11-12-2020

Linking Brain Structure to Function to Value-Based Choice

Josiah Leong
University of Arkansas, Fayetteville

Citation

Linking brain structure to function to value-based choice

by Josiah Leong
at UA Integrative Systems Neuroscience Seminar
on 20/11/12

“Incentivized inhibition”

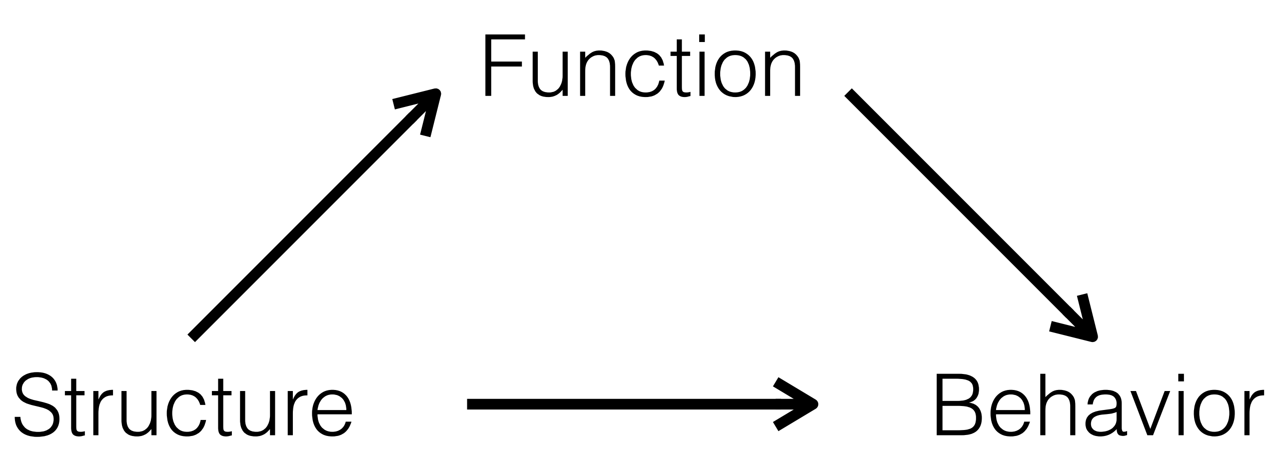
“Incentivized inhibition”

- **Incentive** anticipation
  - brain circuits active when anticipating incentives
  - circuit activity can predict financial decisions
- Response **inhibition**
  - previous tasks not balanced and not incentivized
- Importance
  - individual differences of ability to inhibit for incentives may be important in short and long terms (survival, health, wealth)

Knutson & Greer (2008); Aron, Robbins, & Poldrack (2004 & 2014), TICS

Multimodal approach

- Structure
  - characterize targeted white-matter tracts
- Function
  - link tract structure to functional activity at tract endpoints
- Behavior
  - link brain measures to inhibition in the face of incentives



Leong, Pestilli, & Knutson (in prep), TICS


+$5.25
-$1.75

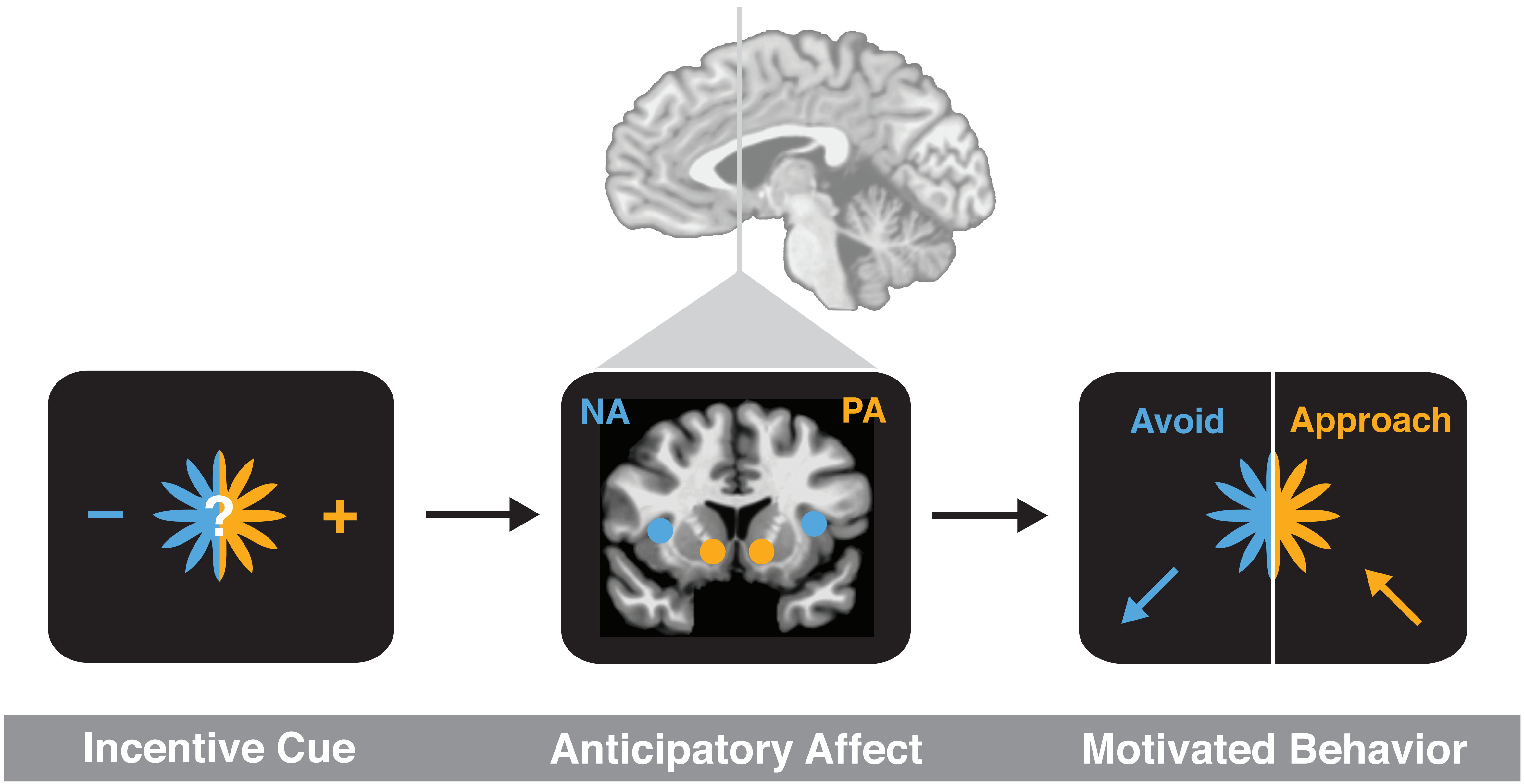

-$5.25
+$1.75

Positive-skew gambling

- Behaviors in real life: lotteries, casino games, slots
- Finance theories do not consider skewness
- Can neuroscience help us understand this behavior?

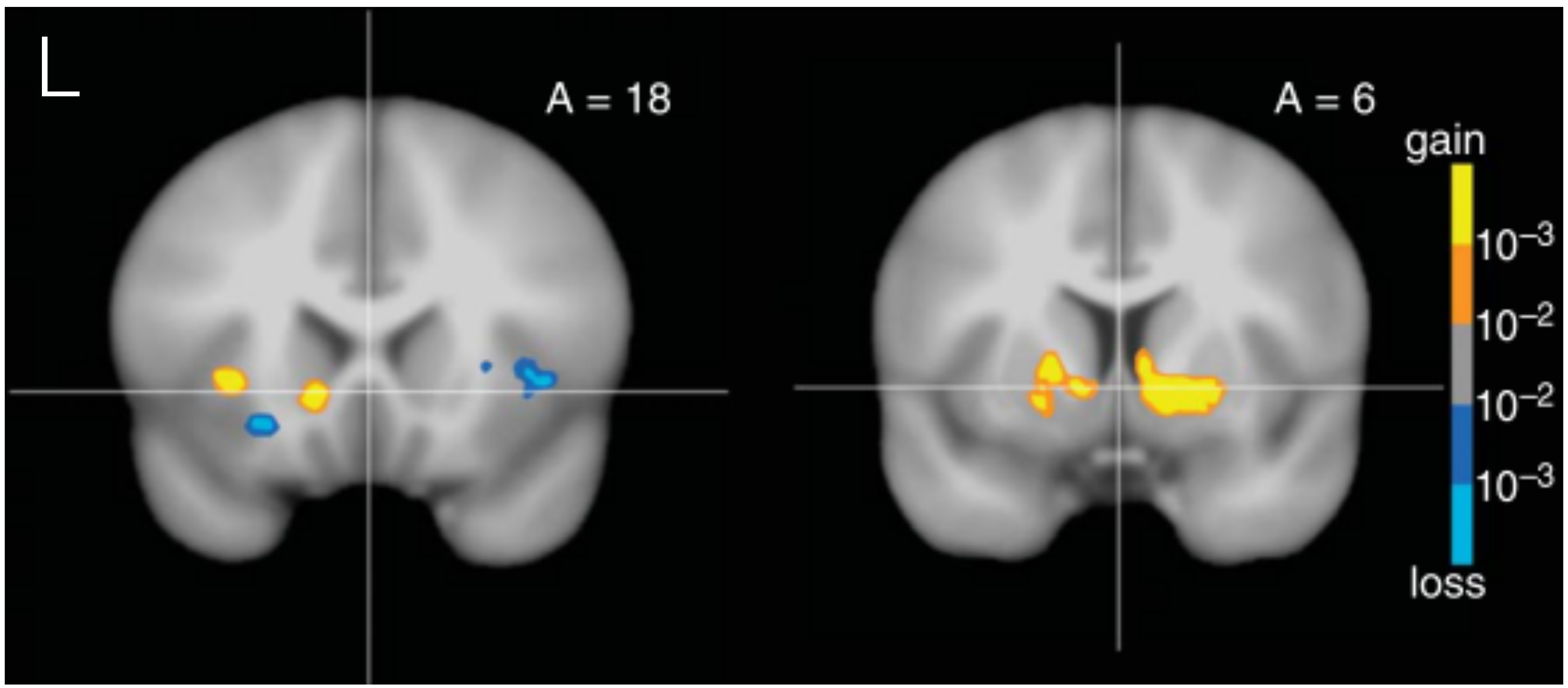
Kraus & Litzenberger (1976)

