

Delineating Intrinsic Connectivity Networks for Emotional Salience Processing and Executive Control



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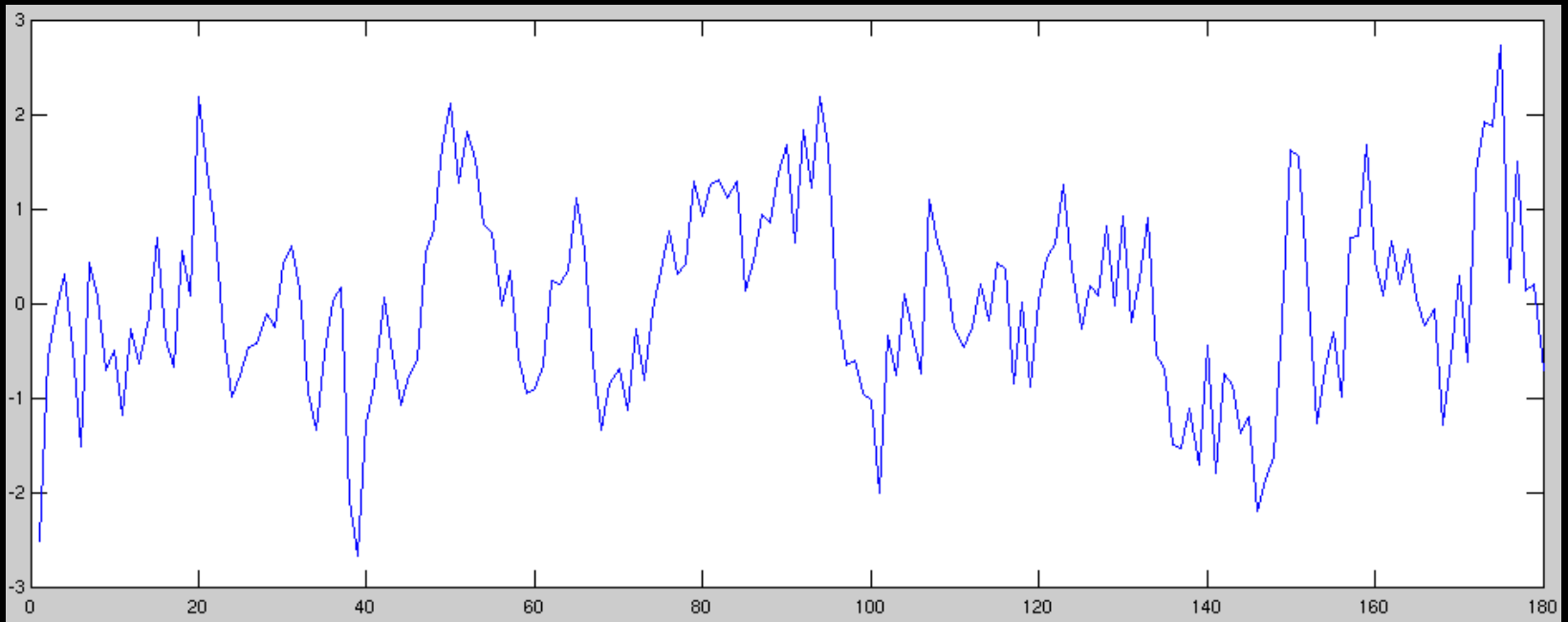
Stanford University School of Medicine

Overview

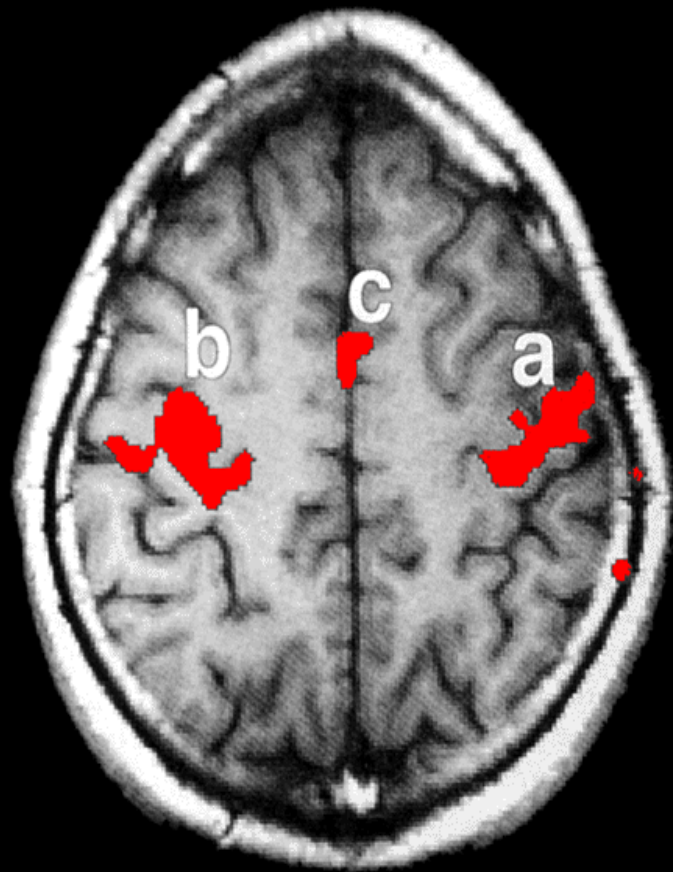
- Resting-state fMRI: Intrinsic connectivity networks
- Emotional salience and executive control networks
- Assigning putative functions to ICNs
- Inter-network interactions
- Implications for addiction research

Resting-State Functional Connectivity

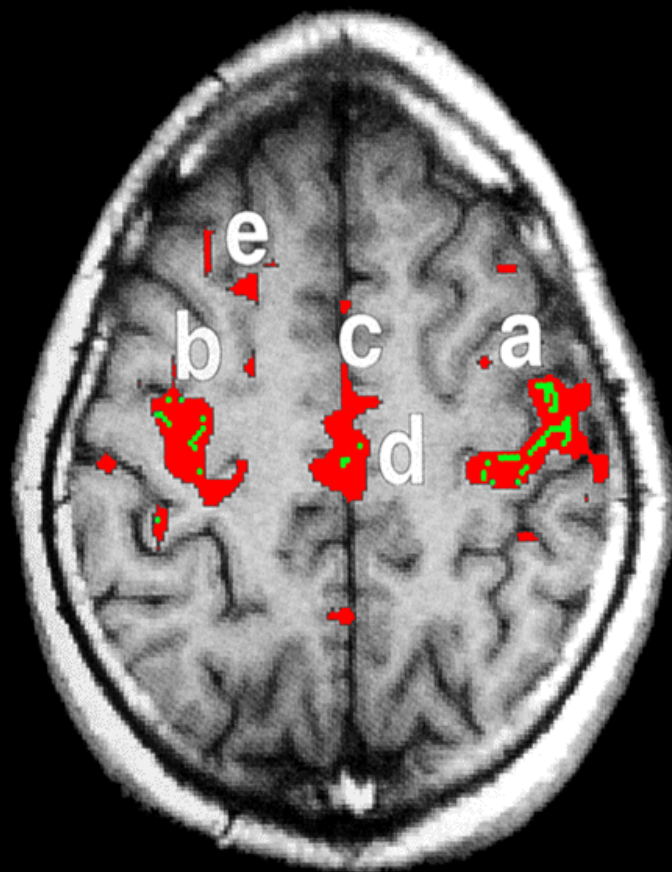
- Brain activity continues in the absence of an externally-cued task
- Brain regions have spontaneous fluctuations in BOLD signal
- A brain region's “resting” BOLD signal timecourse can be used as the regressor



Resting Motor Cortex Connectivity

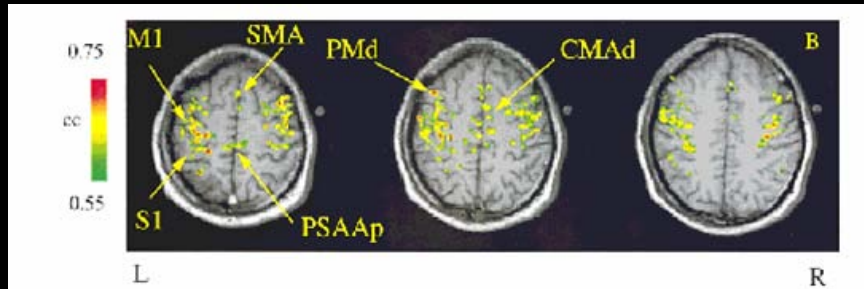


Motor Cortex Defined by *fMRI*

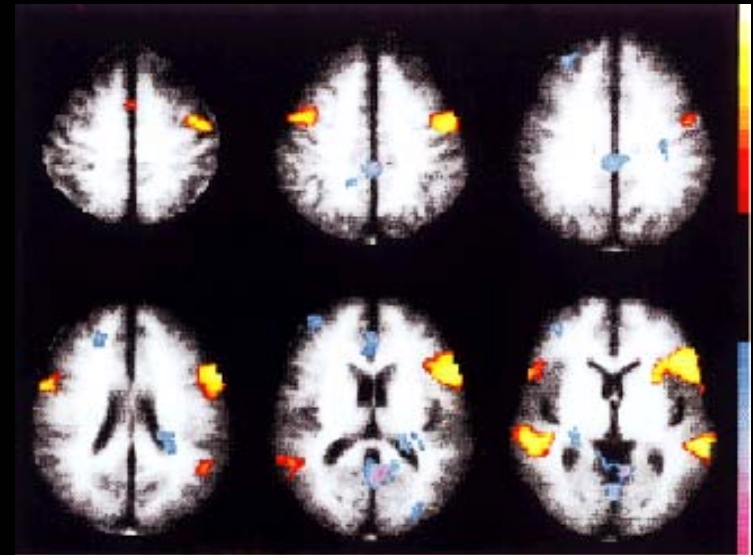


Spontaneous Correlations with
Motor Cortex

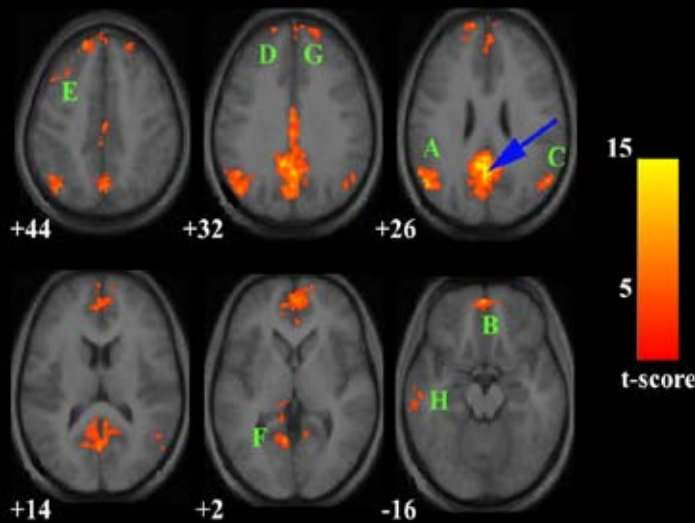
ROI-Derived Intrinsic Connectivity Networks



