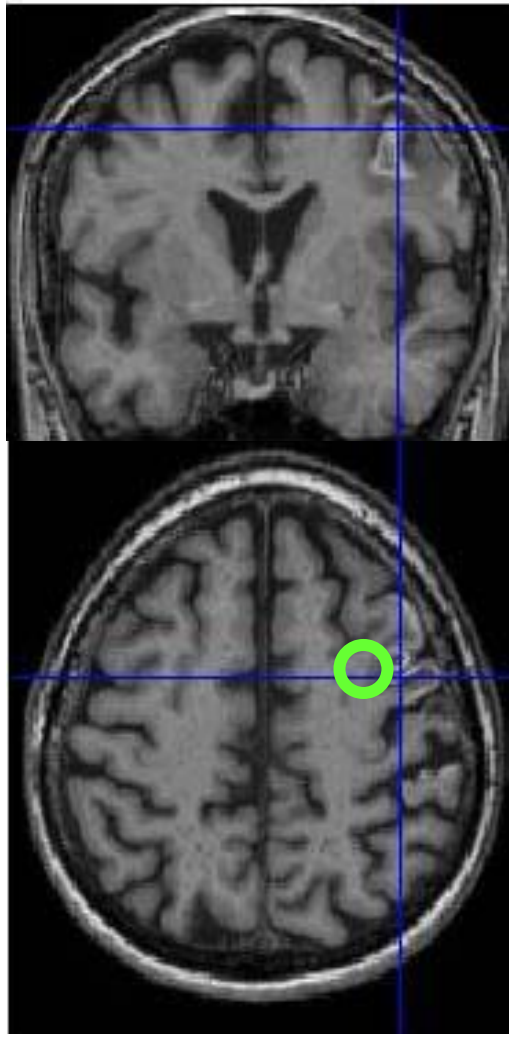


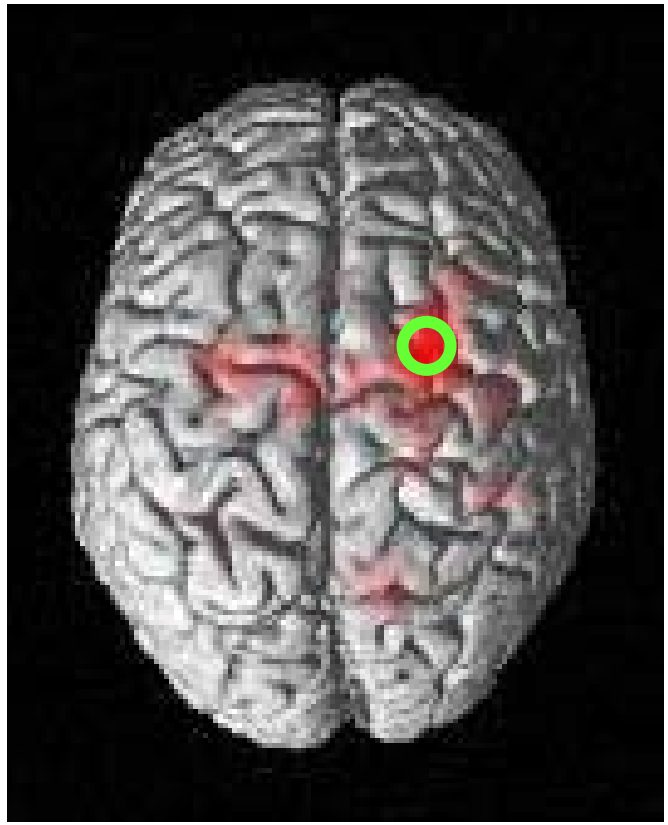
(Young et al., Philos Trans R Soc B, 2000)

Diaschisis after focal ischemic brain lesions



Healthy Controls

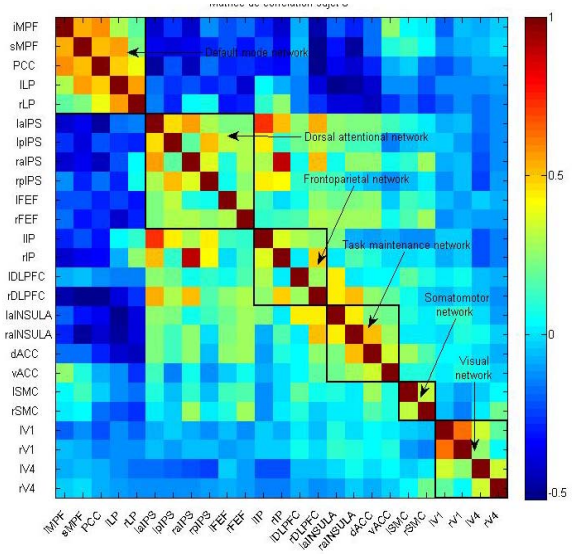


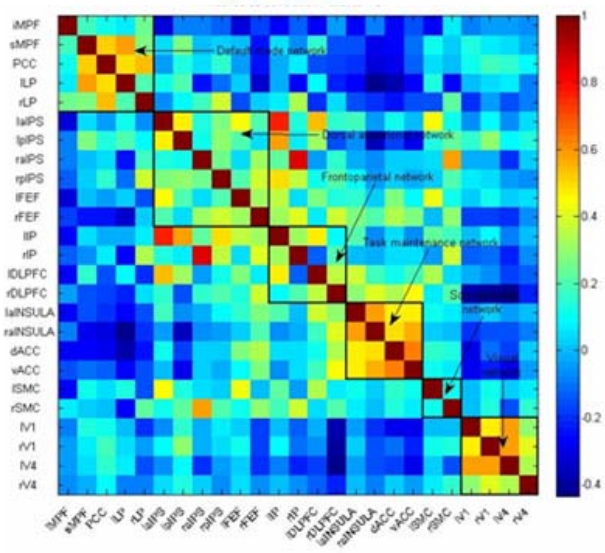


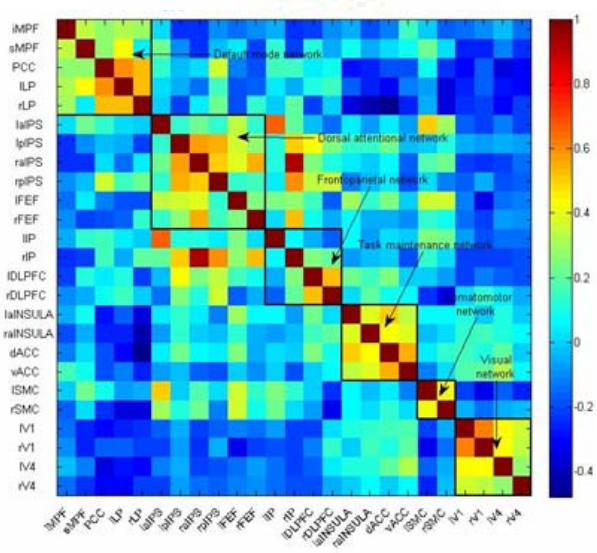
Patient

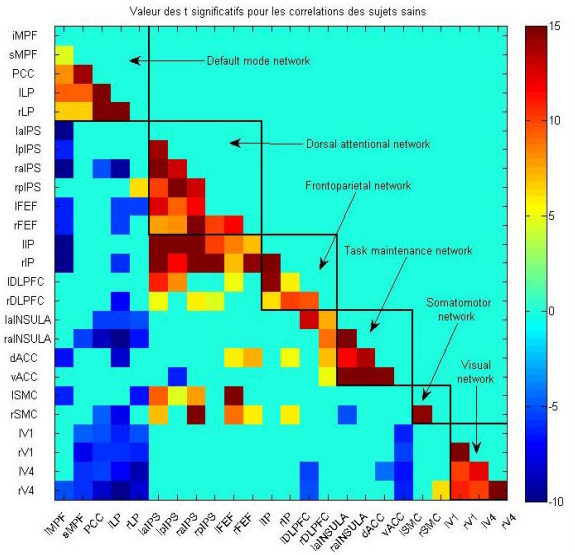
(Baronnet et al., w-i-p)