Anticipatory affect



Knutson & Greer (2008), Proc R Soc B

Incentive anticipation

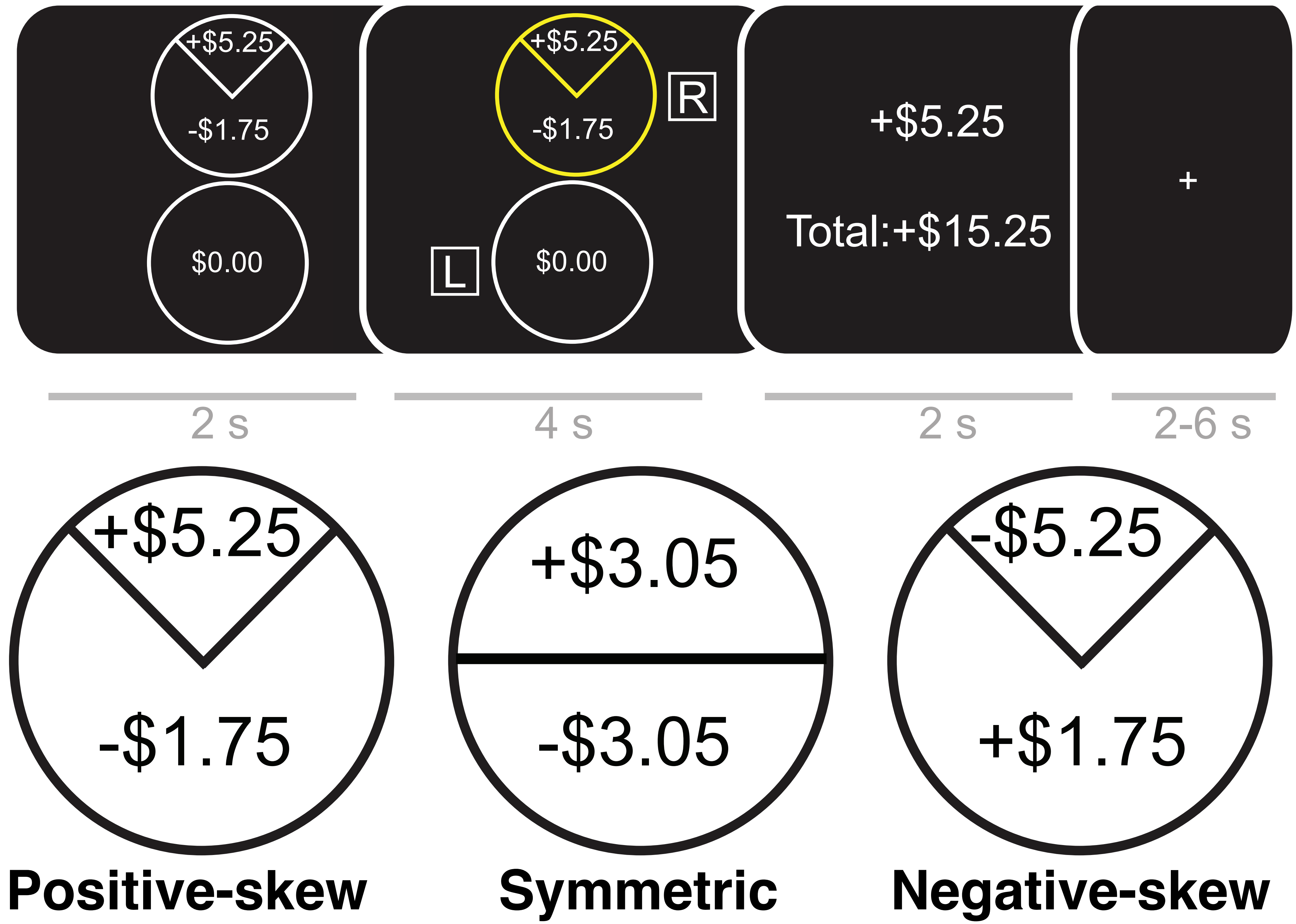


Anterior Insula
(**AIns**)

Nucleus accumbens
(**NAcc**)