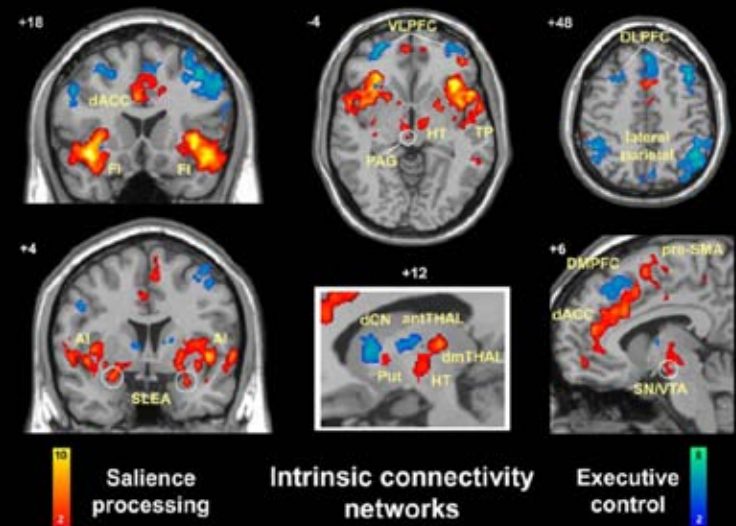
Motor: Xiong et al., 1999



Language: Hampson et al., 2002



Default Mode: Greicius et al., 2003

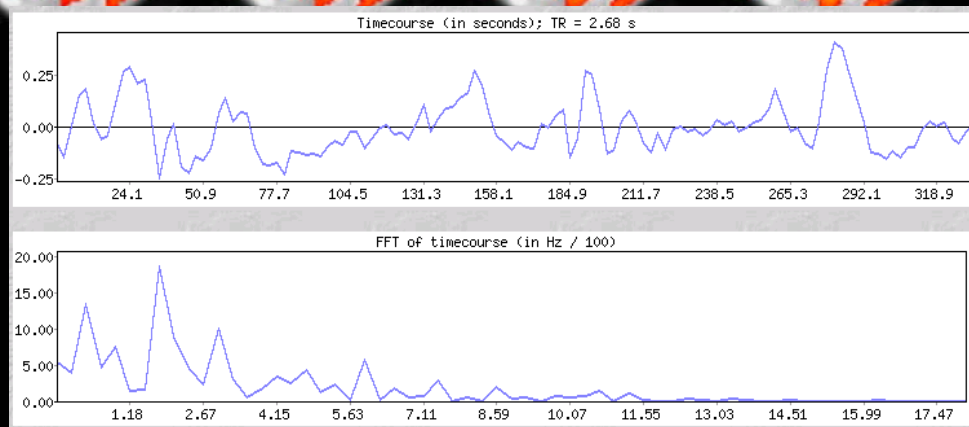
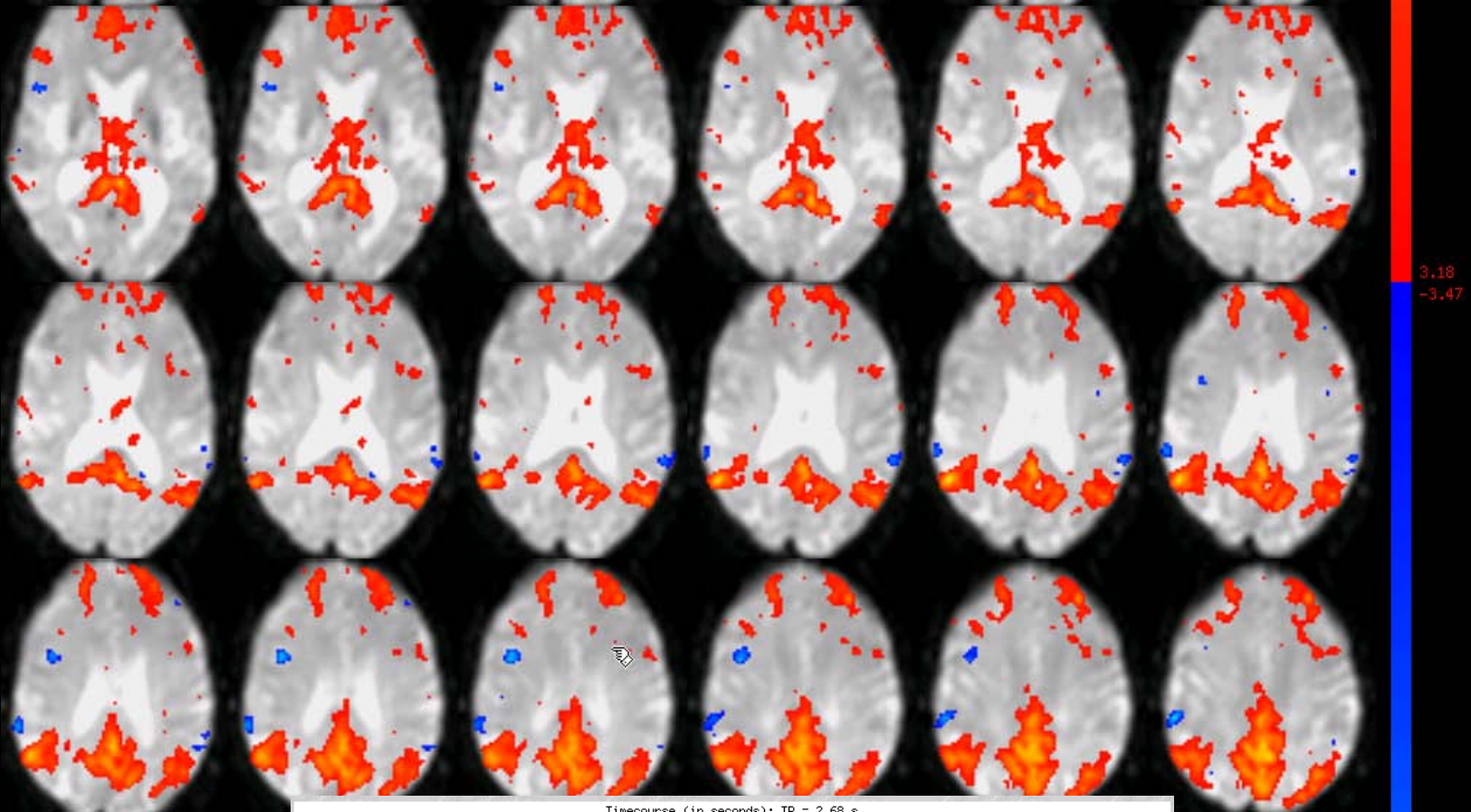


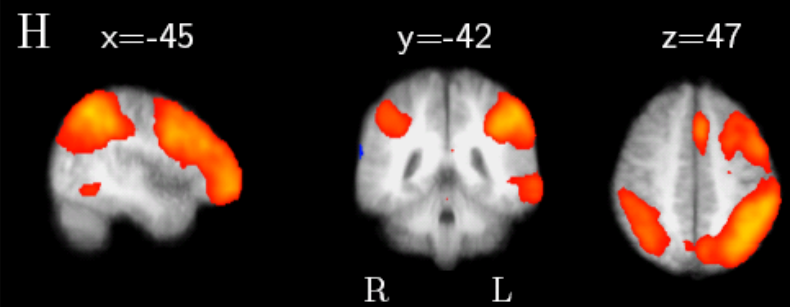
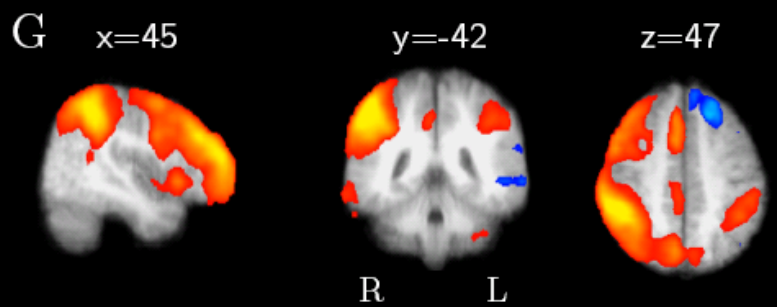
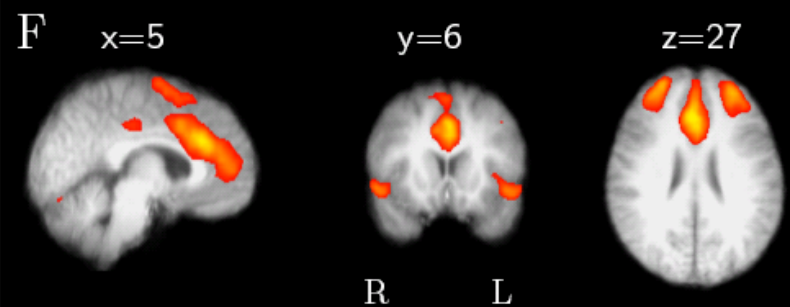
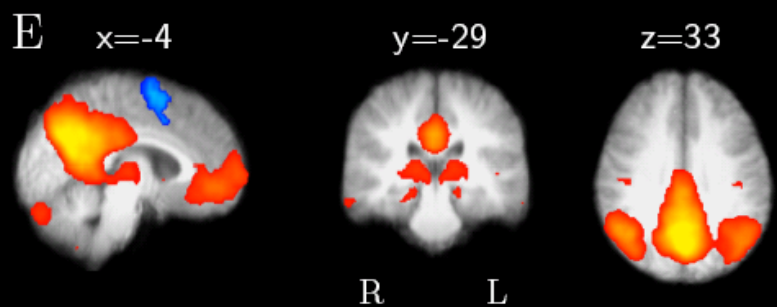
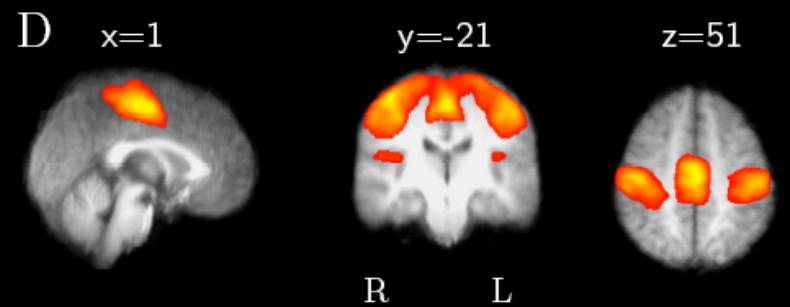
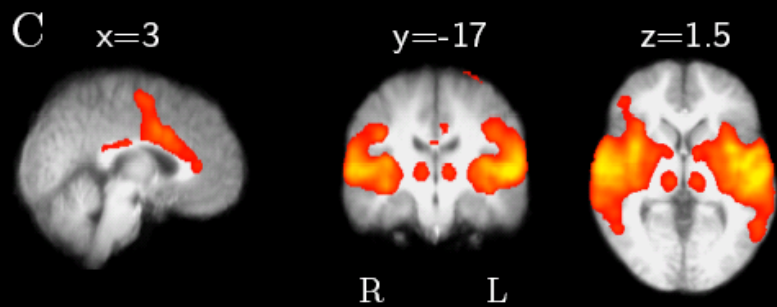
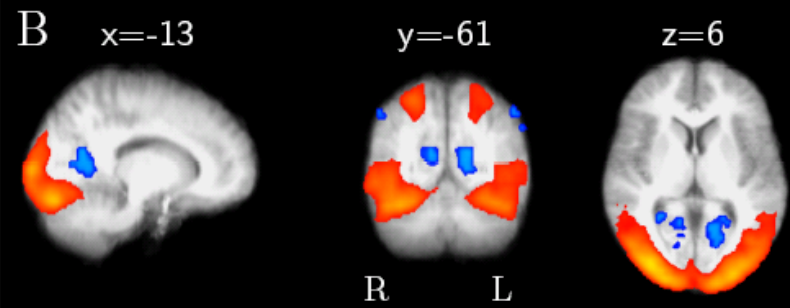
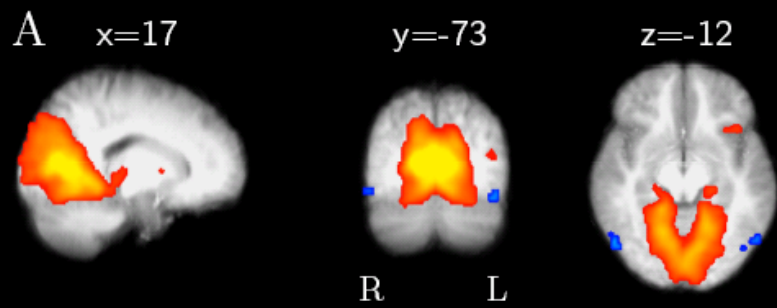
Executive control and Salience: Seeley et al., 2007

Independent Component Analysis in the Detection of Intrinsic Connectivity Networks