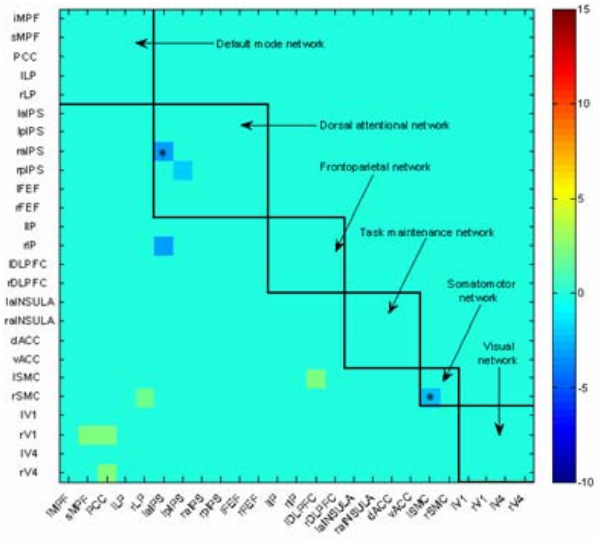
Network Effects of Focal Brain Lesions

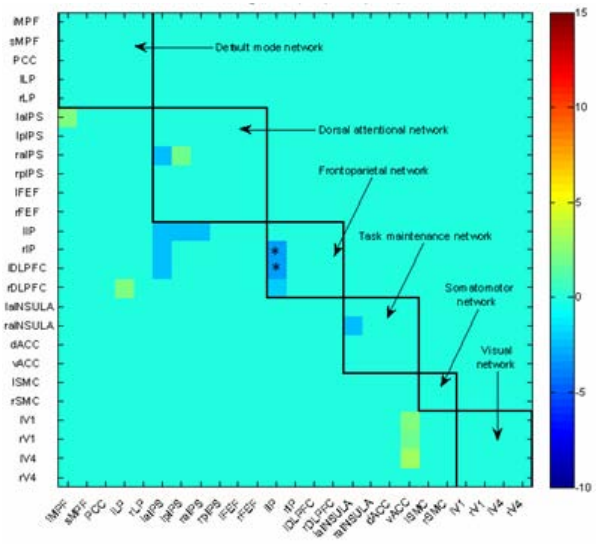






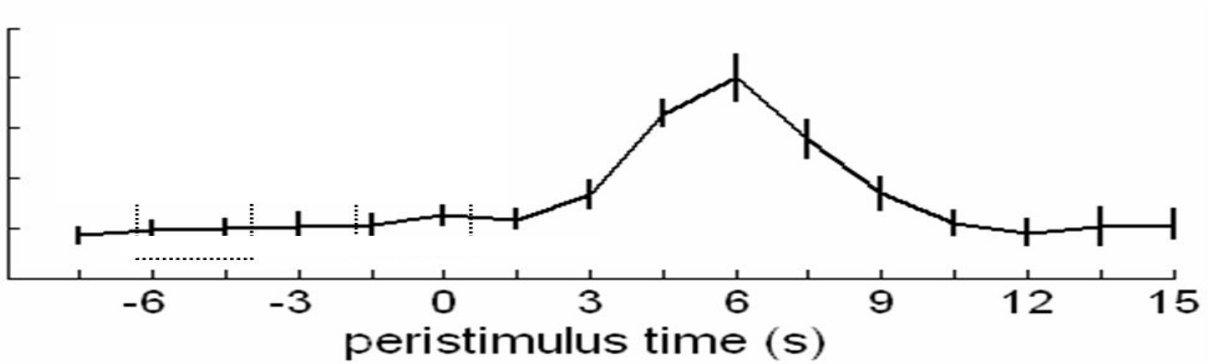




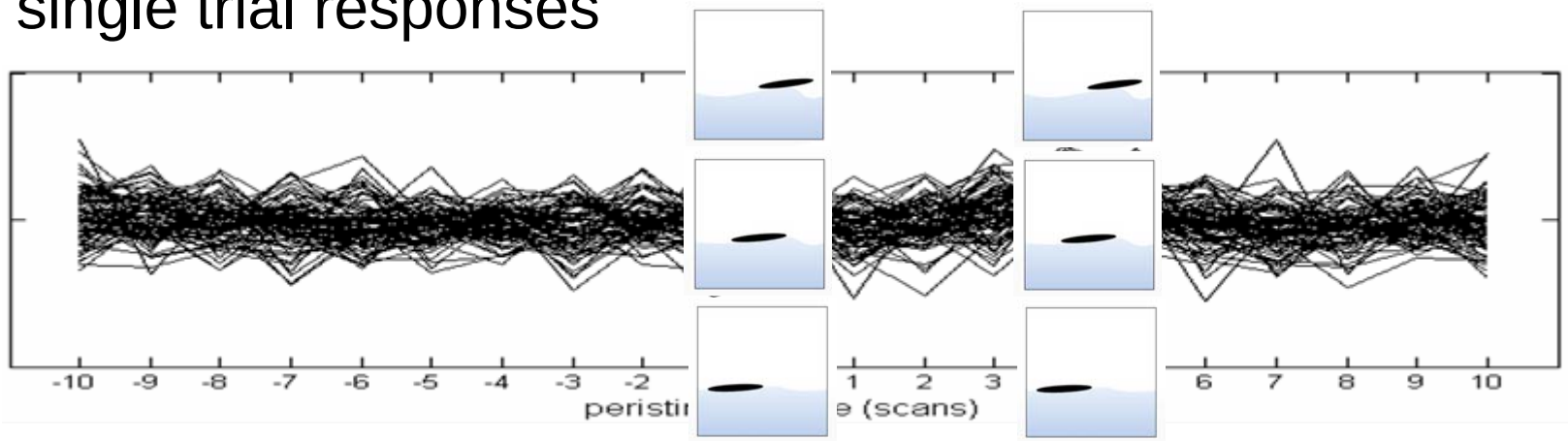


How can we assess the impact from ongoing activity?