Knutson & Greer (2008), Proc R Soc B

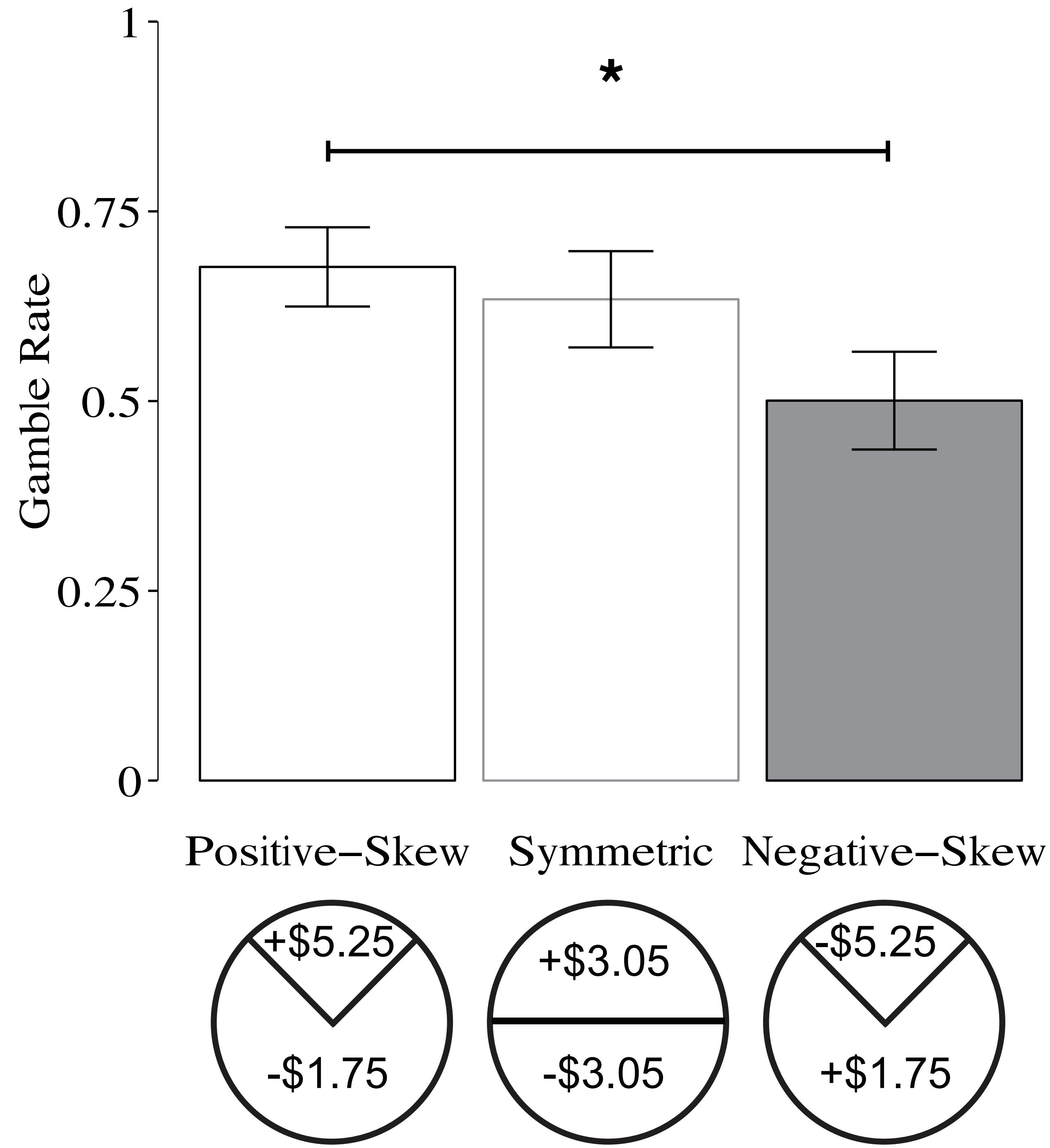
Gambling task



Wu, Bossaerts, & Knutson (2011), PLoS One

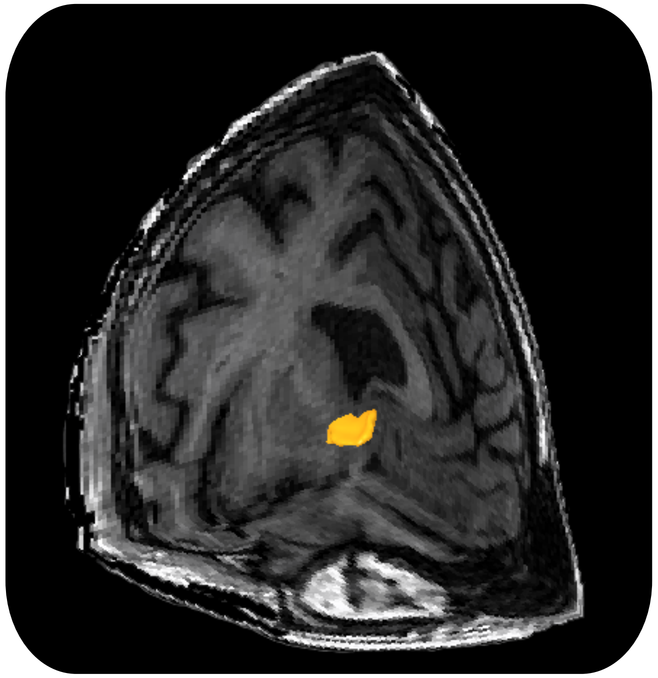
Positive-skew gamble preference

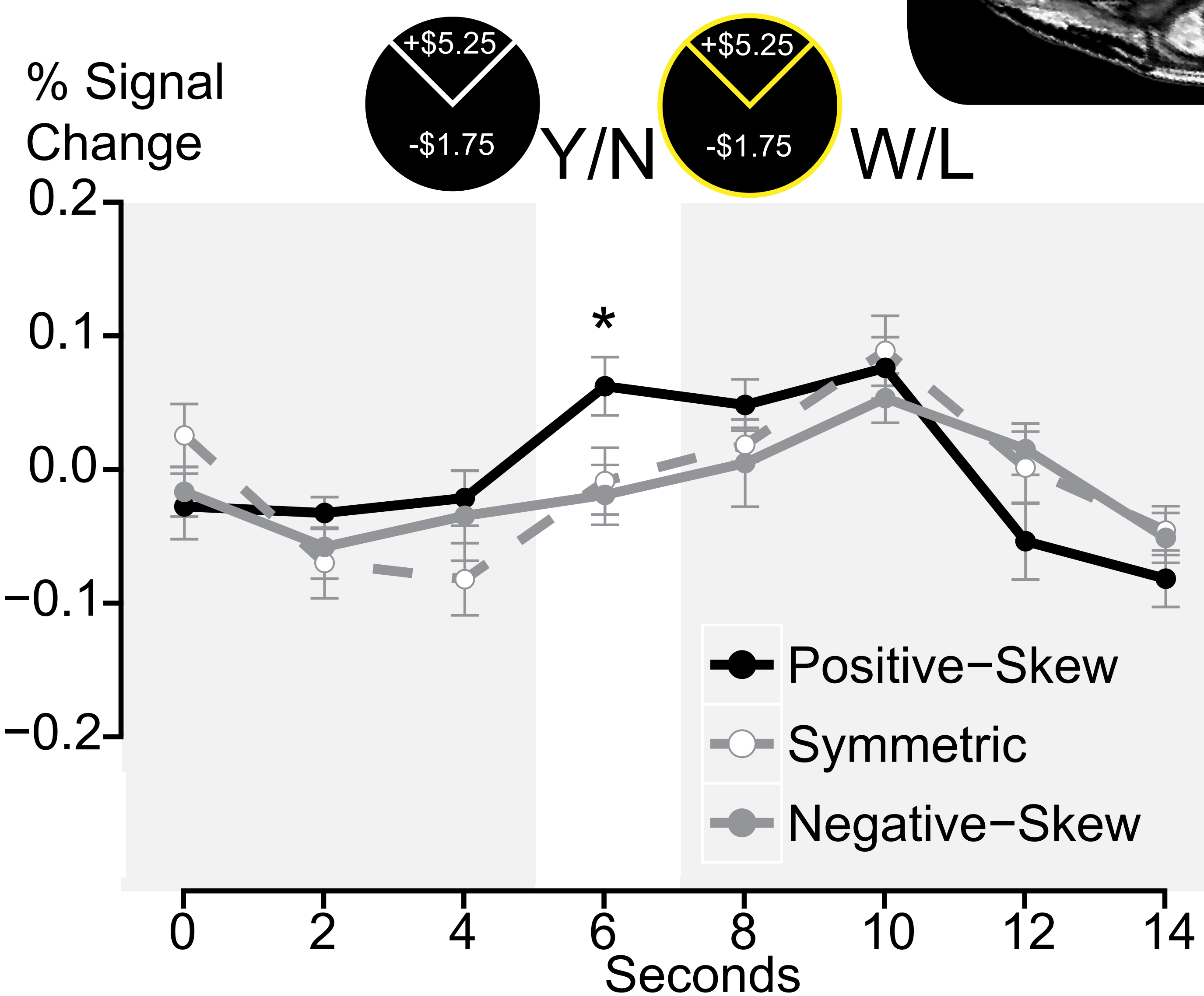
Sample
n=32
age mean=52
14 females
right-handed



*p<0.05

Positive-skew gambles elicit NAcc activity





*p<0.05

Predict trial-by-trial gambling

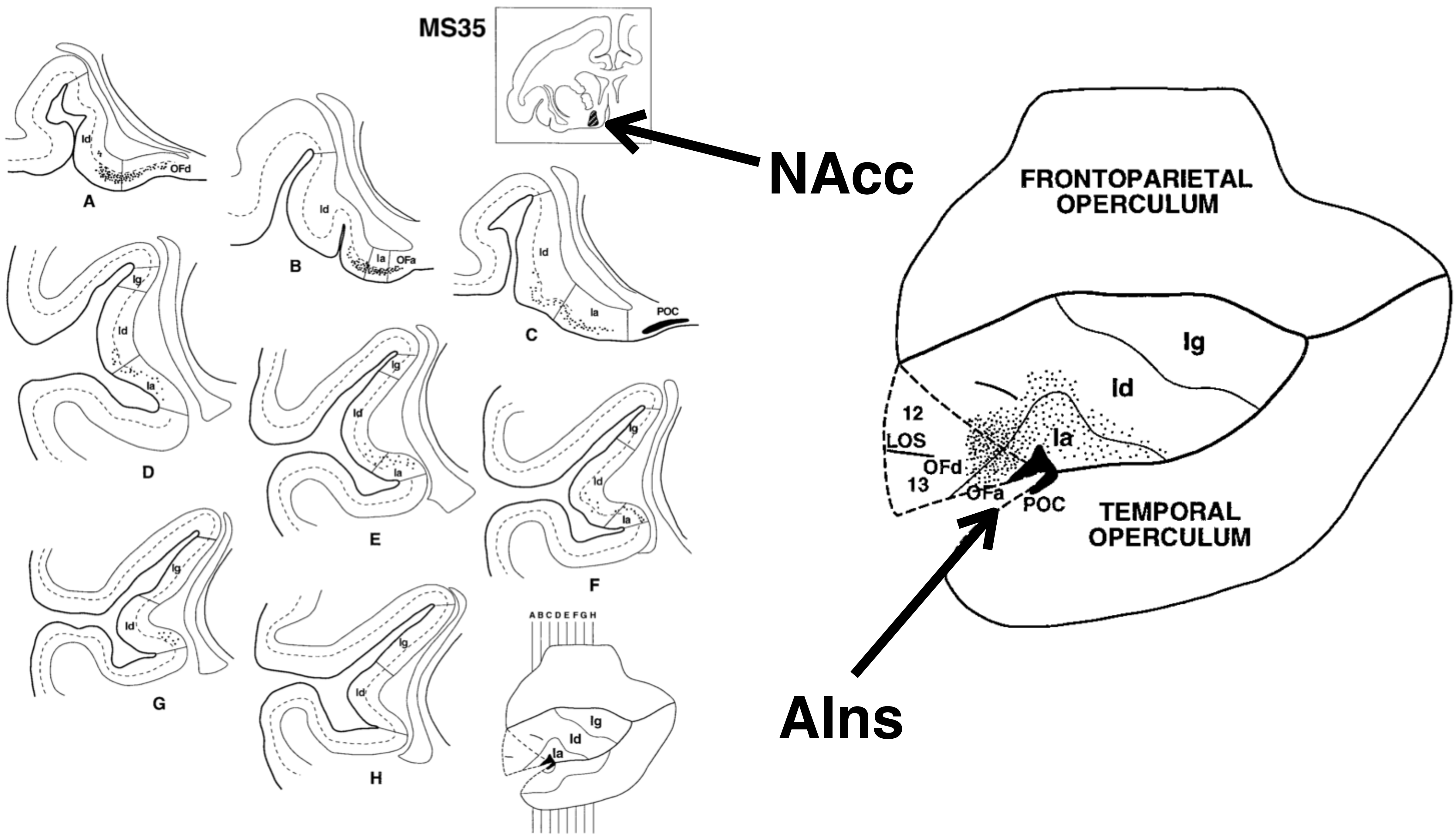
Table 1. Logistic Regression Results, Including Subjects as Random Effects