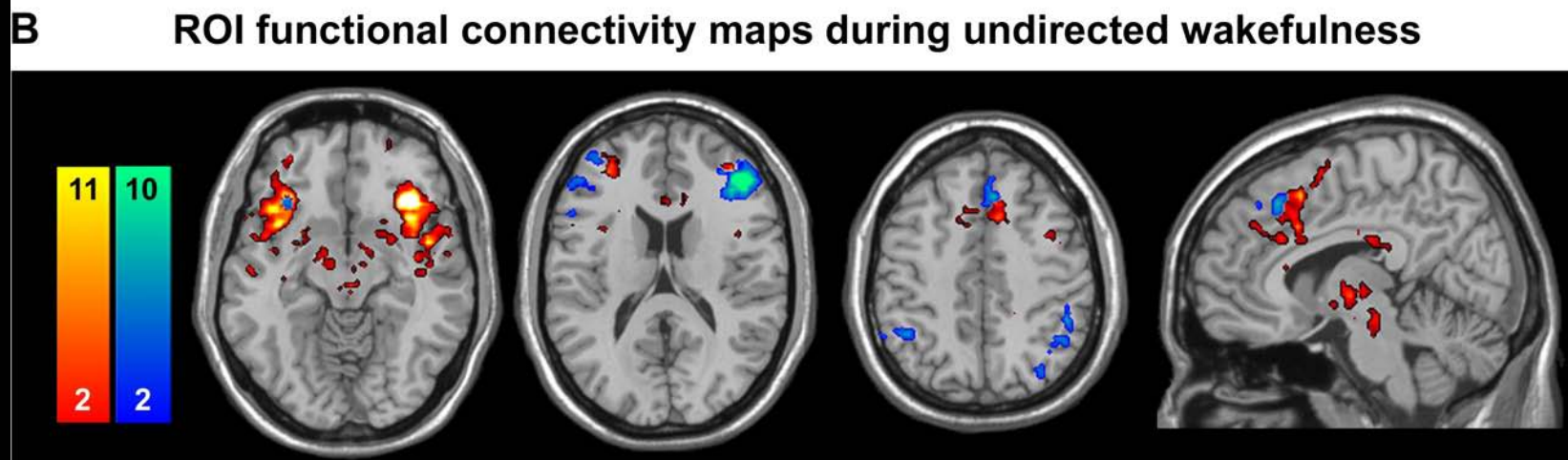
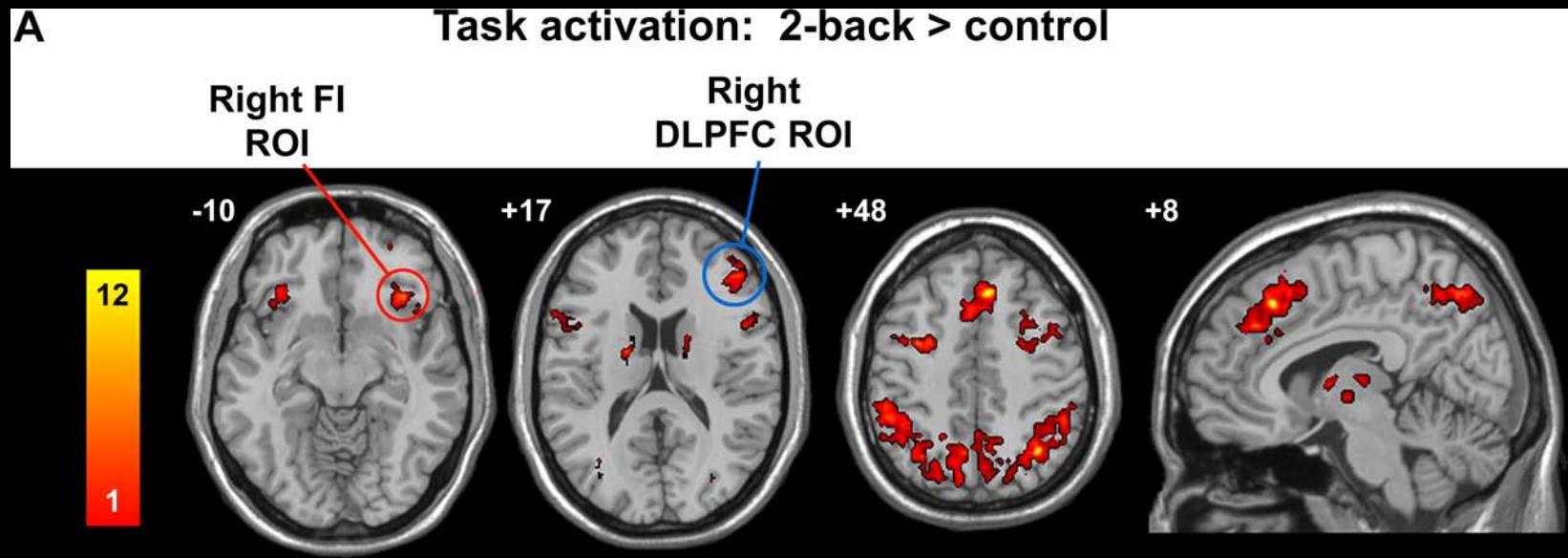
- Separates fMRI signal into independent spatial maps with associated timeseries
- Allows for removal of noisy components
- Reliably extracts several networks, en bloc, as independent components