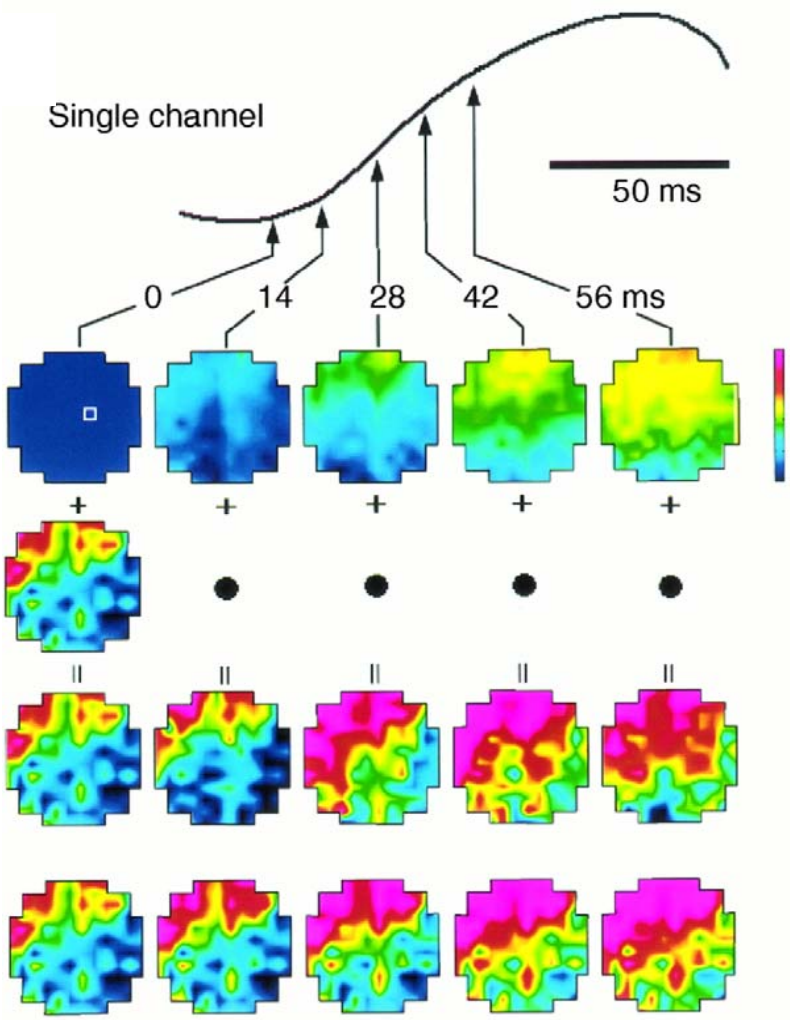
average evoked responses

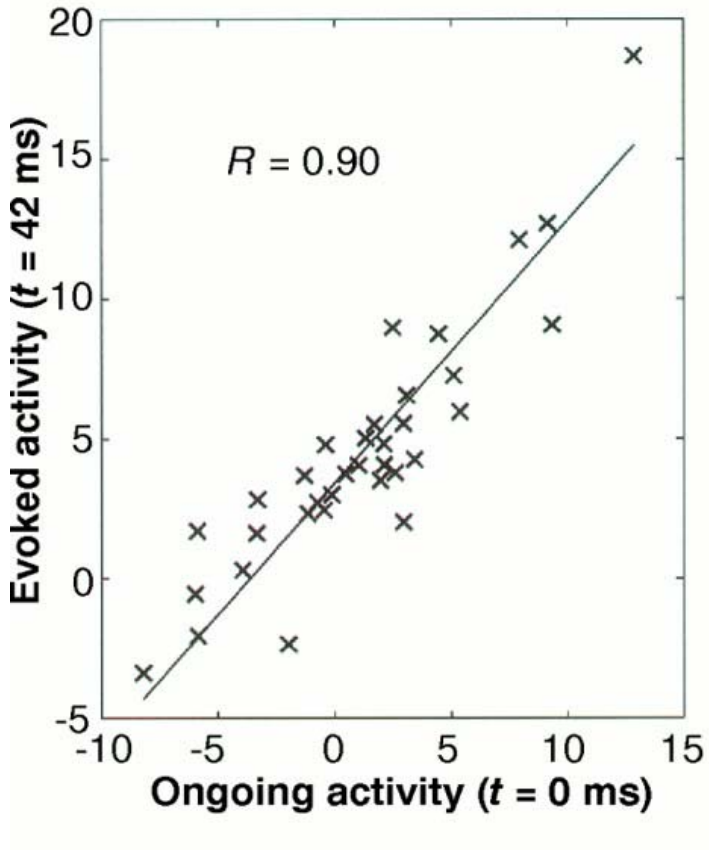


single trial responses



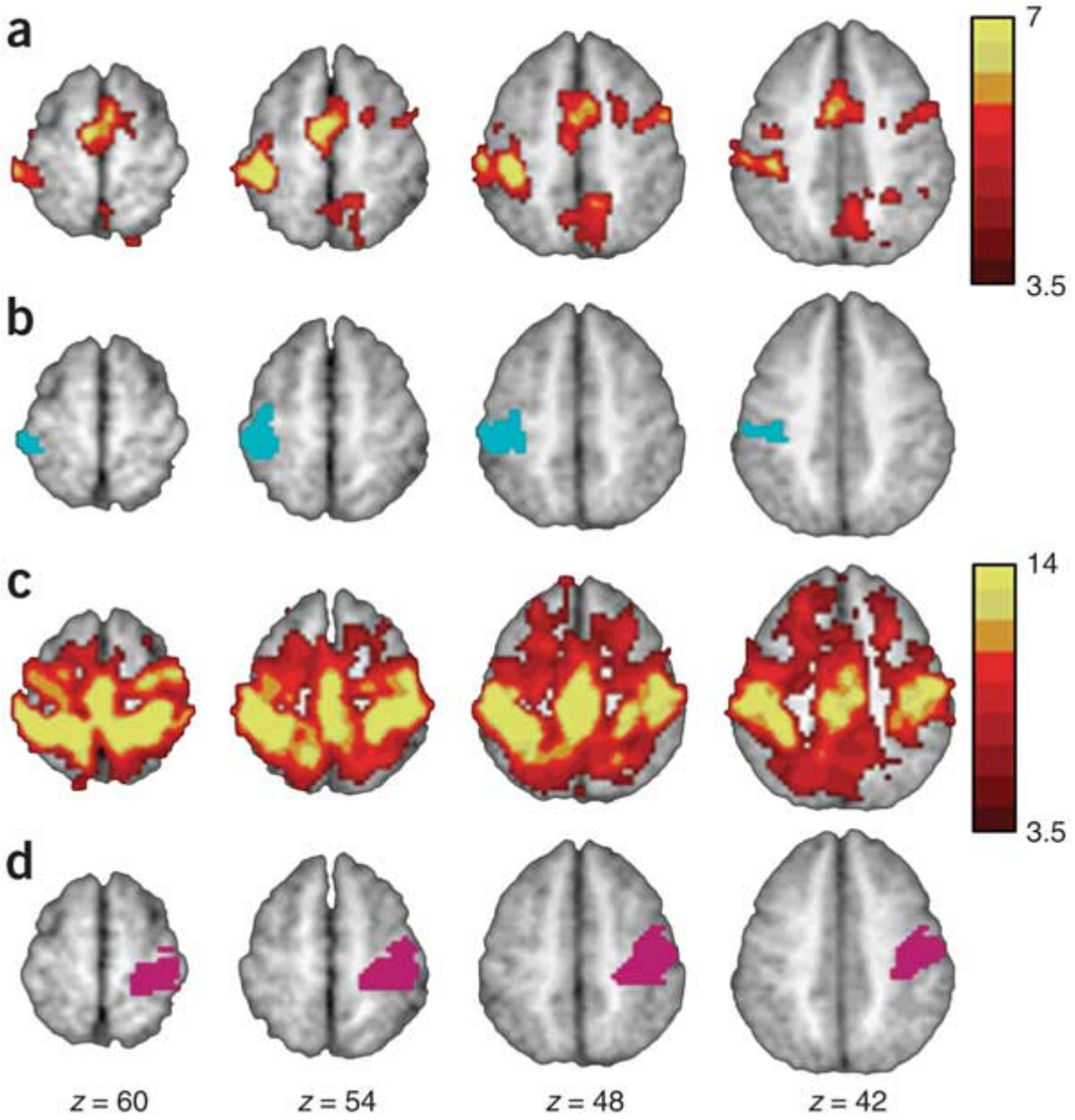
Spontaneous ongoing activity as the determinant of variability in single trial responses