Variable	Contrast	Behavioral Model	Neural Model	Combined Model
Previous gamble outcome	gain > loss	−2.19* (−0.14, 0.06)		−2.55* (−0.17, 0.07)
	accept > reject	1.53 (0.13, 0.09)		2.01* (0.18, 0.09)
Domain of current earnings	loss	1.51 (0.40, 0.26)		1.71 (0.45, 0.26)
	gain	1.35 (0.35, 0.26)		1.52 (0.39, 0.26)
Skewness	positive > negative	6.16*** (0.36, 0.06)		5.50*** (0.32, 0.06)
	skewed > symmetric	−5.61*** (−0.49, 0.09)		−5.86*** (−0.52, 0.09)
Right NAcc			4.96*** (0.63, 0.13)	5.09*** (0.67, 0.13)
Right AIns			−3.30*** (−0.39, 0.12)	−3.00** (−0.36, 0.12)
Right MPFC			3.70*** (0.35, 0.10)	3.50*** (0.34, 0.10)
Pseudo R^2		0.27	0.27	0.30
AIC		2,644	2,666	2,594
BIC		2,689	2,695	2,657

Based on AIC, BIC, and a likelihood-ratio test for nested models, the best model for predicting trial-by-trial risky choice includes terms for right hemisphere neural activity, gamble type, previous gamble outcome, and domain of current earnings ($\chi^2(3) = 55.32$, $p < 0.0001$). Winning a previous gamble significantly predicted risk aversion on the following trial. A model including left-hemisphere neural activity did not improve model fit (Table S3). Z scores are shown with coefficient estimates and SE in parentheses. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

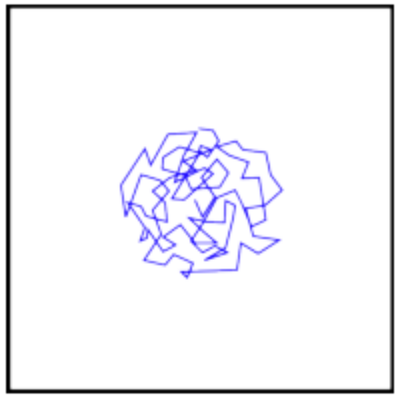
Leong et al (2016), Neuron

AIns—NAcc axon tracing in monkeys

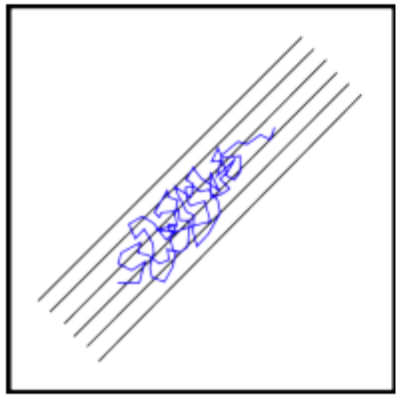


Chikama et al (1997); Reynolds & Zahm (2005), J Neuro

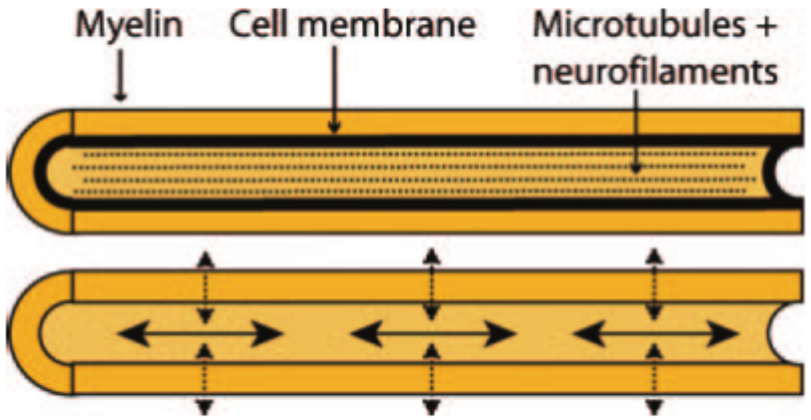
Diffusion MRI



Free Isotropic Diffusion



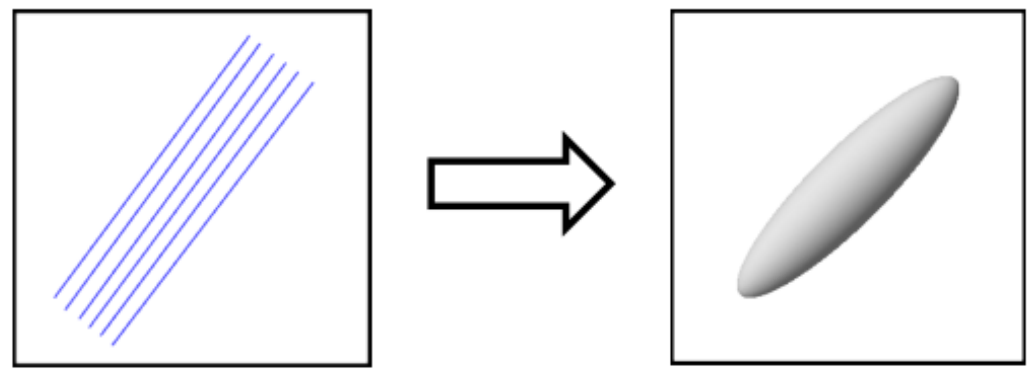
Hindered Anisotropic Diffusion

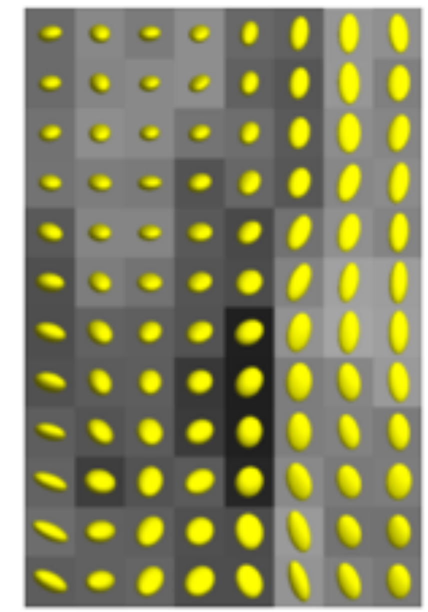


Basser & Pierpaoli (1996), J Magn Reson B; Jones & Cercignani (2010)