Default-Mode Network Detected with ICA

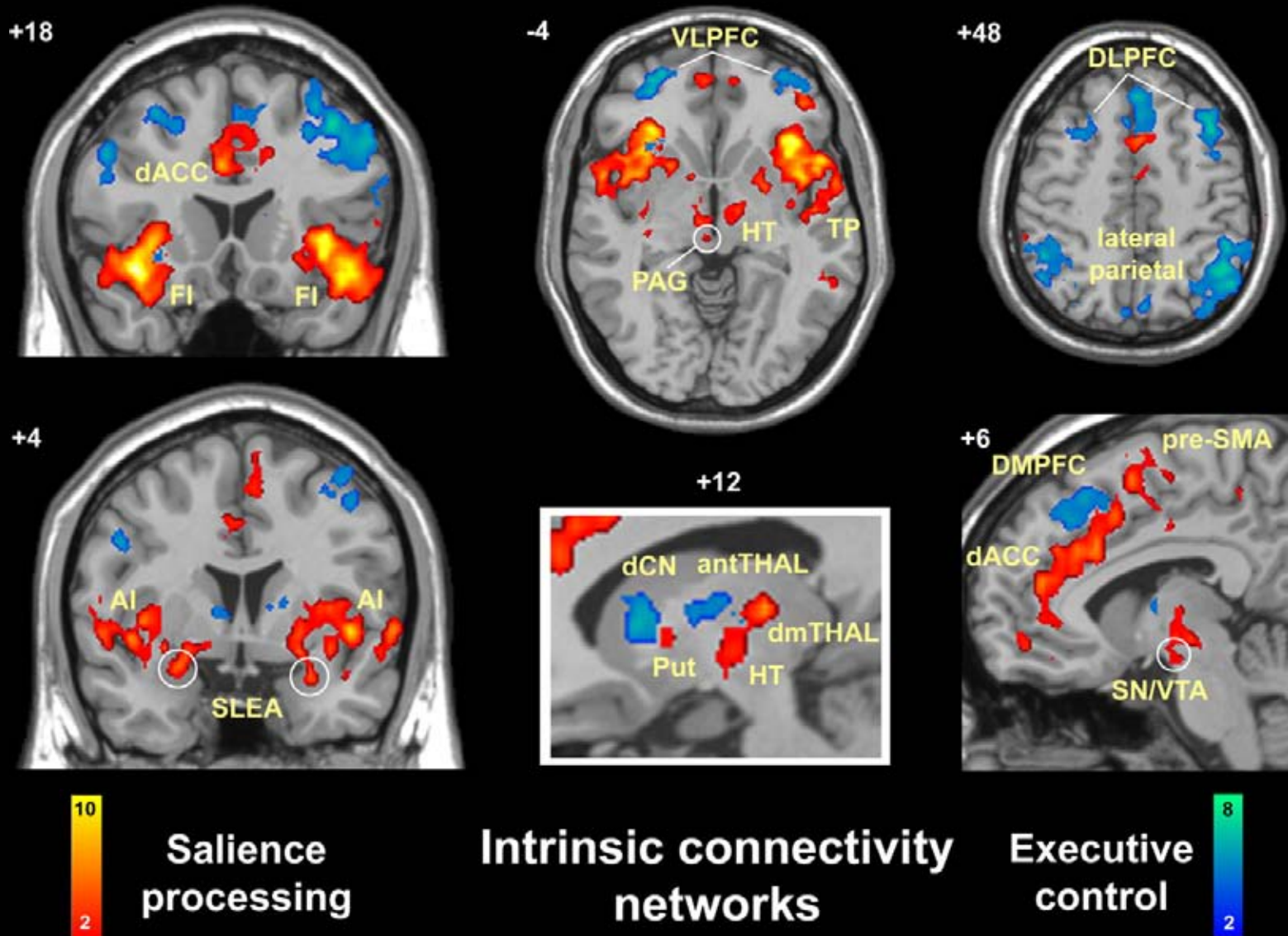




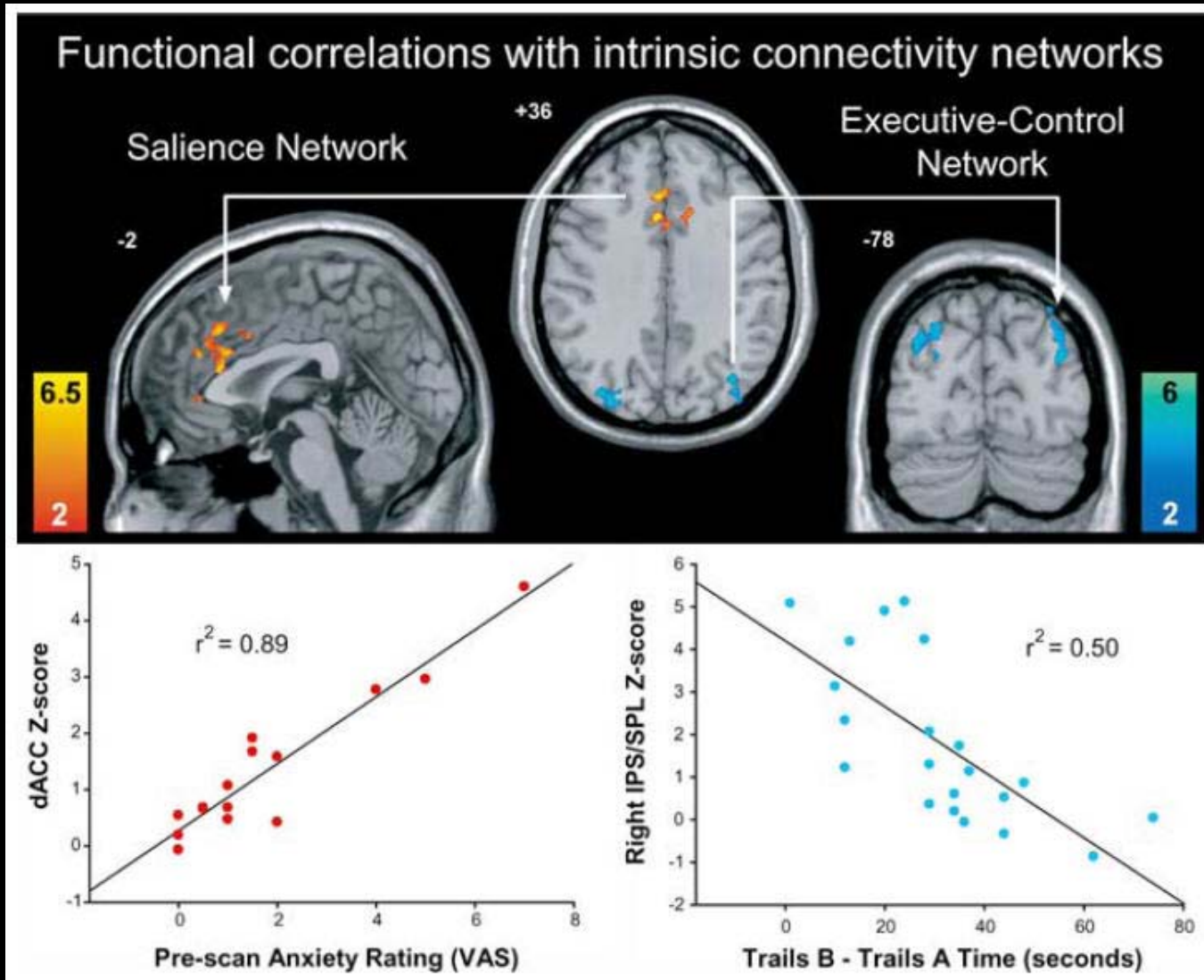
One Task Activation Network, Two ICNs



Replication in a Separate Sample Using ICA

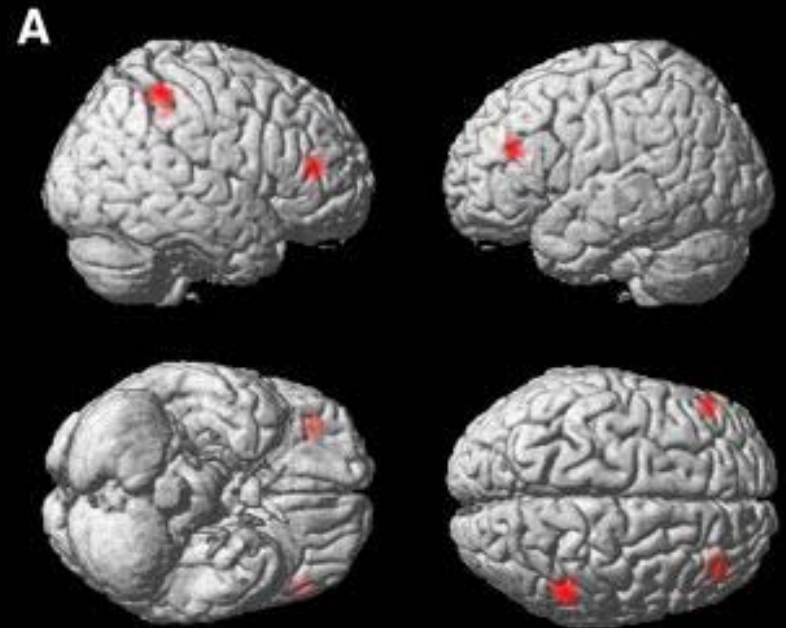
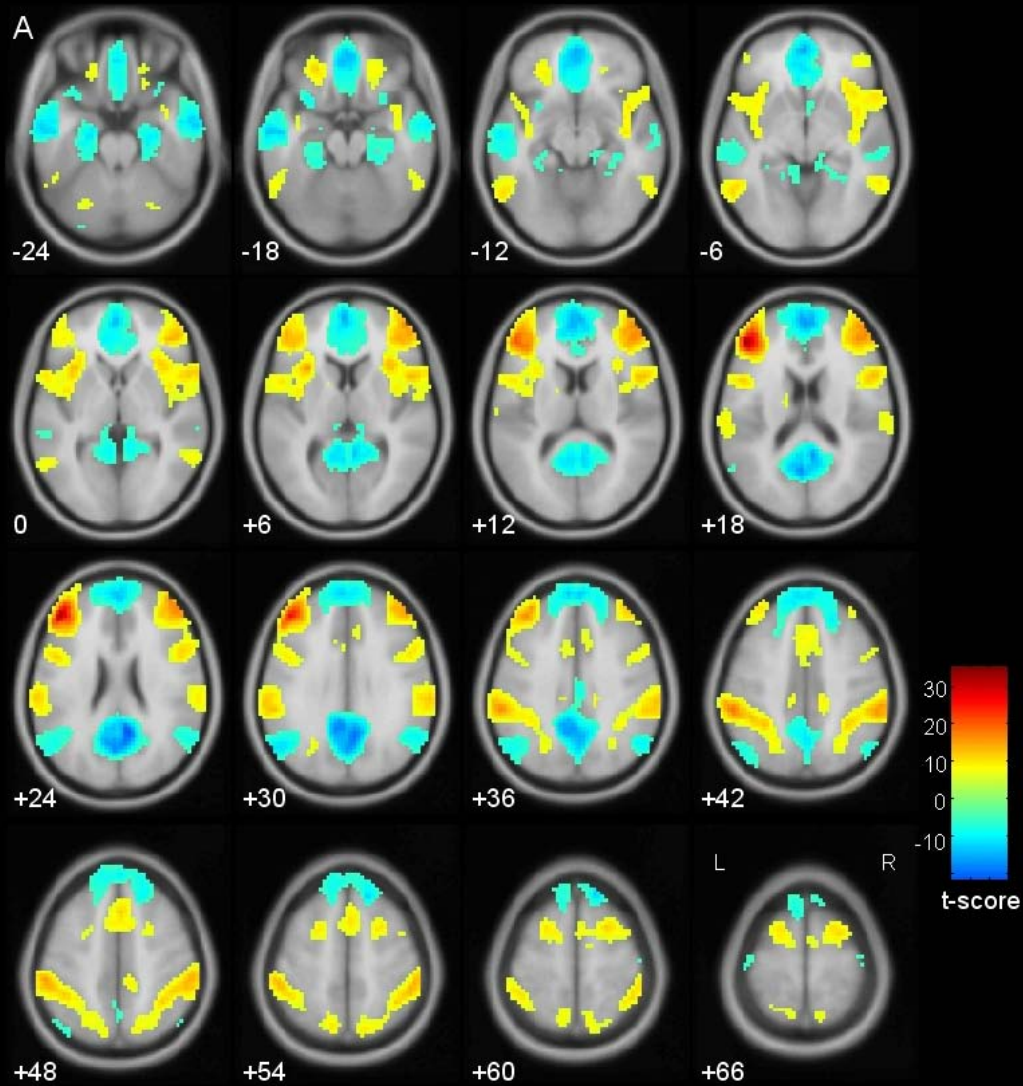