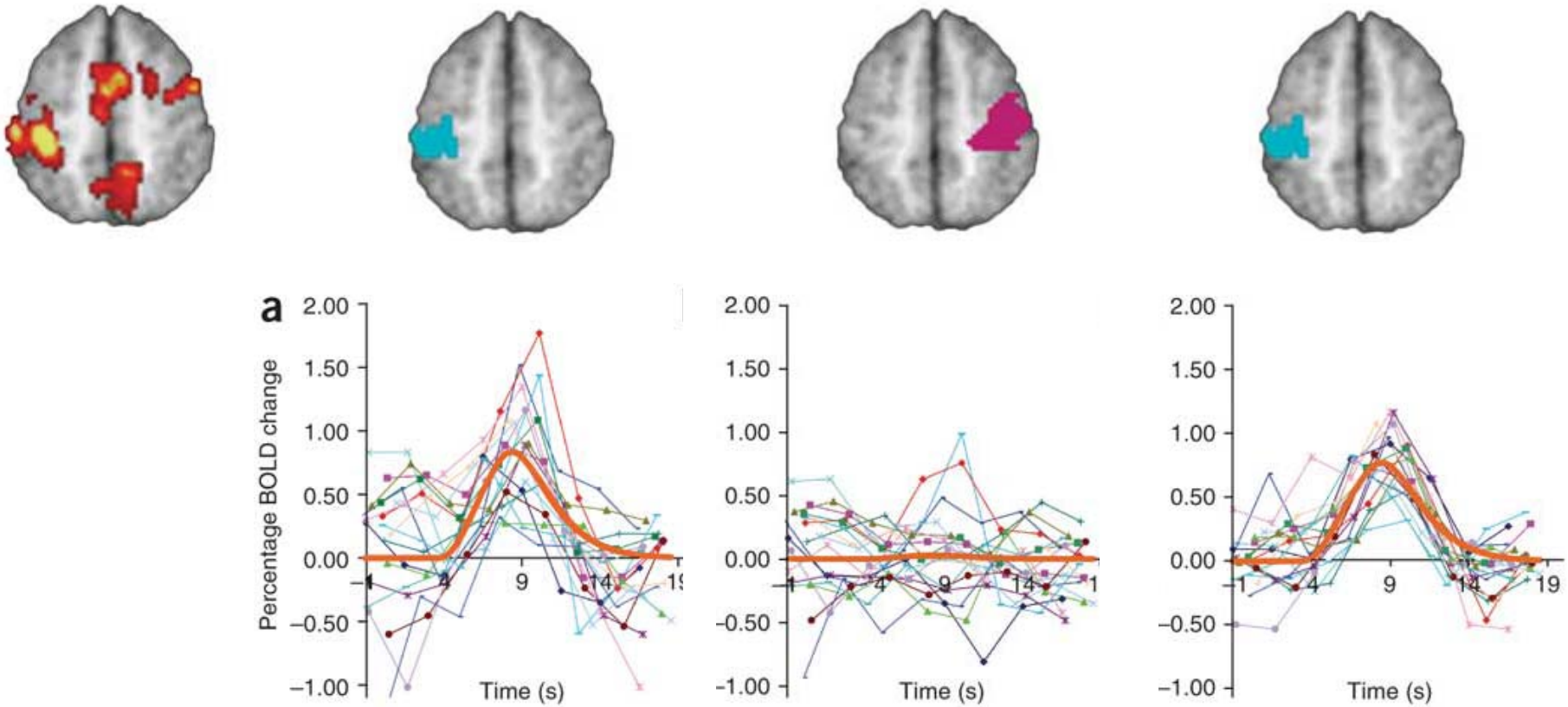
(Arieli et al., Science 1996)

Task-induced and spontaneous activity fluctuations in sensorimotor cortical regions



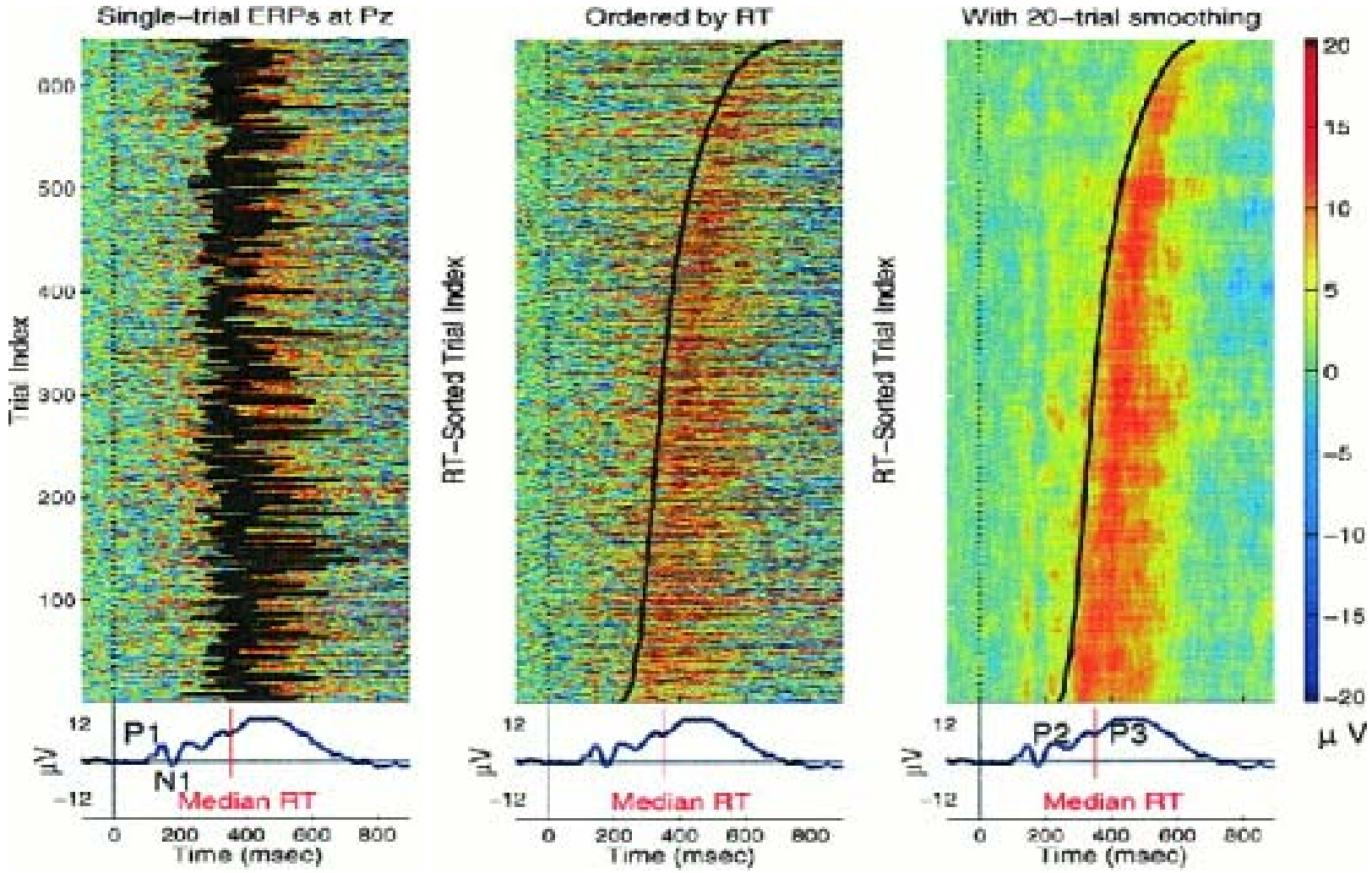
(Fox et al., Nature Neuroscience, 2006)

“Coherent spontaneous activity accounts for trial-by-trial variability in human evoked brain responses“



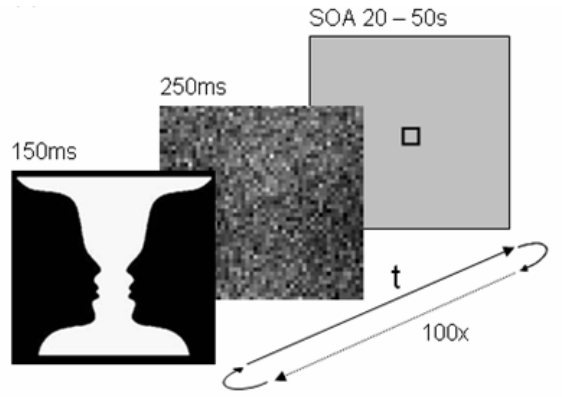
(Fox et al., Nature Neuroscience, 2006)

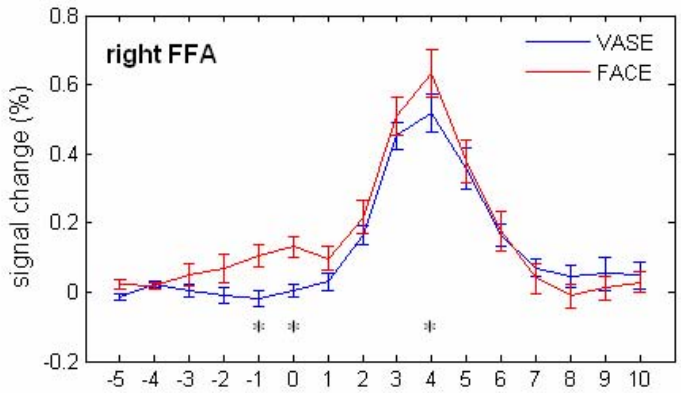
Brain-behavior relation: coupled variability