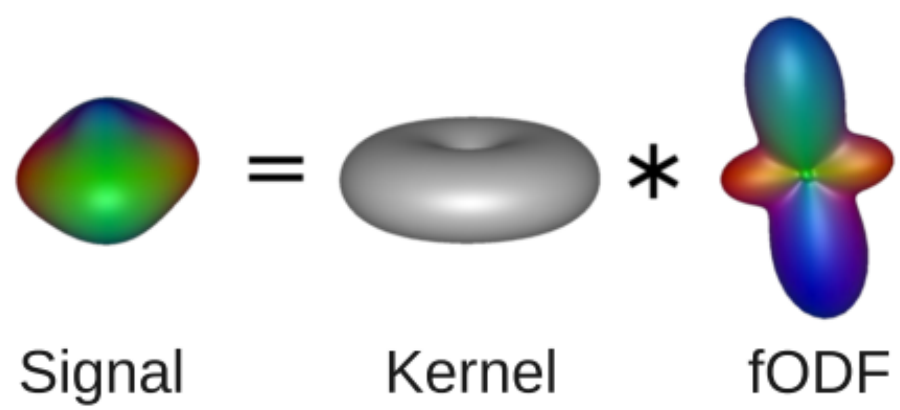
Fiber orientation distribution

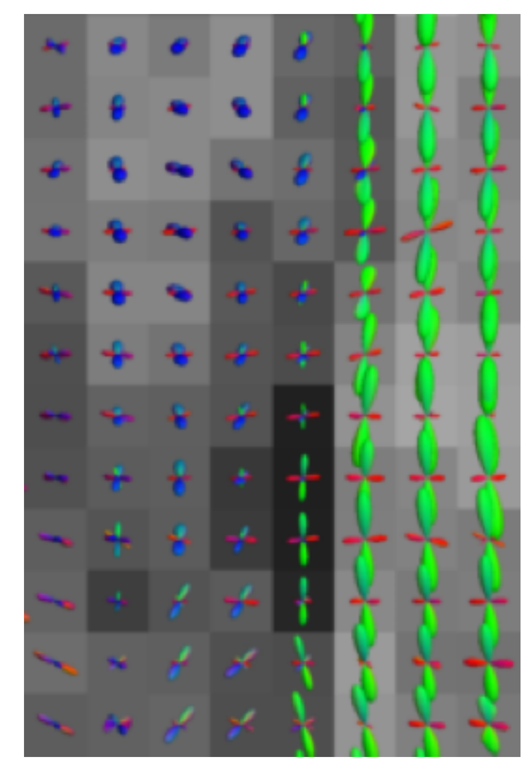
Tensor model





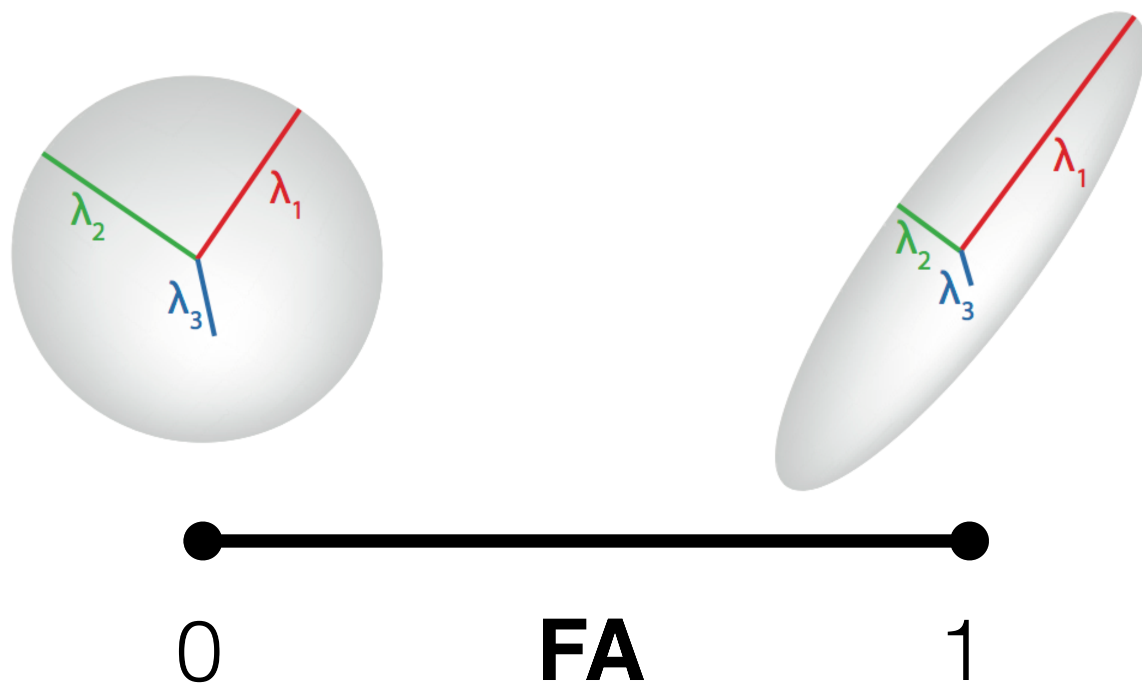
Constrained spherical deconvolution





Tournier et al (2007), NeuroImage

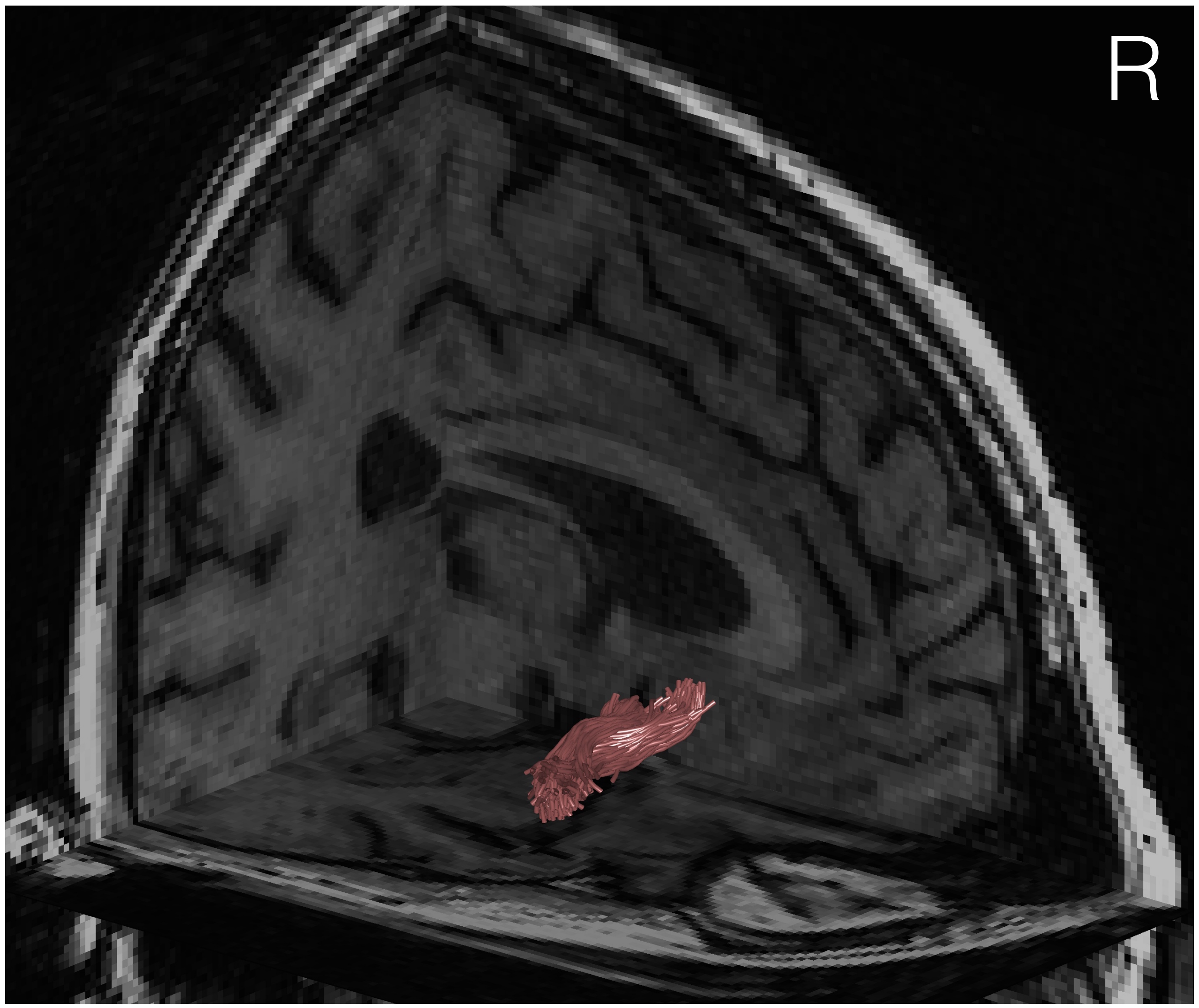
Measures of tract coherence

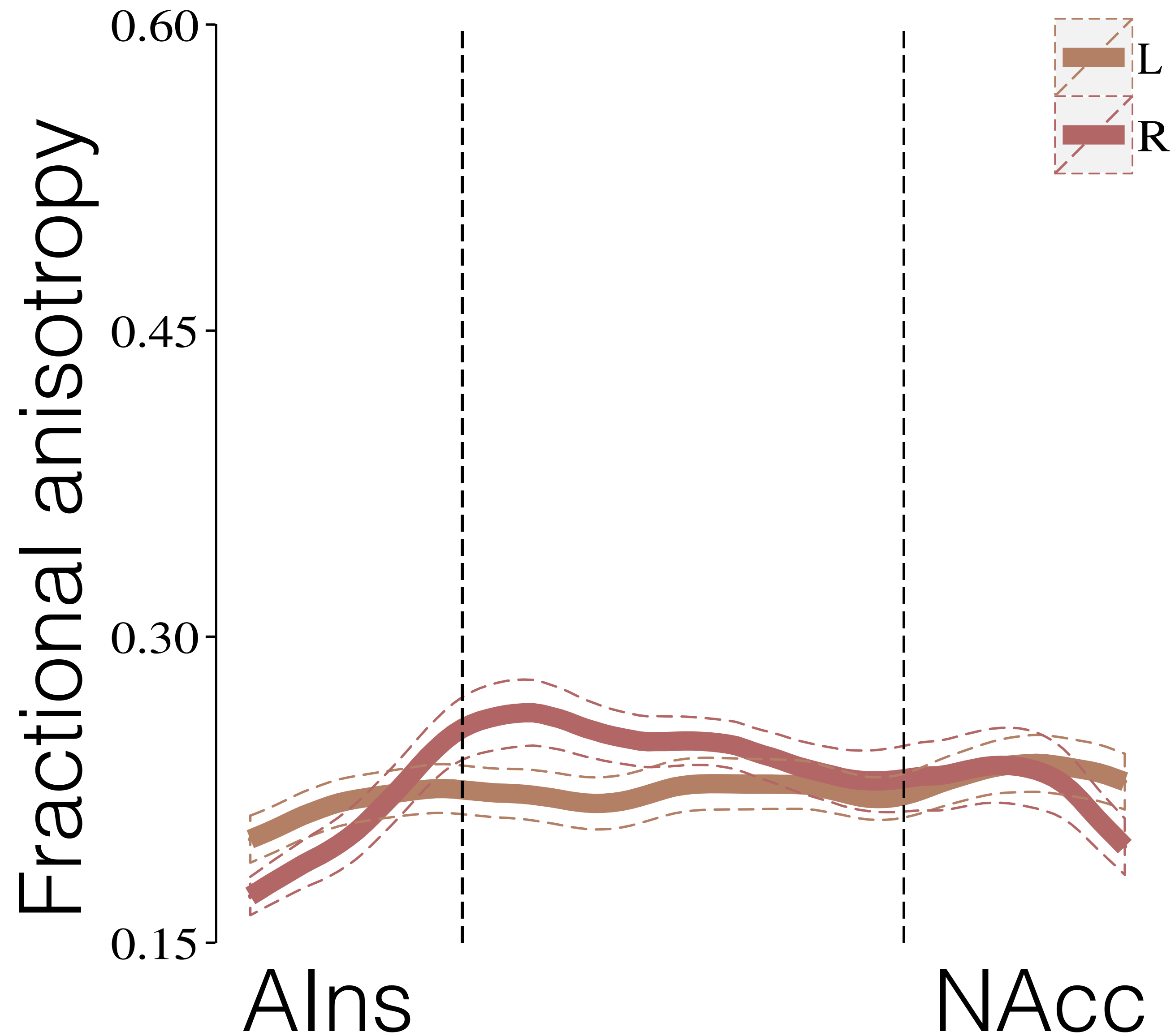


Fractional anisotropy (FA)