Behavioral Double Dissociation

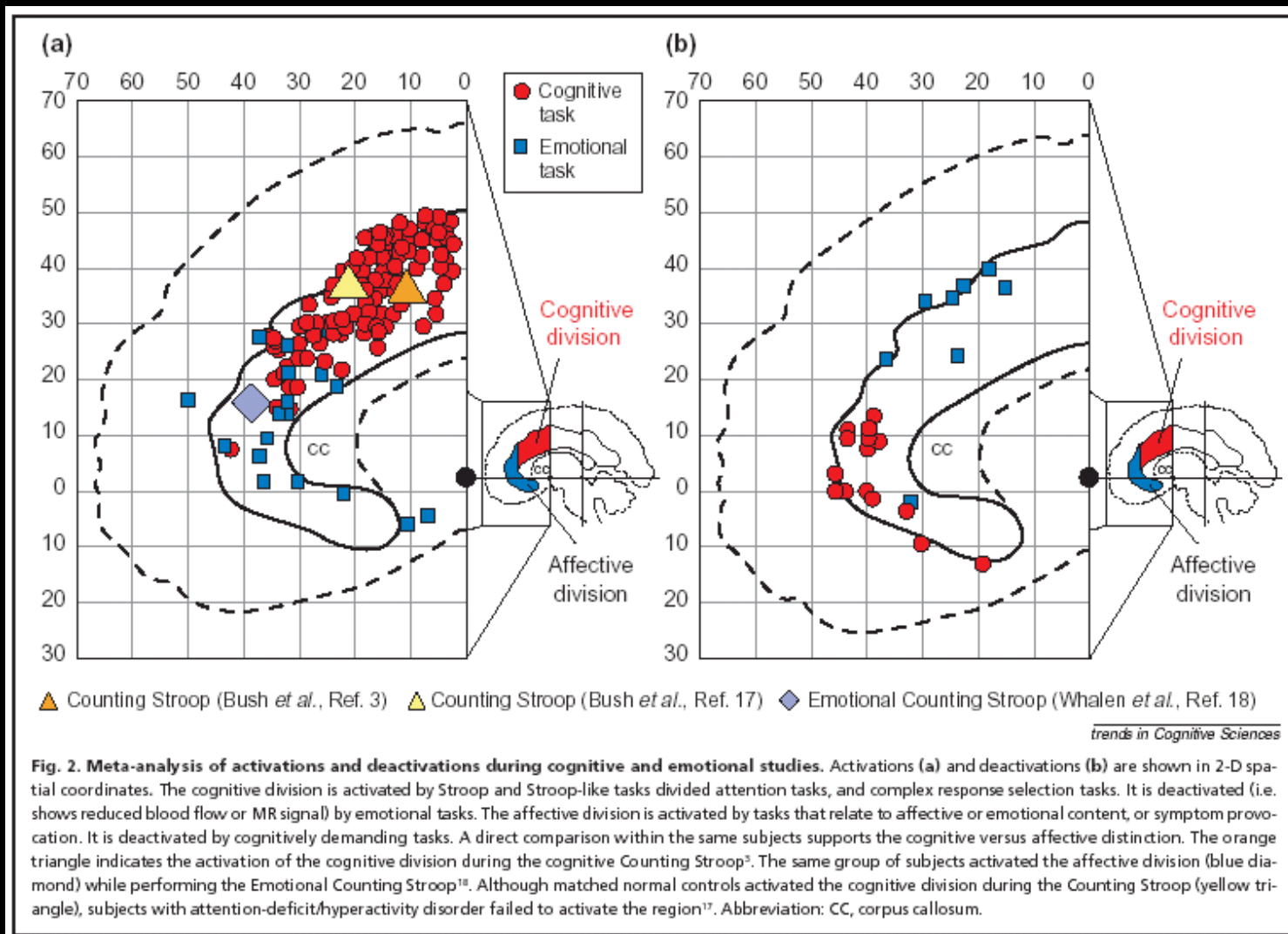


Seeley et al., *J Neurosci*, 2007

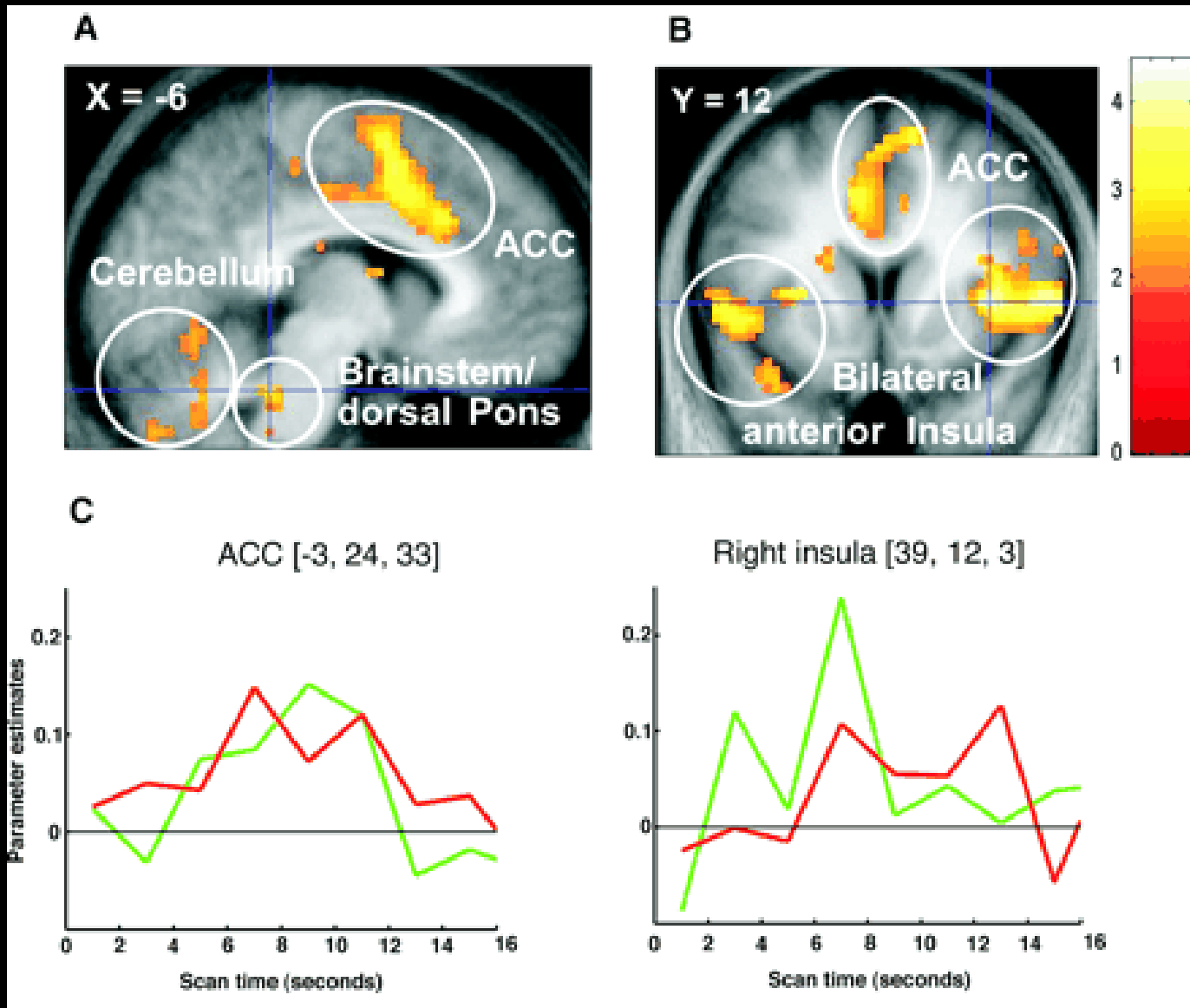
ECN Correlates with IQ



The Cognitive Control Network

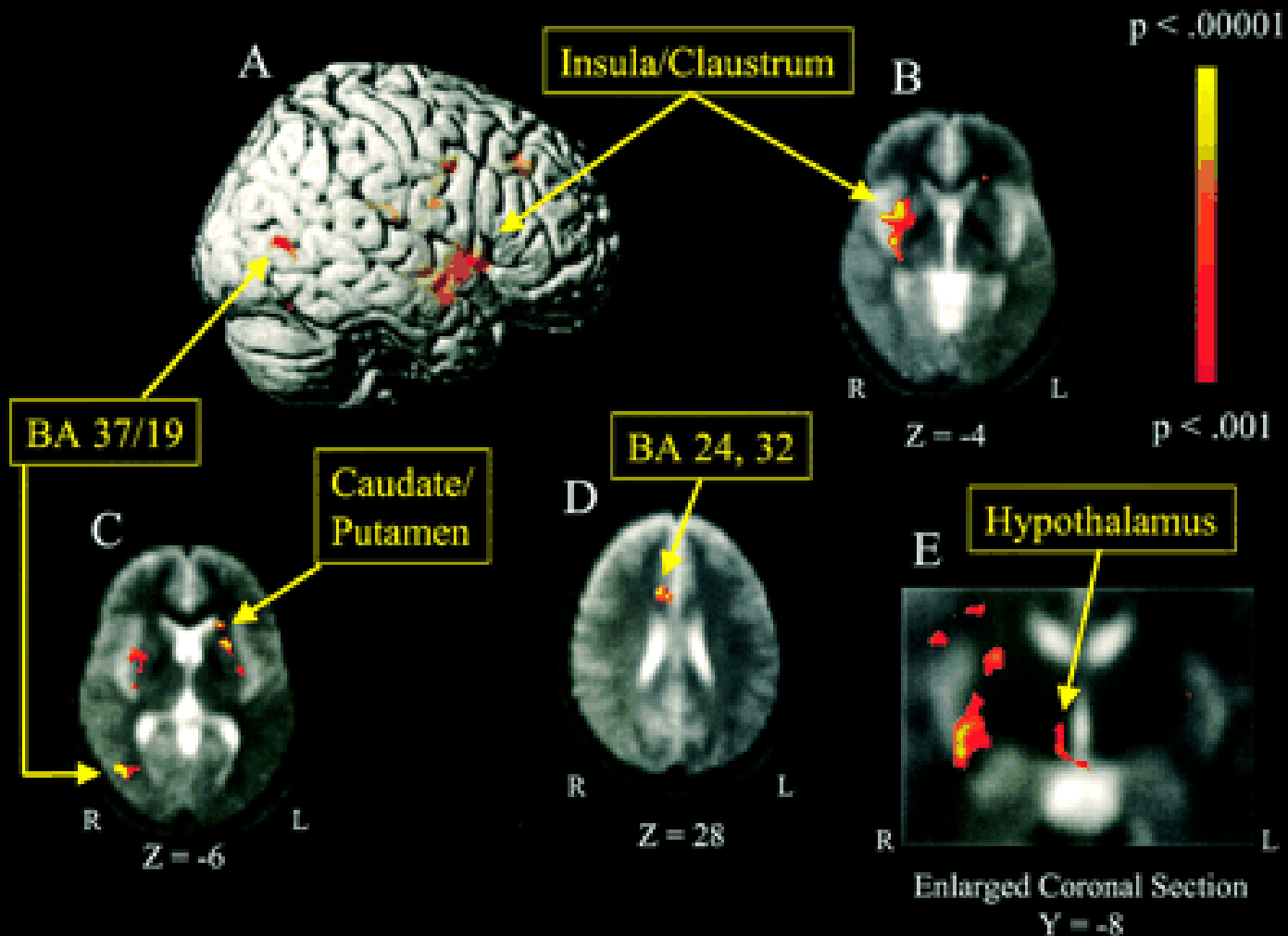


The Pain Network



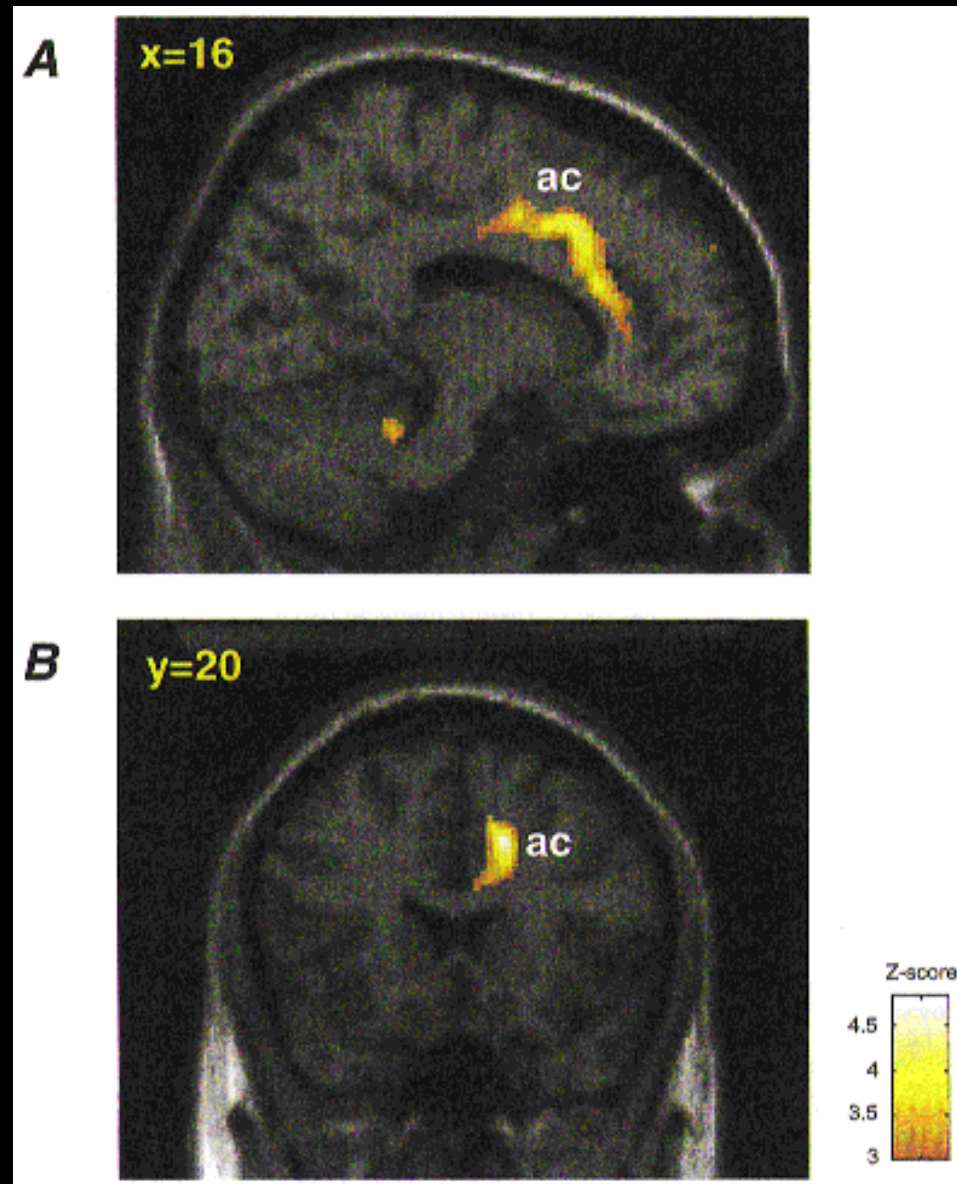
The Turgidity Network

Turgidity-Correlated Activations



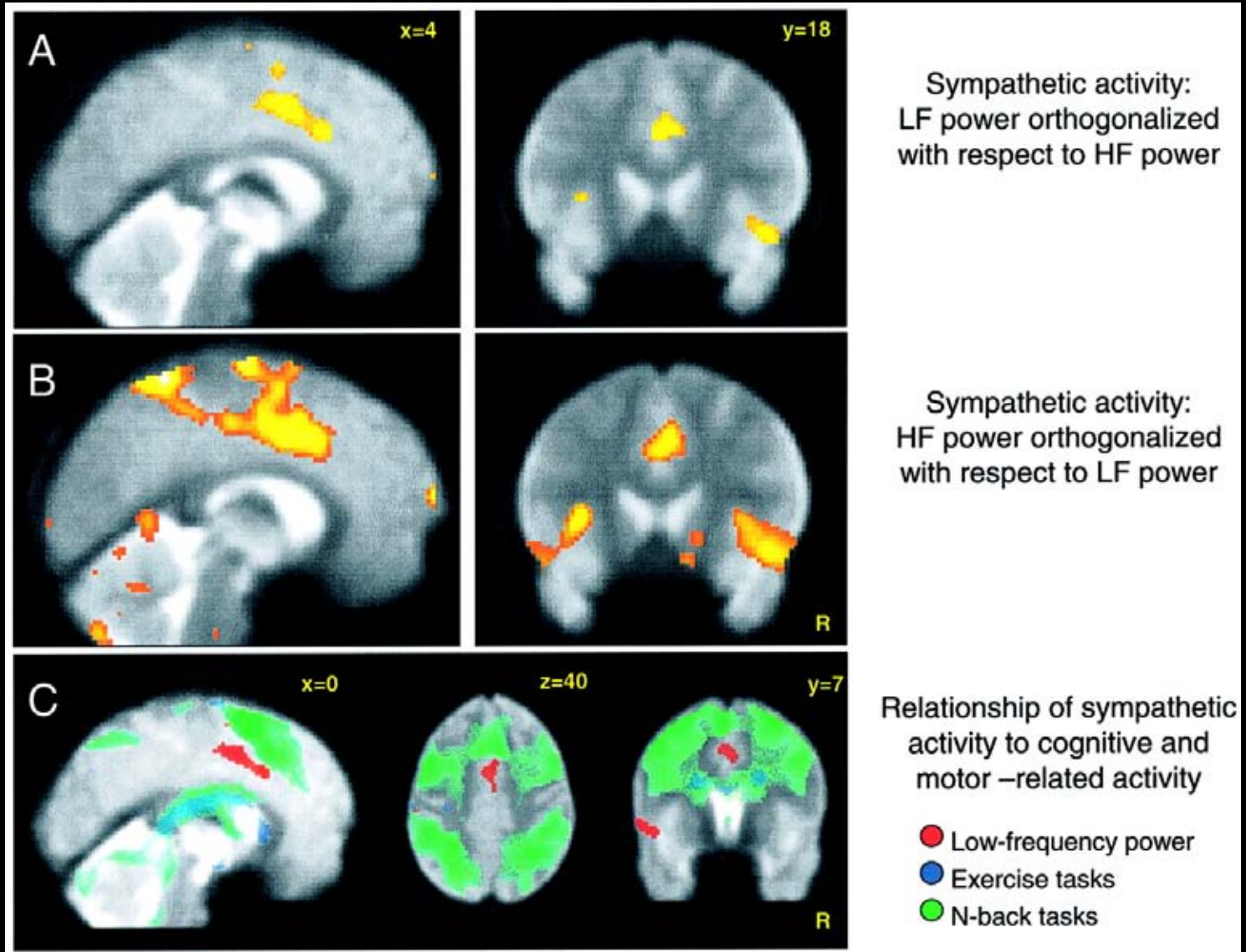
The Autonomic Nervous System Network

Blood pressure
during arithmetic
and exercise tasks
(PET)