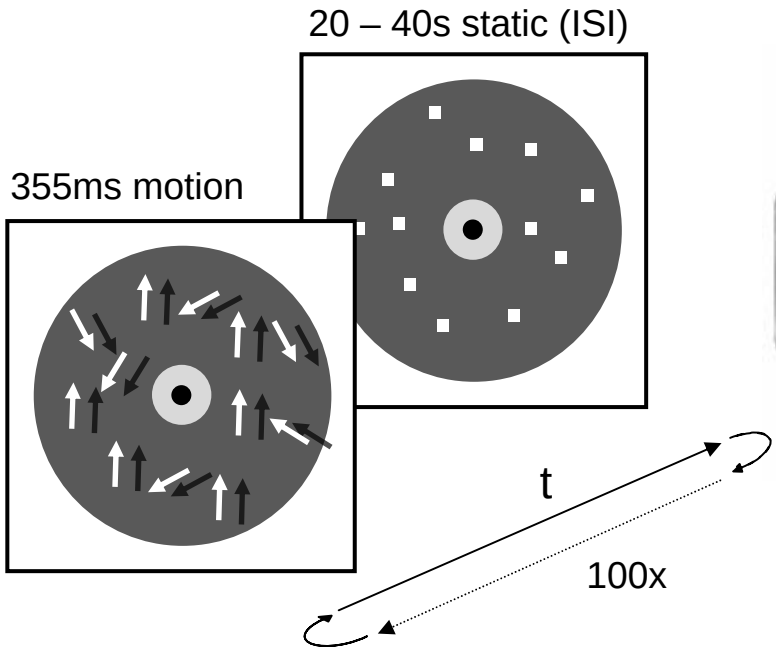
(Jung et al., Human Brain Mapp 2001)

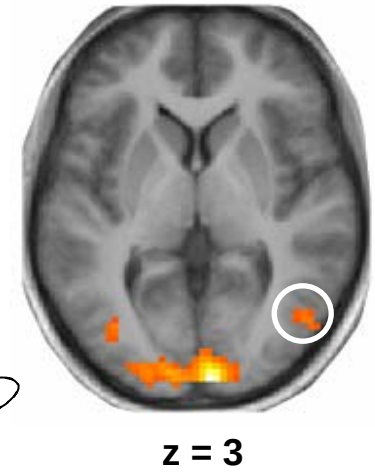
Spontaneous local variations in ongoing pre-stimulus neural activity bias perceptual decisions

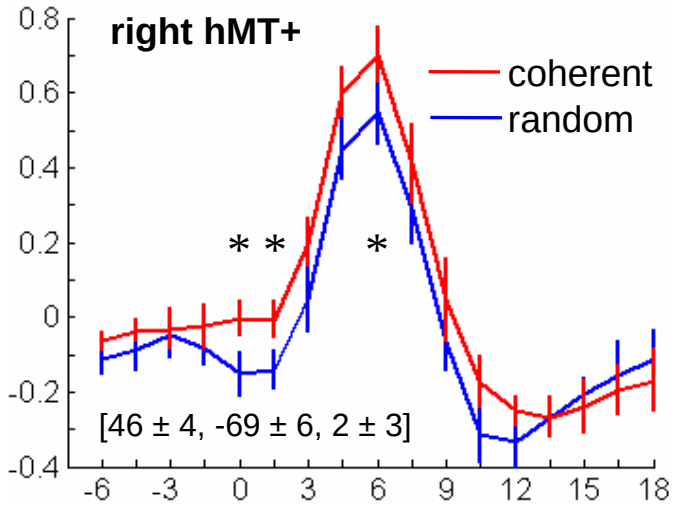




(Hesselmann et al., PNAS, 2008)