Jones & Cercignani (2010), NMR Biomed

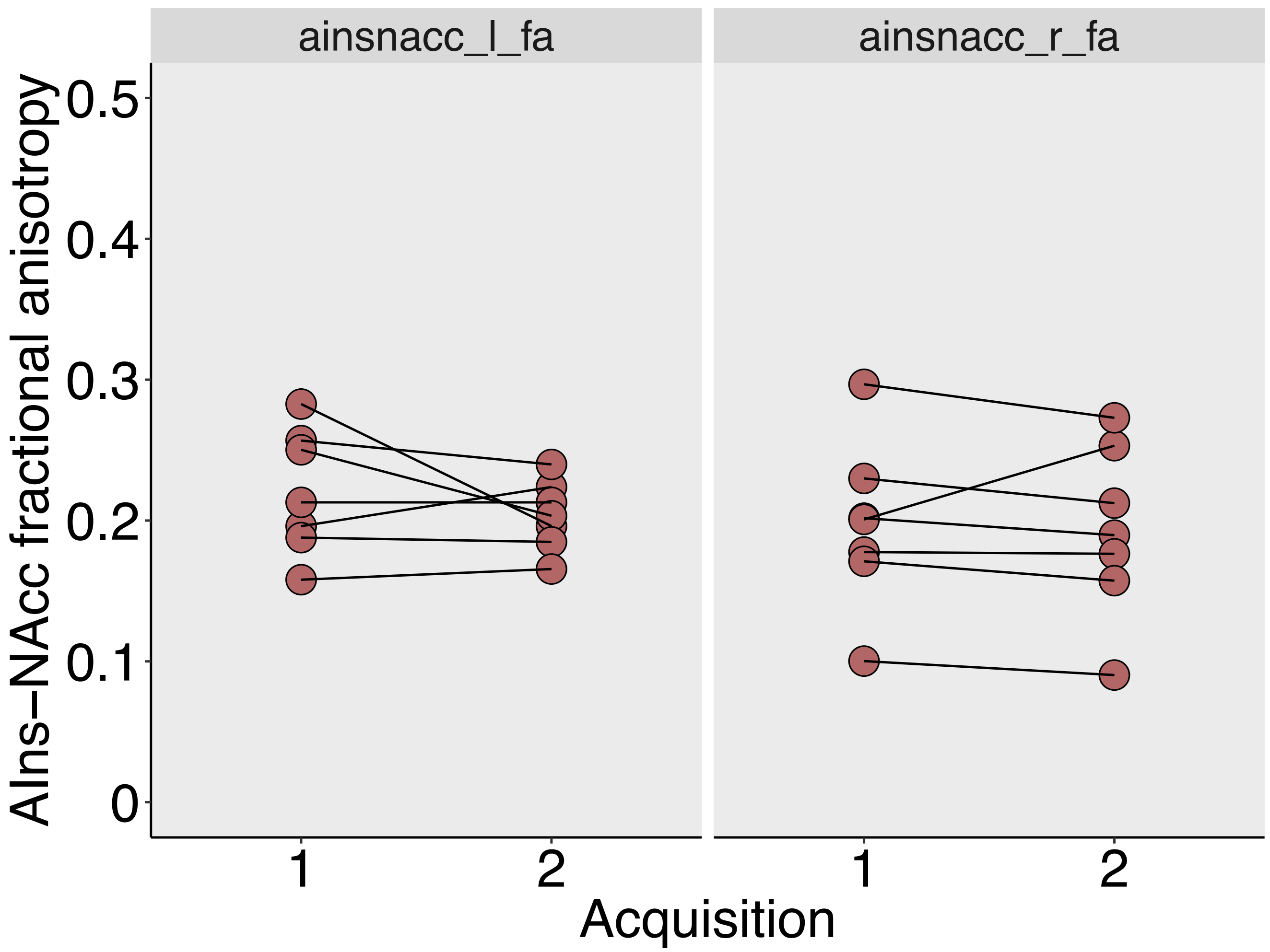
AIns—NAcc tract

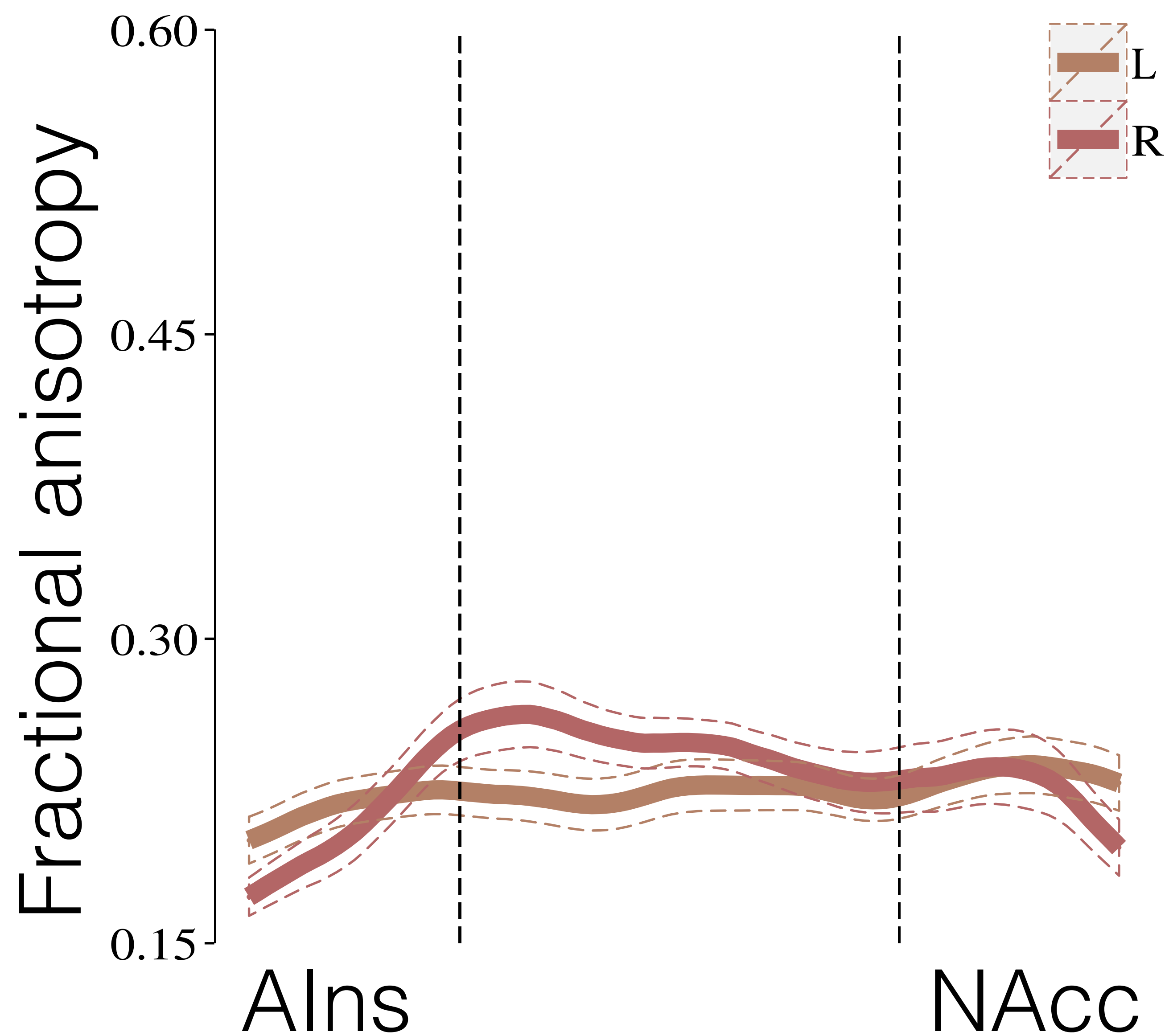




Leong et al (2016) Neuron; Leong et al (2018) NeuroImage

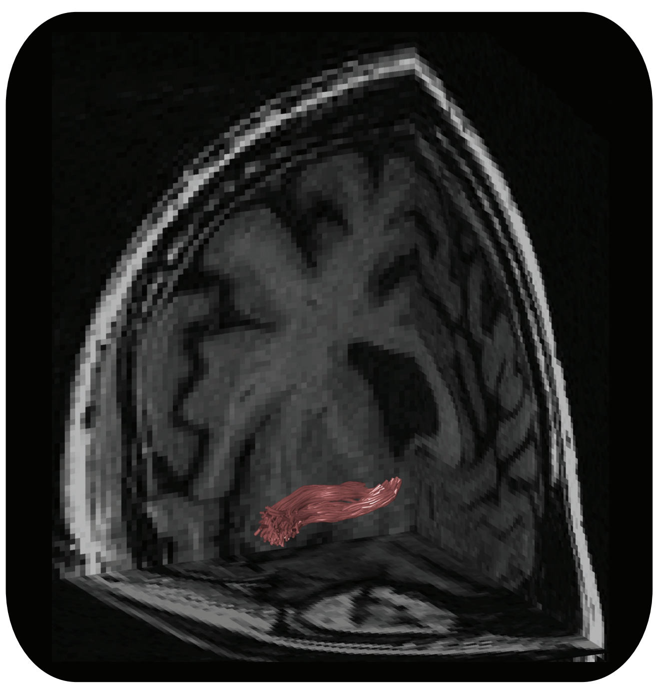
Test-retest reliability





Right: ICC2k = 0.96, $p < 0.001$
Left: ICC2k = 0.58, $p = 0.15$

AIns—NAcc tract coherence correlates with less preference for positive-skew gambles