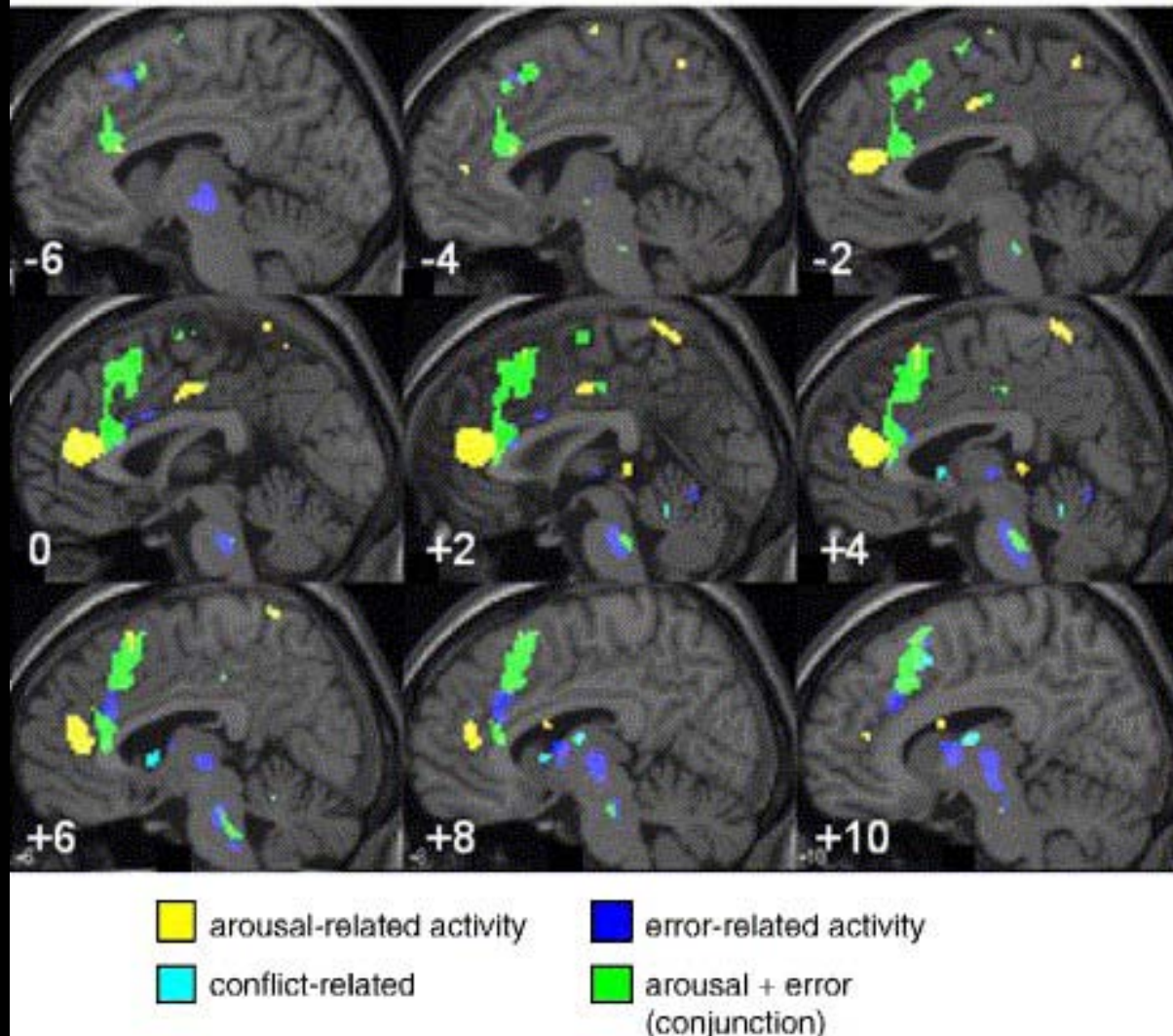
The Autonomic Nervous System Network

Heart rate
during
N-back and
exercise



The Autonomic Nervous System Network

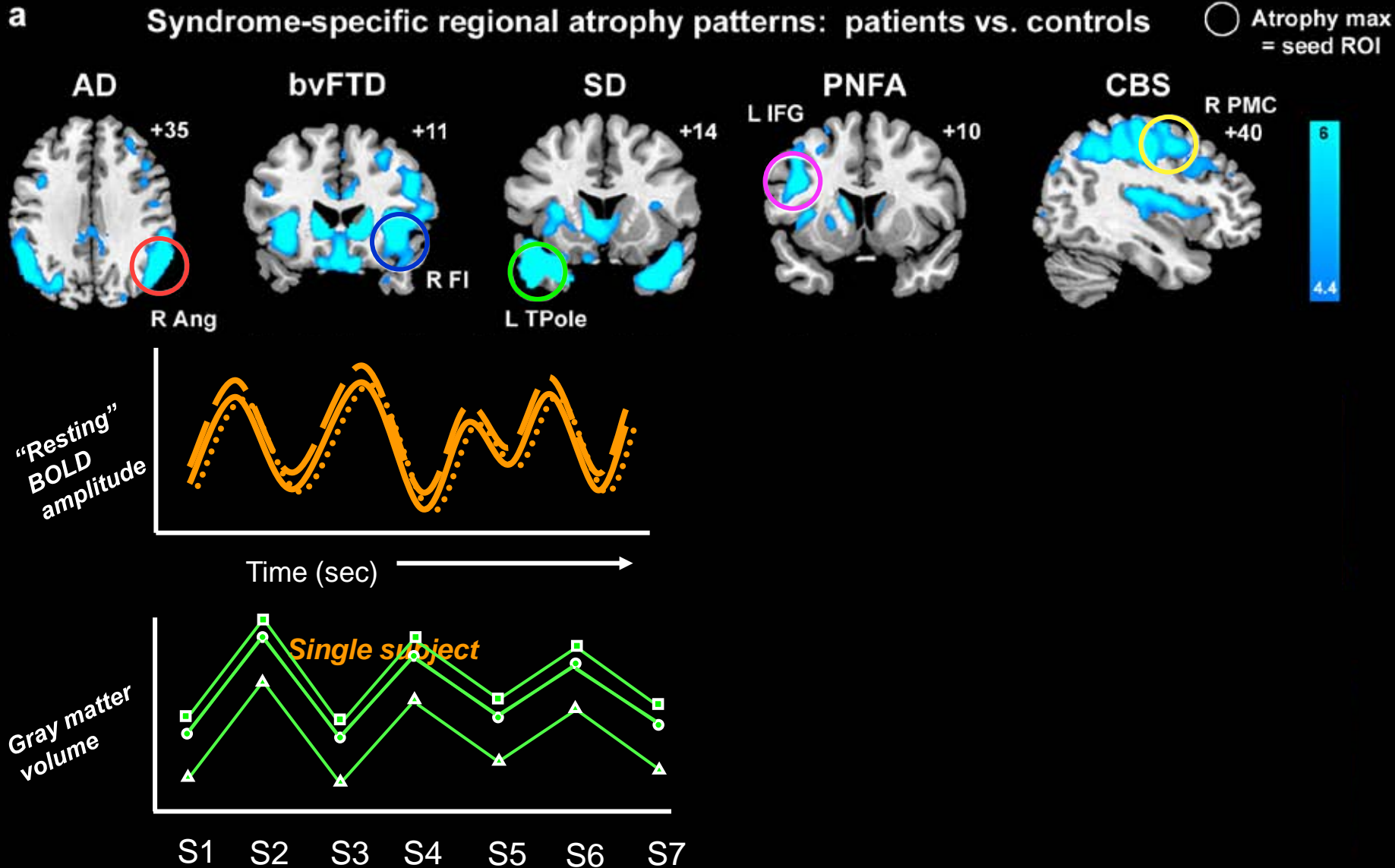
Medial cerebral activity associated with autonomic arousal, error and conflict during Stroop task performance