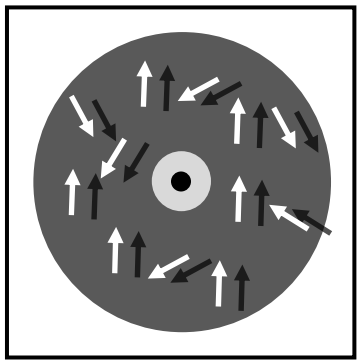


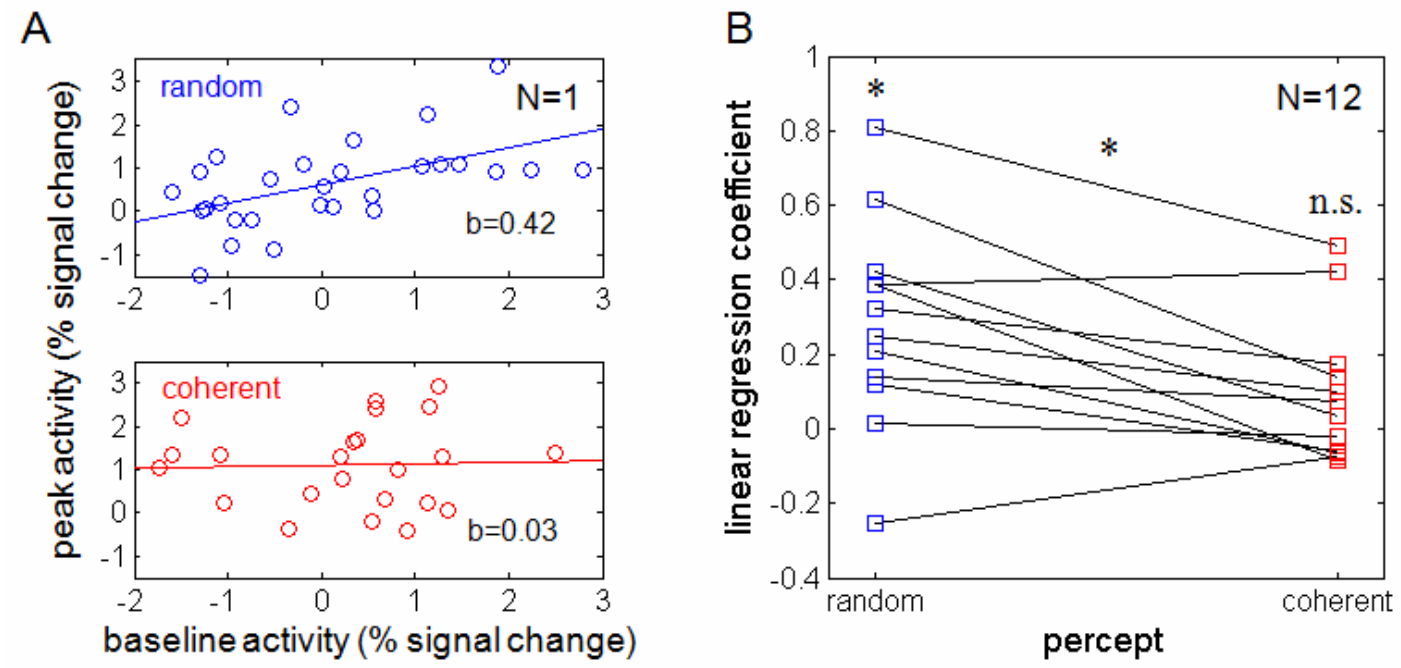


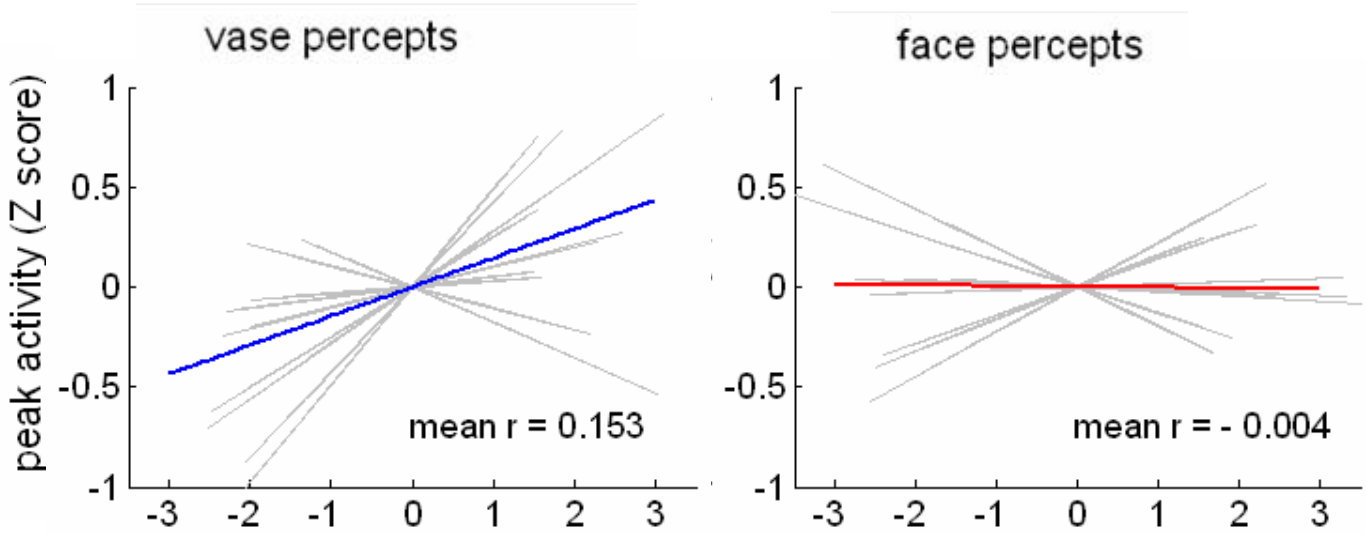


(Hesselmann et al., J Neurosci, 2008)

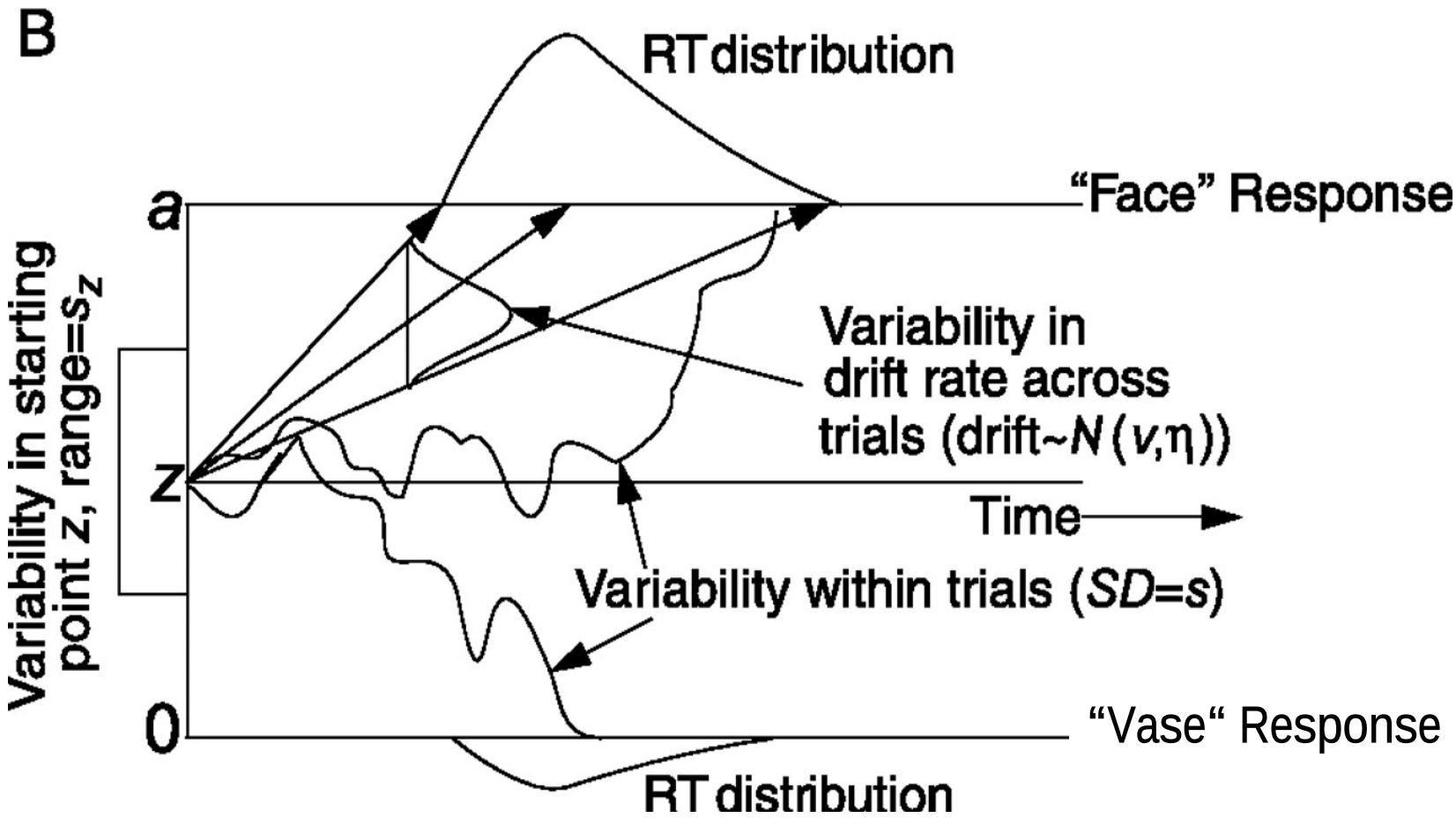
Trial-by-Trial Correlation of Ongoing and Evoked Activity







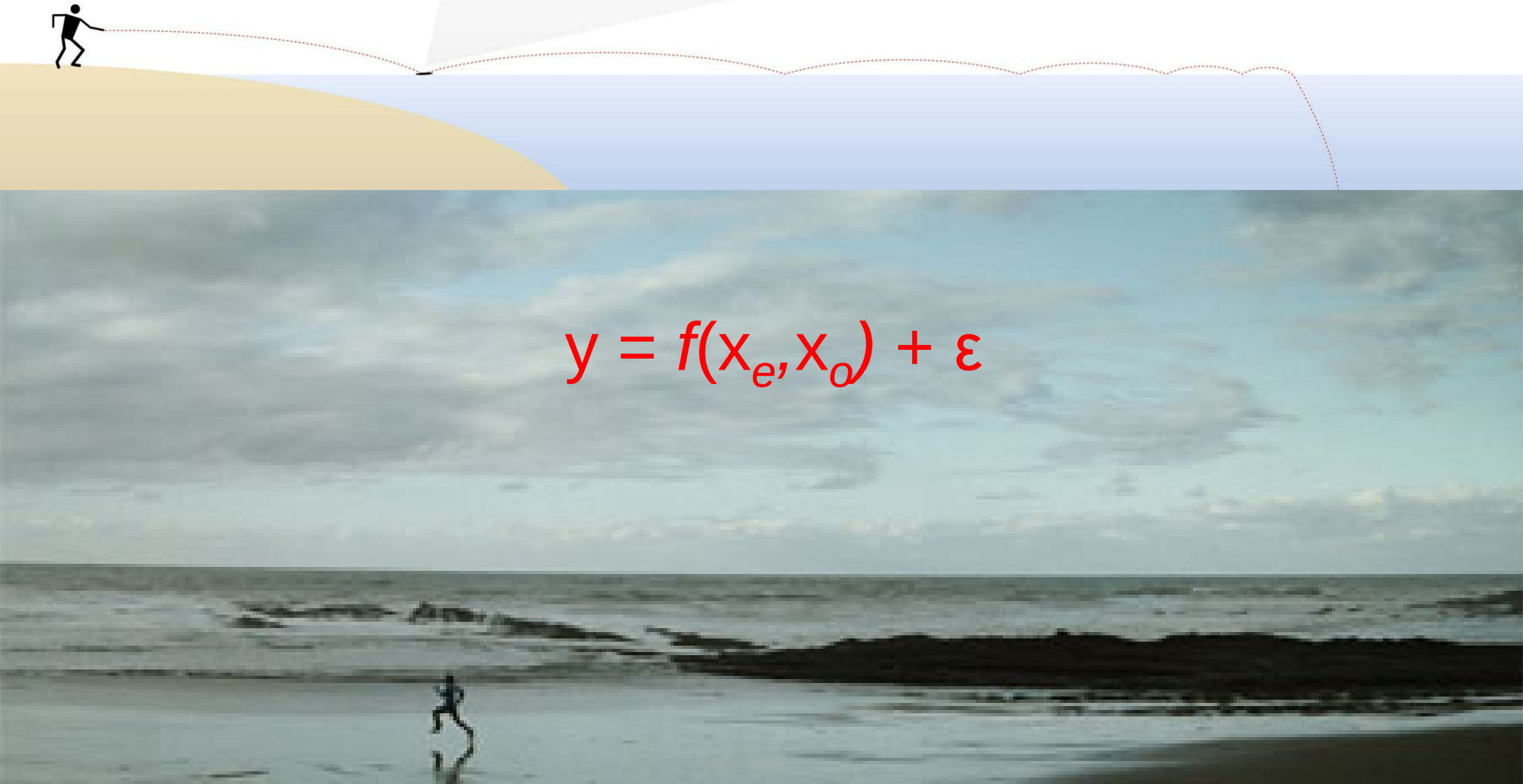
Models of perceptual decisions: diffusion, leaky accumulators …