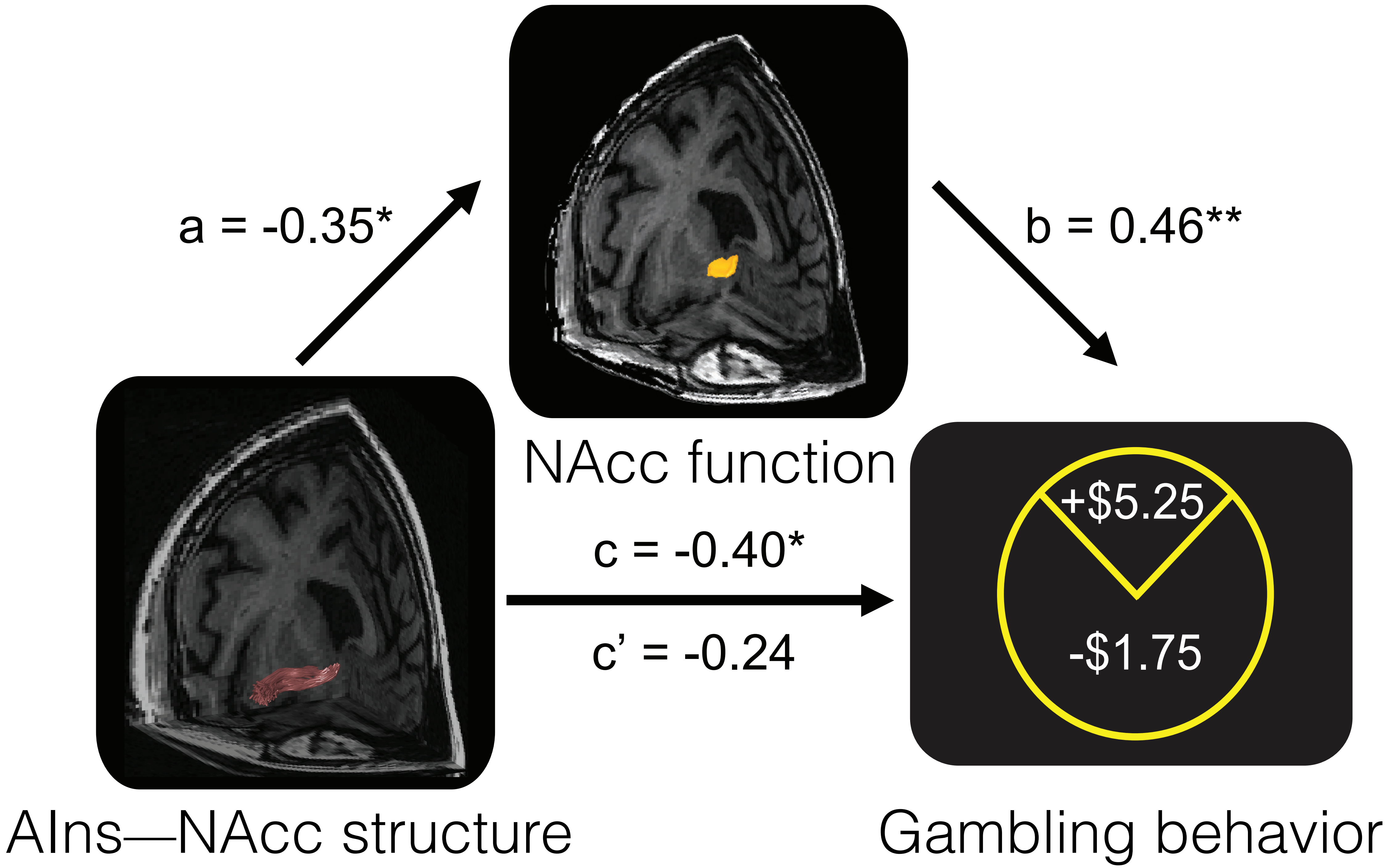


AIns—NAcc structure

c = -0.40*

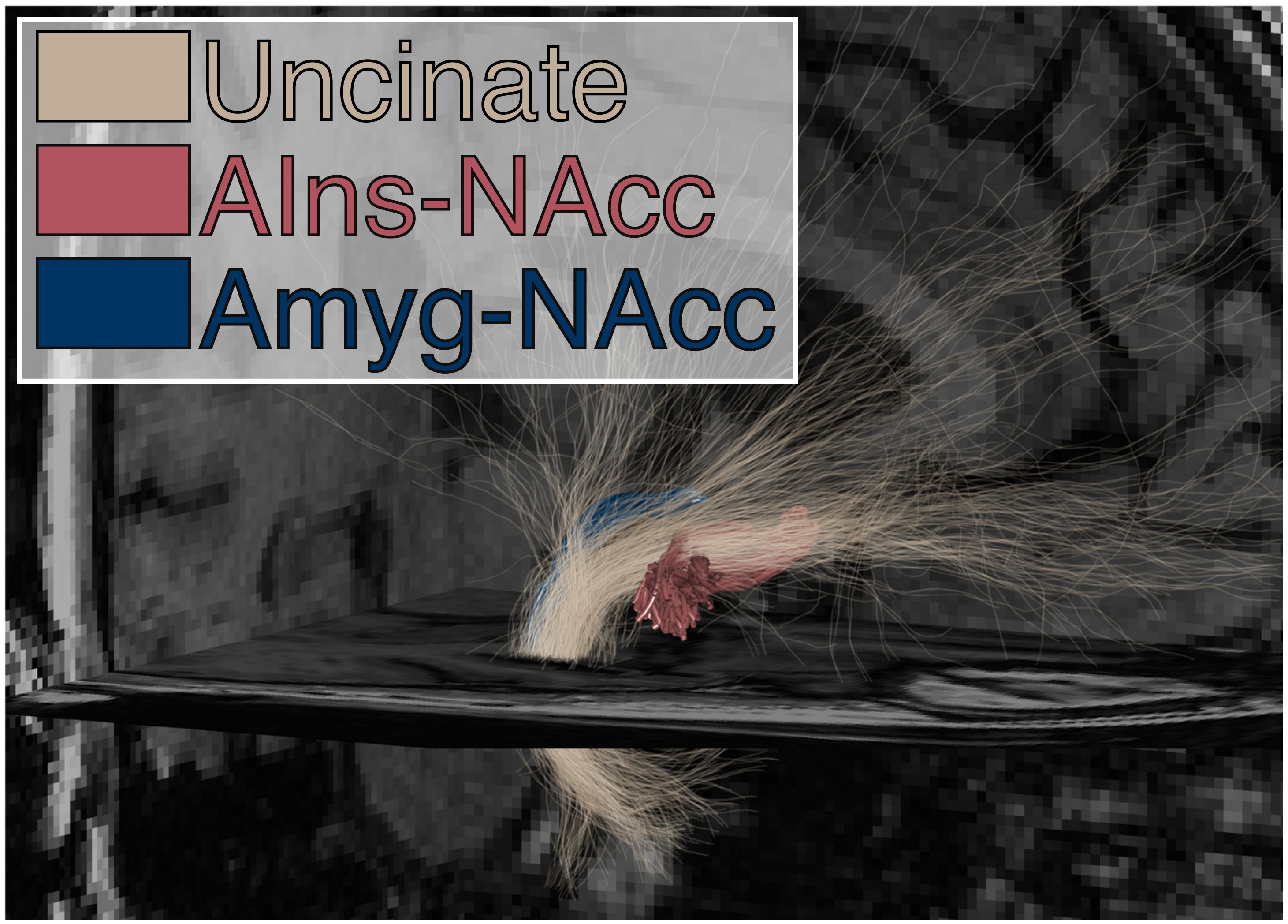
Gambling behavior

Linking structure to function to behavior

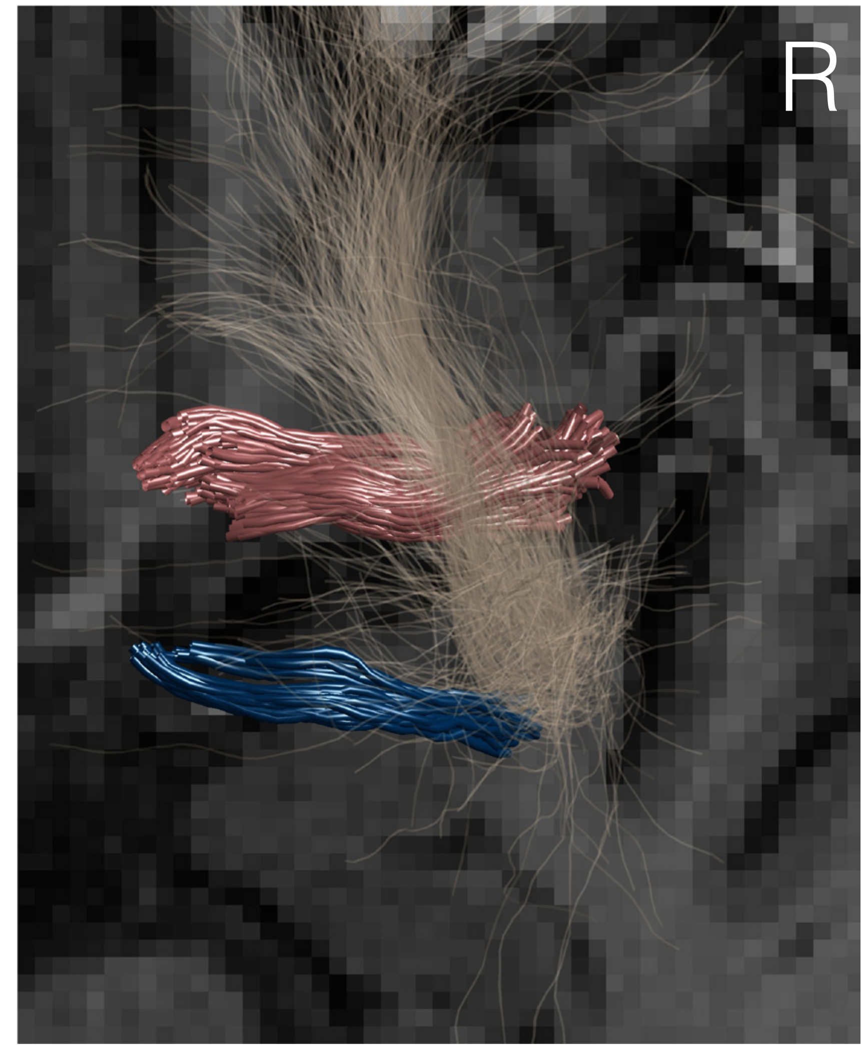