Pupillary response during Stroop task

Network-Based Neurodegeneration

Fire Together, Wire Together, Expire Together



Inter-Network Interactions

Left VLPFC

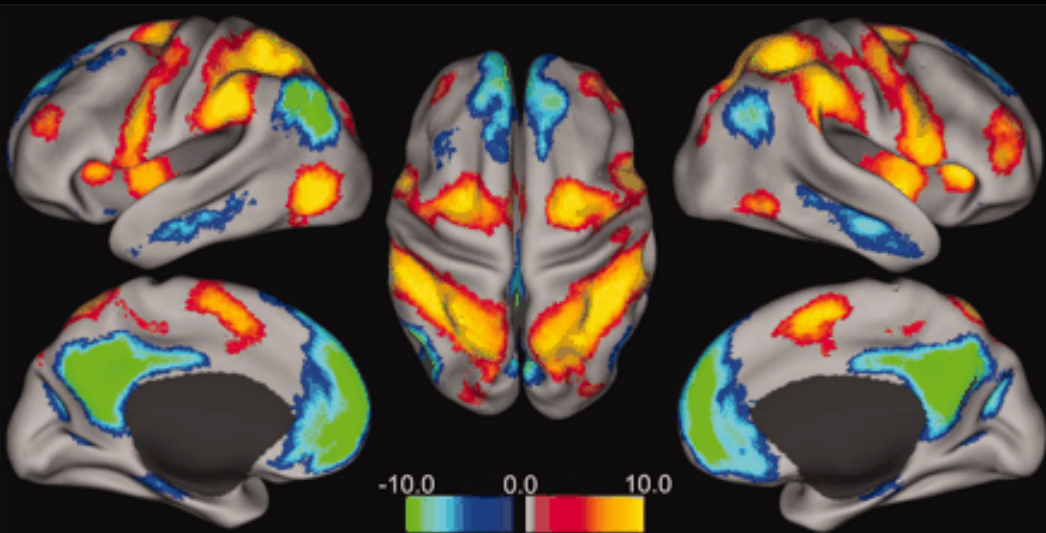
Right VLPFC

Right DLPFC

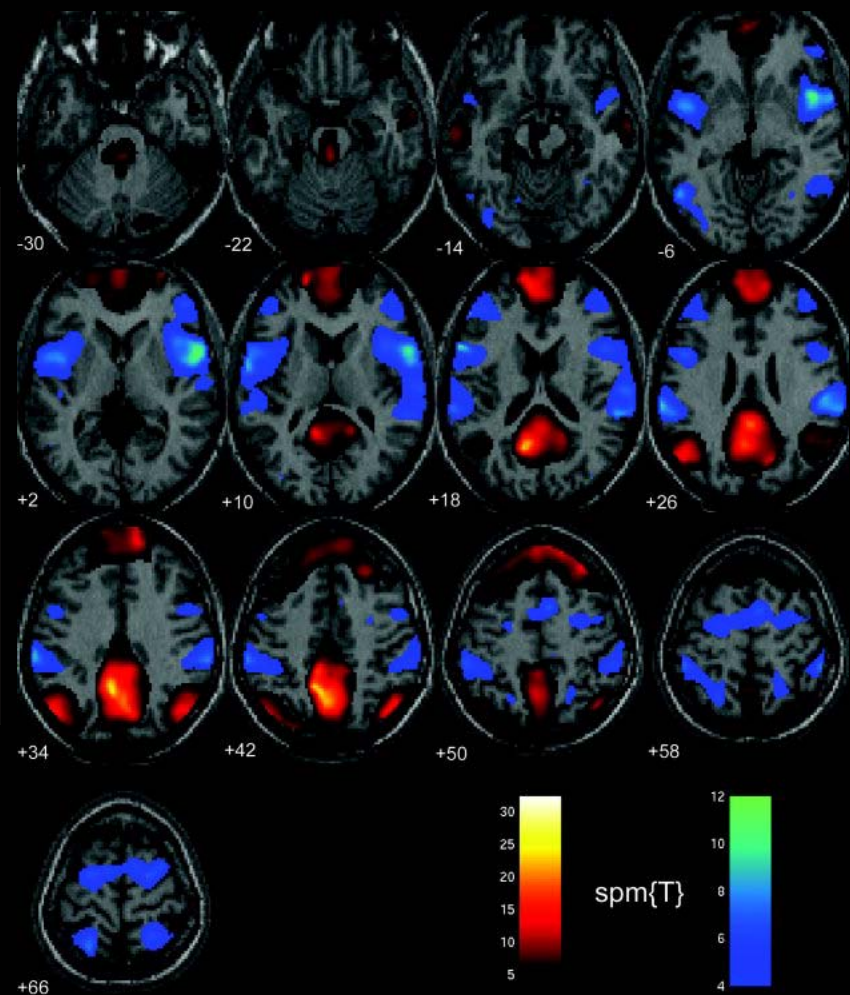


Greicius et al., *PNAS*, 2003

Inter-Network Interactions

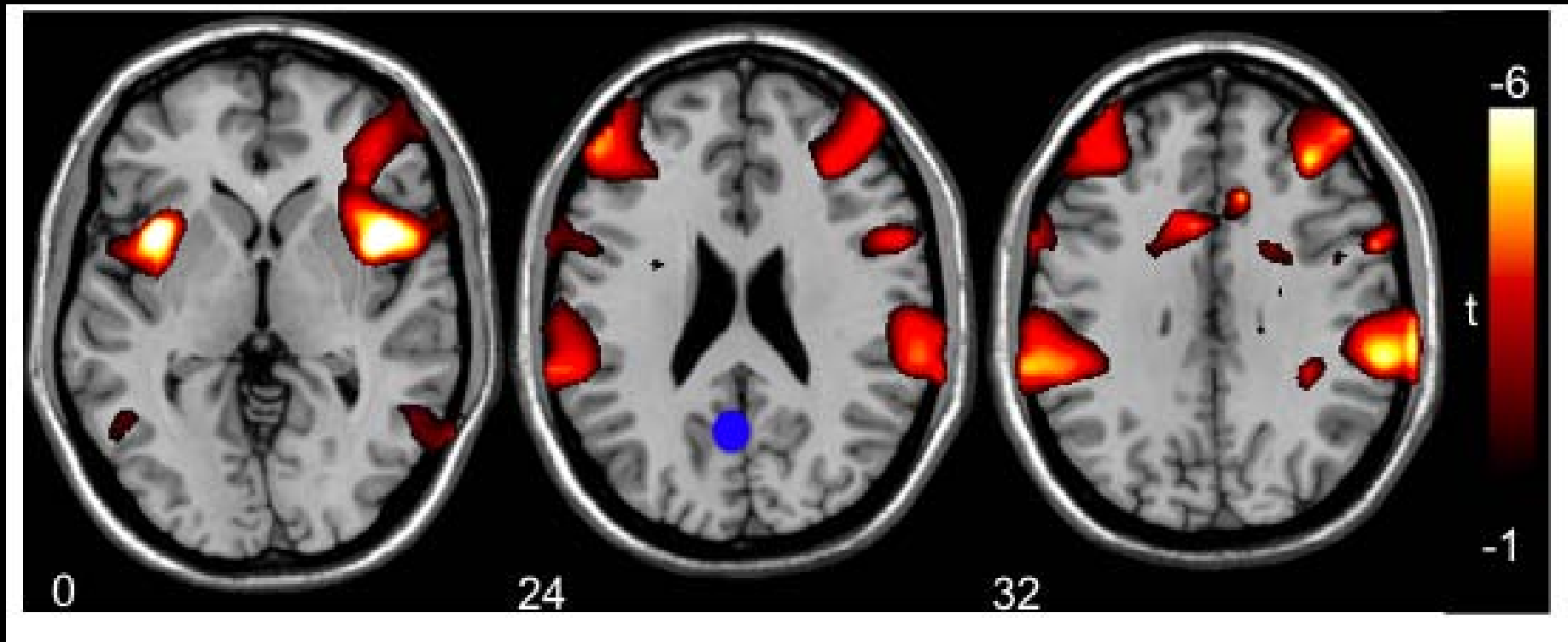


Fox et al., *PNAS*, 2005



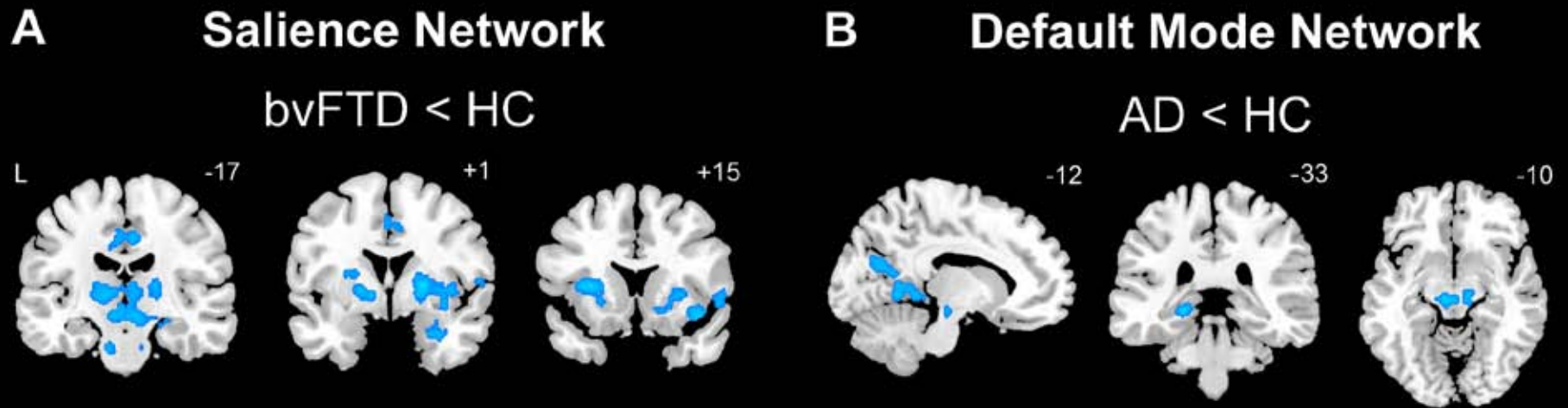
Fransson, *Hum Brain Mapp*, 2005

Anti-Correlations at the Group Level (careful physio correction, no global scaling)