(Mocdified from Philiastides et al., J Neurosci, 2006)

The need for a paradigm shift

$$y = bx_e + x_o + \varepsilon$$



$$y = f(x_e, x_o) + \varepsilon$$

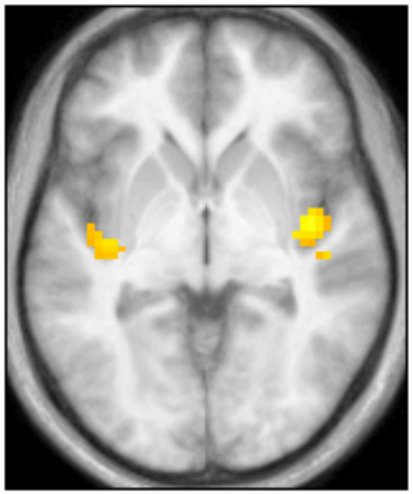
Generic Principle? Extension to Auditory Perception

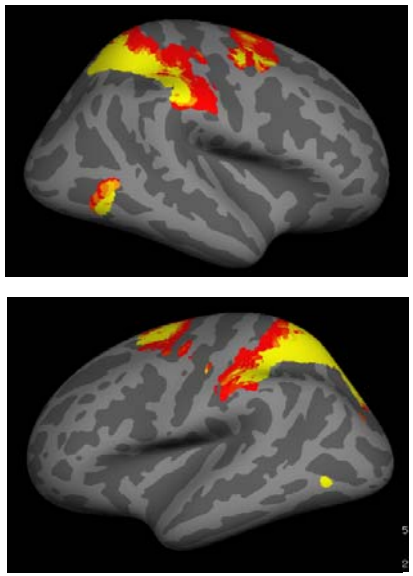
auditory cortex

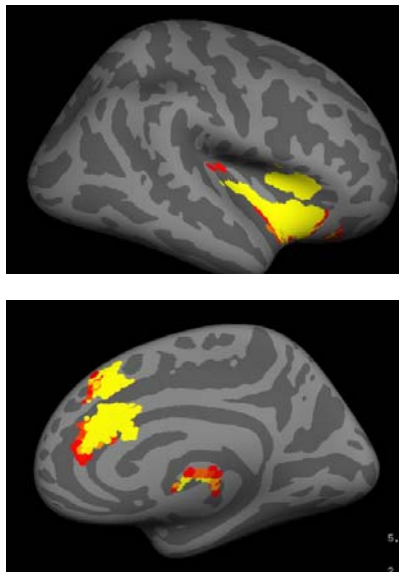
attention system

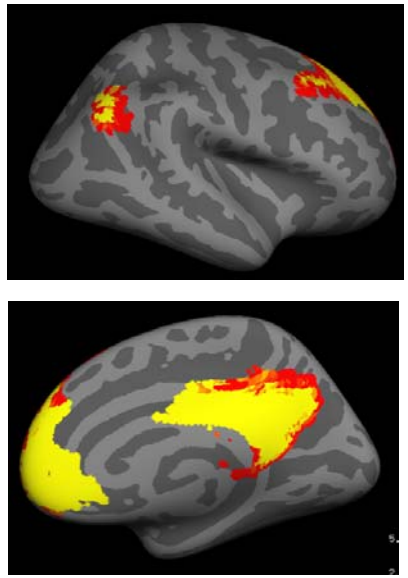
alertness system

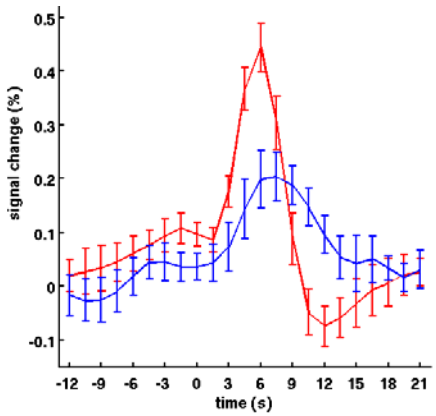
default mode system

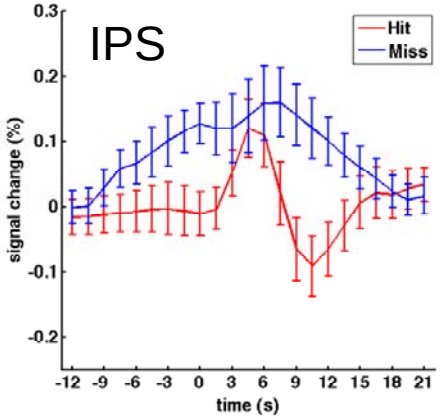


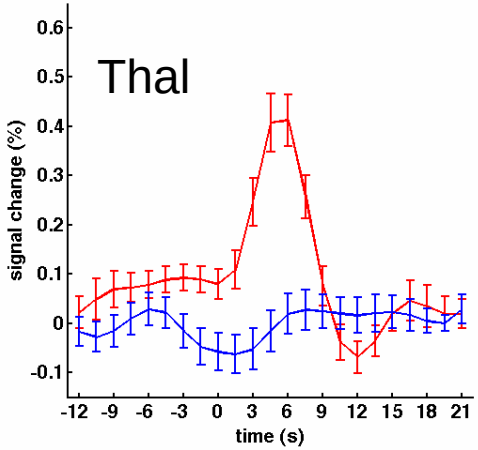