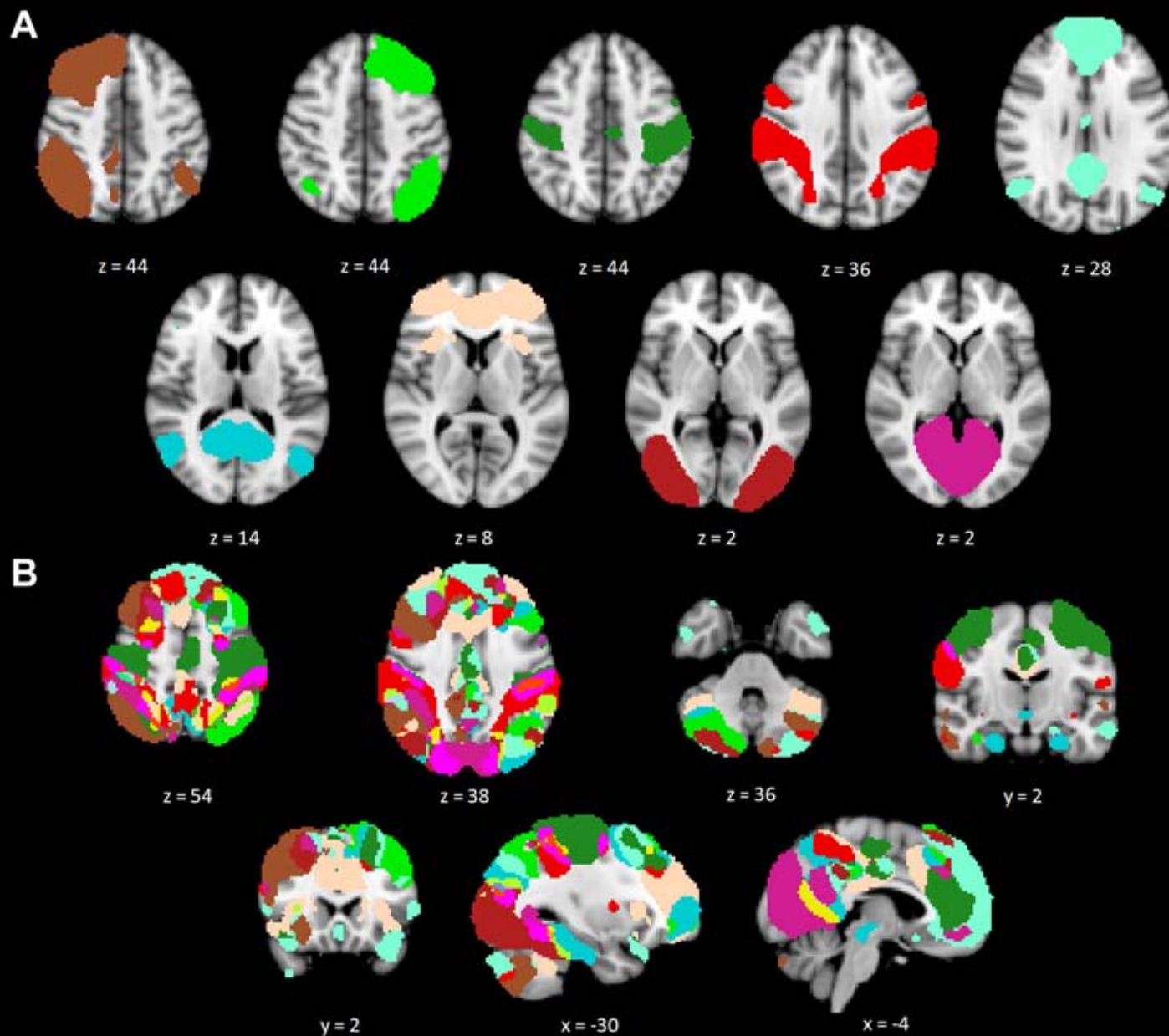


Chang and Glover, *Neuroimage*, 2010

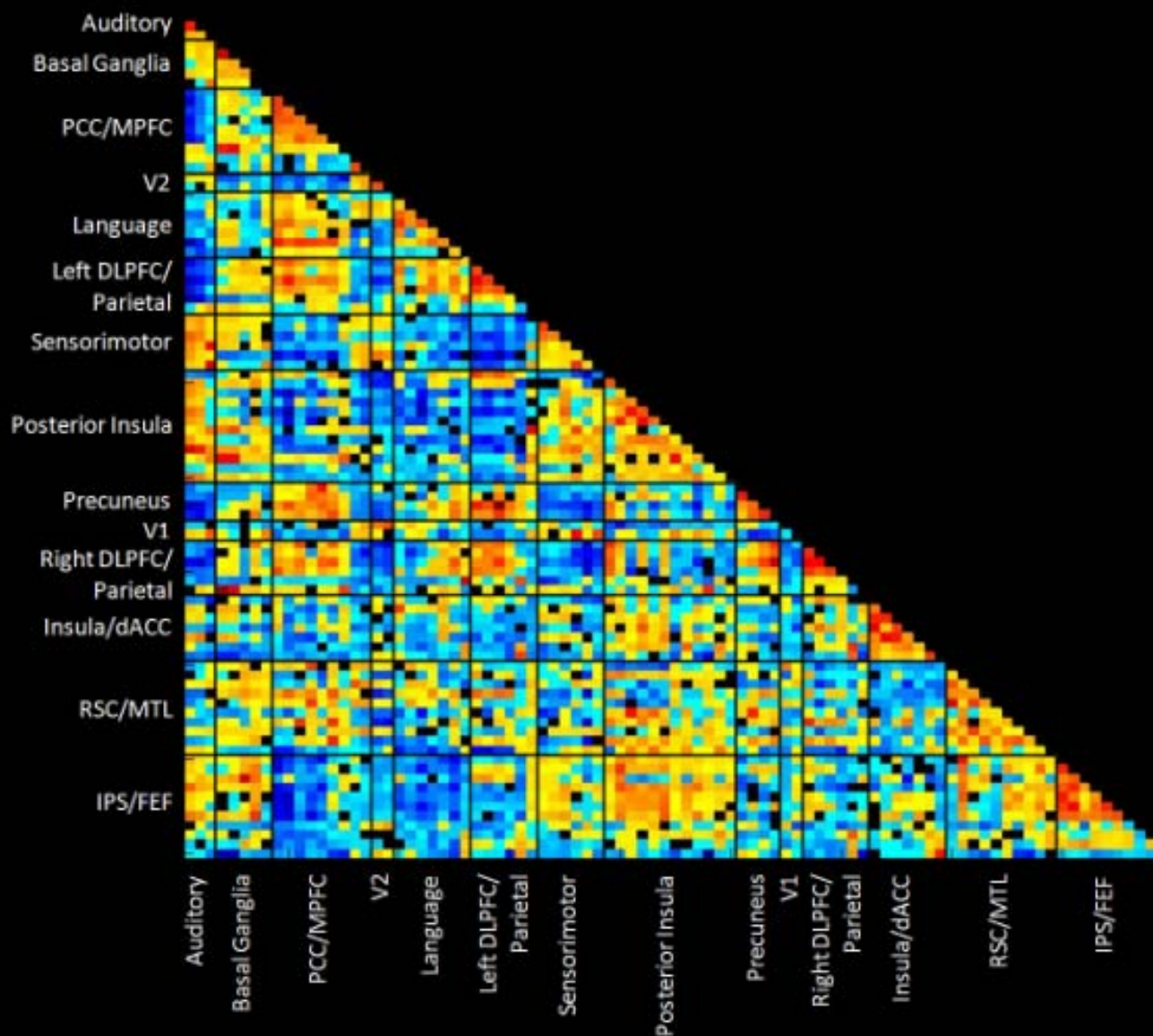
Inter-Network Interactions in Dementia



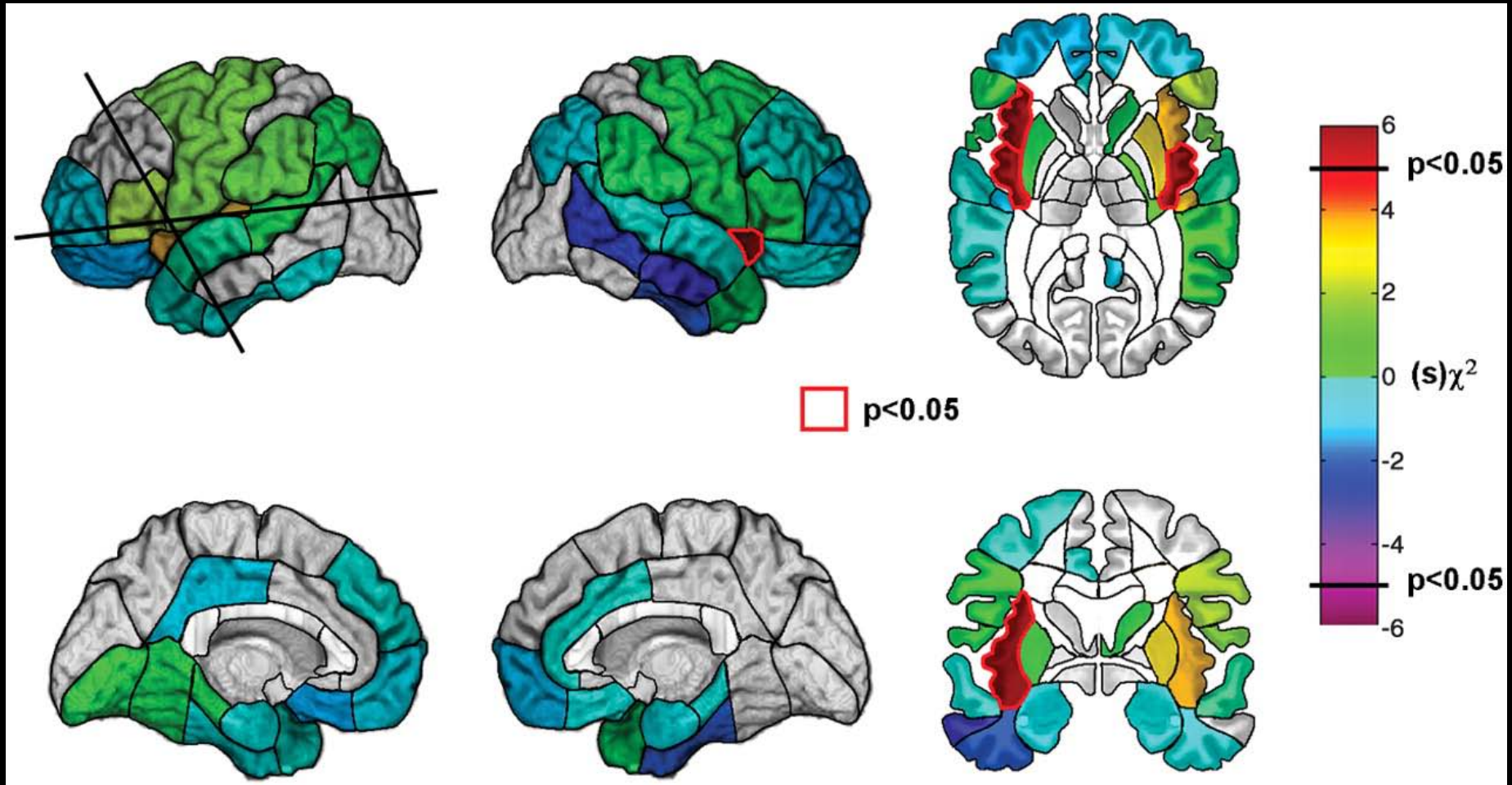
FIND Lab Parcellation (14 ICNs yield 90 ROIs)



Whole-Brain Functional Connectivity Matrix



Insular Lesions and Addiction



Navqi et al., *Science*, 2007

Saliience Network and Cue-Induced Urges

Table 1. Functional imaging studies demonstrating activity in the insula during drug urges^a

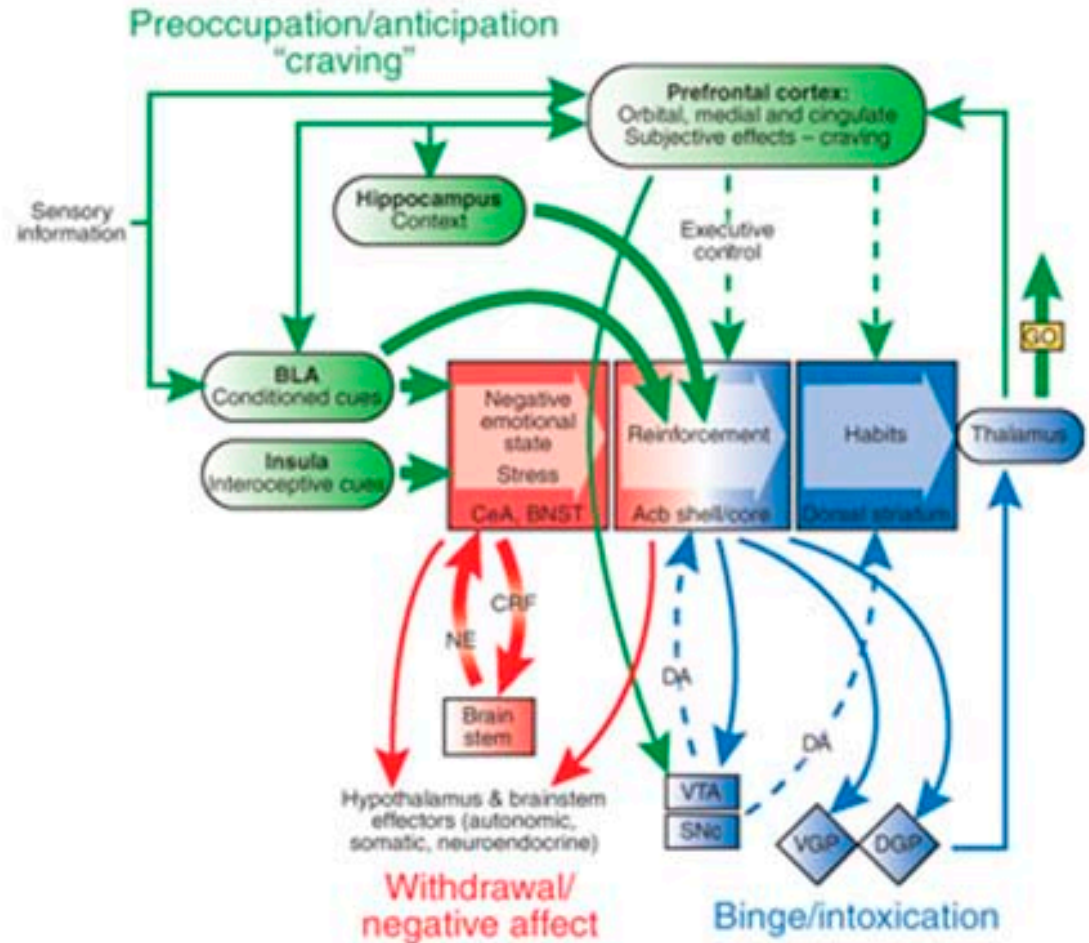
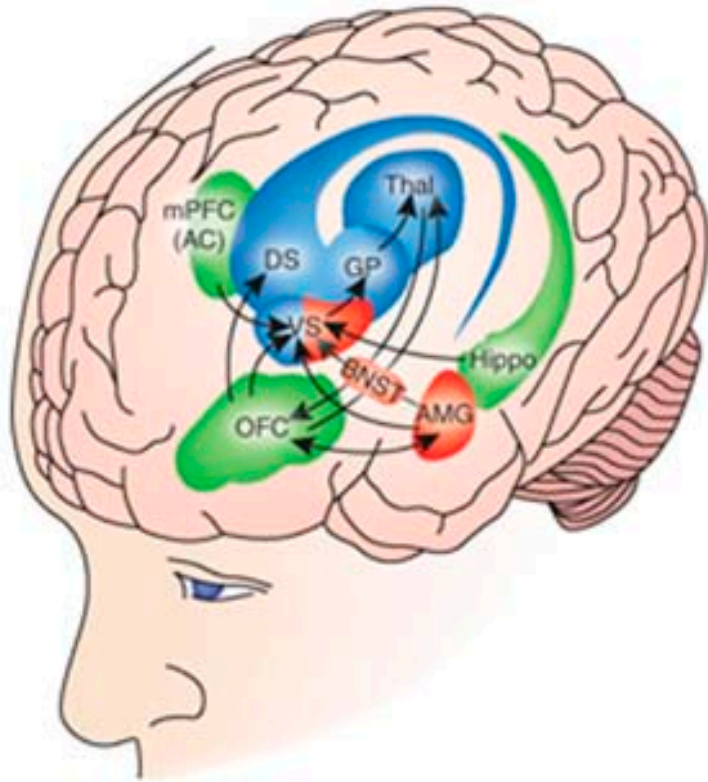
Drug	Insula	OFC ^b	ACC	DLPFC	Amygdala	VS	HF	Refs
Cigarettes	L	L	L,R	L ^c	No activity	No activity	No activity	[129]
Cigarettes	L	R	No activity	L ^c	L,R	L,R	L,R	[130]
Cigarettes	L ^c ,R ^c	L ^c ,R ^c	L,R	L ^c ,R ^c	L	No activity	No activity	[131]
Cigarettes	L ^c ,R ^c	No activity	L ^c ,R ^c	L ^c	No activity	No activity	No activity	[115]
Cigarettes	L,R	No activity	L ^c ,R ^c	L ^c ,R ^c	No activity	No activity	No activity	[132]
Cigarettes	R	L	L	R	No activity	No activity	No activity	[133]
Cigarettes	R ^c	R ^c	R ^c	R ^c	R ^c	R ^c	L ^c ,R ^c	[134]
Cocaine	L	No activity	R	No activity	L,R	R	No activity	[135]
Cocaine	L ^c	L ^c	No activity	R ^c	L ^c	No activity	No activity	[136]
Cocaine	L ^c ,R ^c	L ^c ,R ^c	L	No activity	L,R	R	No activity	[137]
Cocaine	L,R ^c	L ^c ,R ^c	No activity	No activity	No activity	No activity	No activity	[138]
Cocaine	R	No activity	L	L,R	No activity	No activity	No activity	[139]
Cocaine	R	No activity	L,R	L	No activity	No activity	No activity	[140]
Alcohol	L,R	L ^c ,R ^c	L ^c ,R	No activity	No activity	L ^c ,R	L	[141]
Alcohol	L,R	No activity	L	L	No activity	No activity	No activity	[142]
Heroin	L	L	L,R	No activity	No activity	No activity	No activity	[143]

^aAll are studies of cue-induced urges, except Ref. [134], which is a study of abstinence-induced urges.

^bAbbreviations: ACC, anterior cingulate cortex; DLPFC, dorsolateral prefrontal cortex; HF, hippocampal formation; L, left; OFC, orbitofrontal cortex; R, right; VS, ventral striatum.

^cIndicates correlation with self-reported urges. Note that activity in the insula is frequently correlated with subjective urges. Also note the paucity of activation in subcortical structures, which indicates that conscious urges mediated by the insula might be dissociable from processes mediated by these subcortical regions.

Network Interactions in Addiction



Imaging ICNs in Addiction

- Brain can be segregated into a 14+ ICNs
- Several potential networks of interest in addiction
- Consider inter- as well as intra-network changes
- Different drugs may alter networks differentially
- Future studies: genetics, plasticity, pharmacology

Collaborators

Stanford

Vinod Menon

Bob Dougherty

Gary Glover

Jeske Damoiseaux

Will Shirer

UCSF

Bruce Miller

Bill Seeley

Helen Zhou

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Reviews

Craig, *Nat Rev Neurosci*, 2002

Seeley et al., *Alzheimer Dis Assoc Disord*, 2007

Naqvi and Bechara, *Trends Neurosci*, 2008