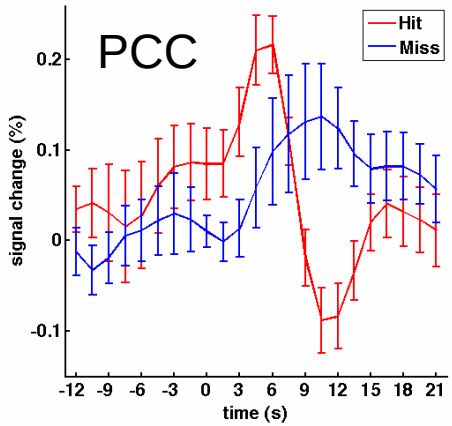






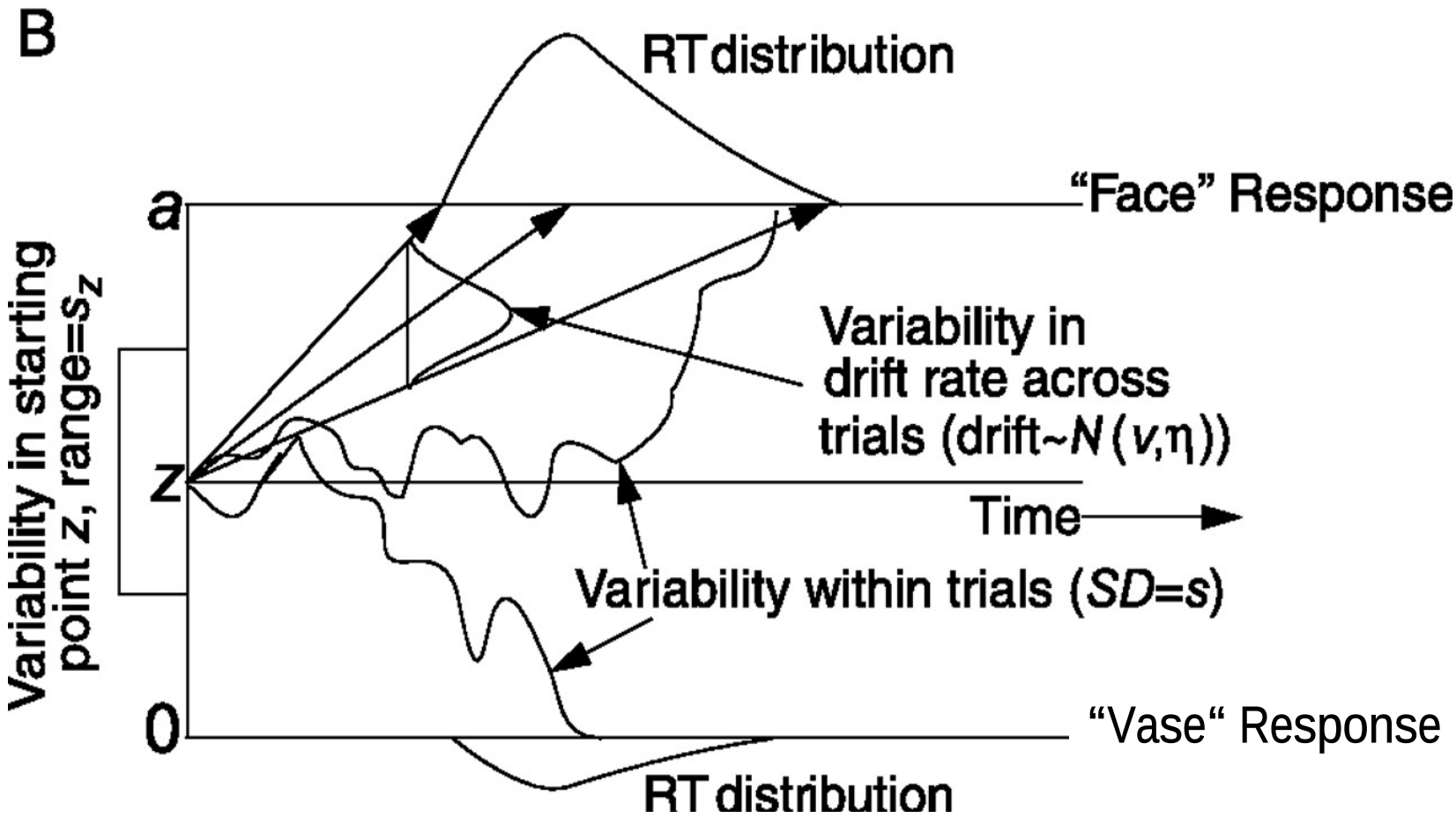






(Sadaghiani et al., J Neurosci, in press)

Models of perceptual decisions: diffusion, leaky accumulators …

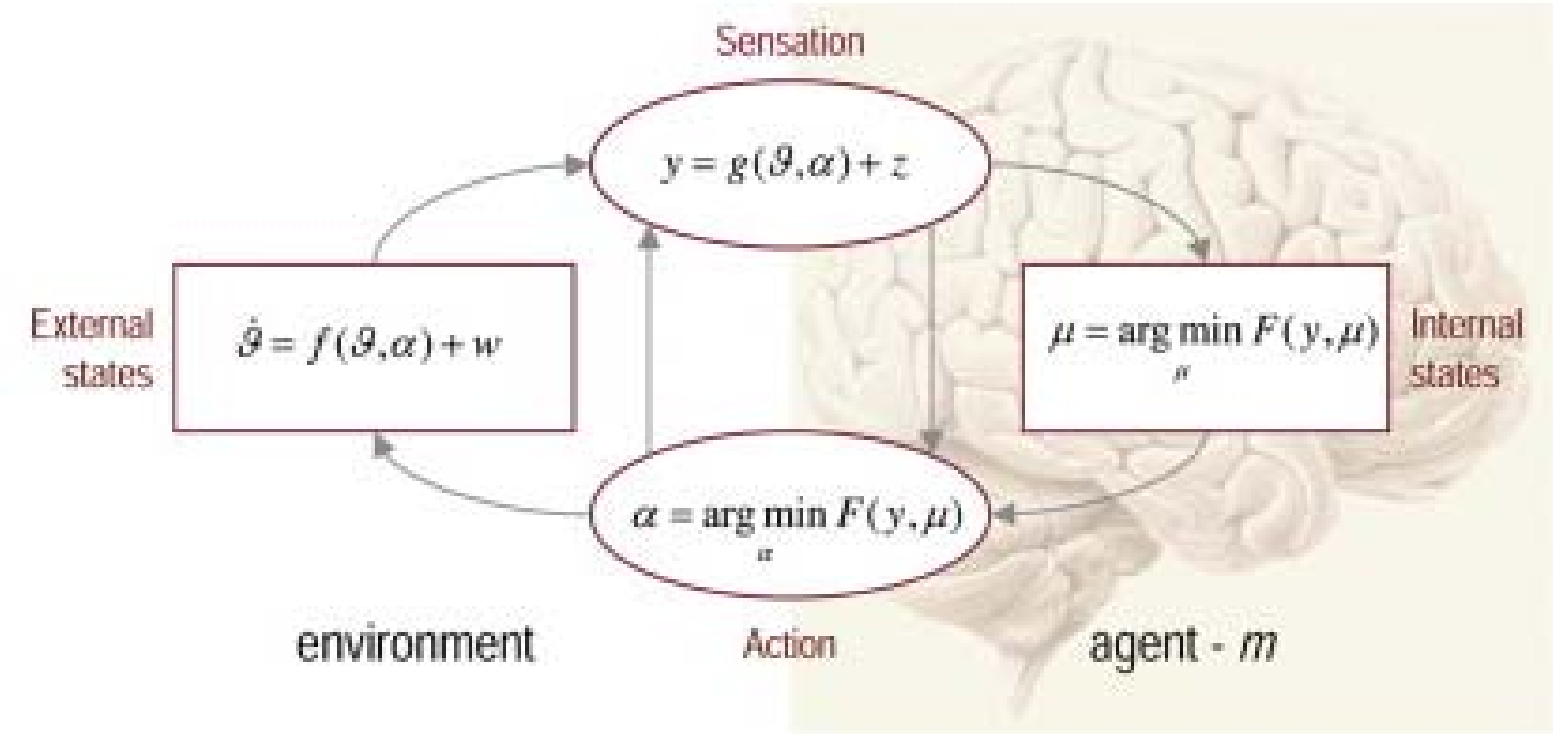


(Mocdified from Philiastides et al., J Neurosci, 2006)

Construing a Biologically Adequate Model of Brain Function

$$y = f(x_e, x_o) + \varepsilon$$

The Brain builds a Predictive Model of the World



$$F = Energy - Entropy = -\langle \ln p(y, \vartheta \mid m) \rangle_q + \langle \ln q(\vartheta) \rangle_q$$

(Friston, Trends Cogn Sci, 2009)