**p<0.01; *p<0.05

Control for uncinate fasciculus and amygdala—NAcc tract



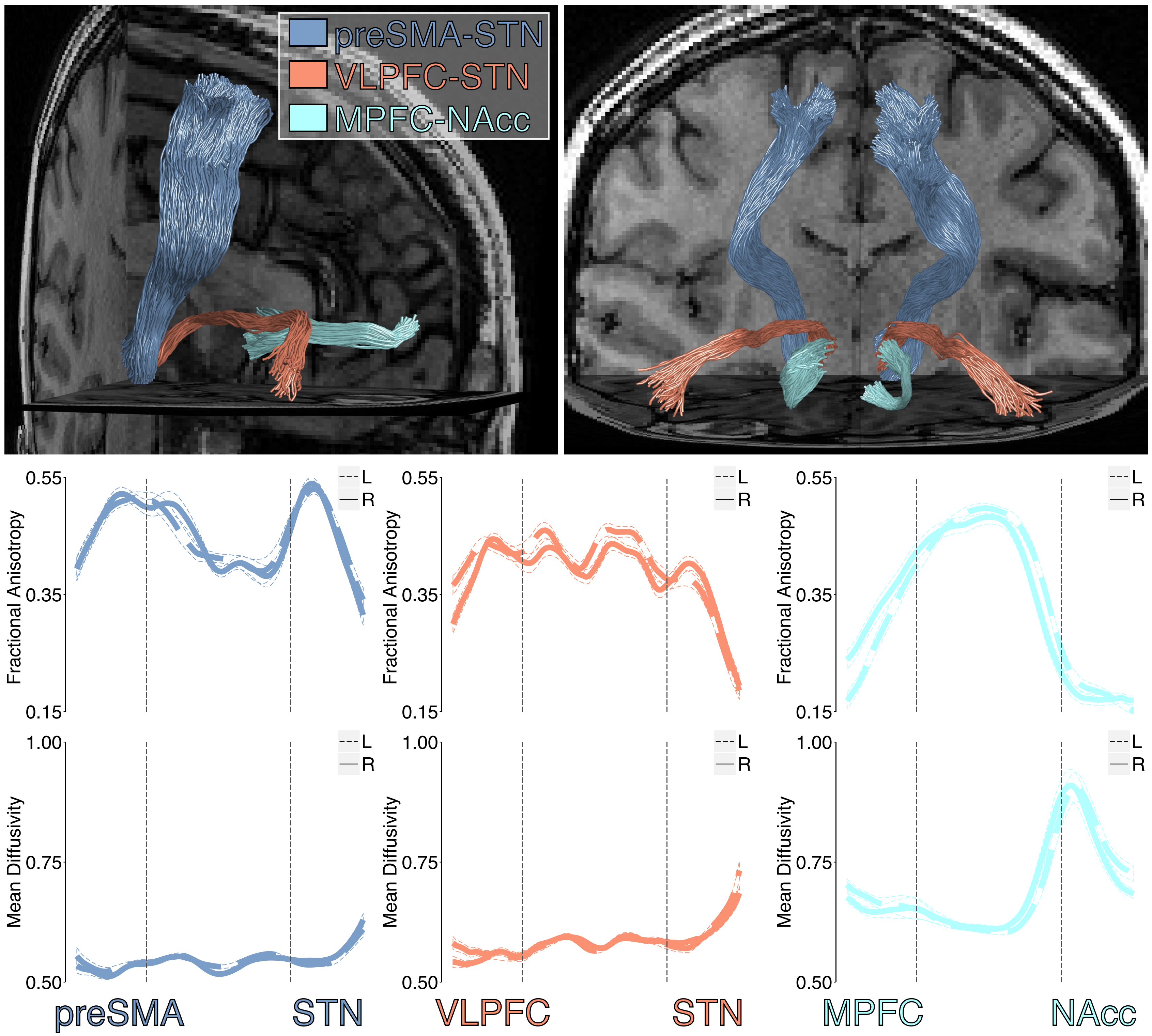
Sagittal



Axial

Leong et al (2016) Neuron

Control for motor tracts



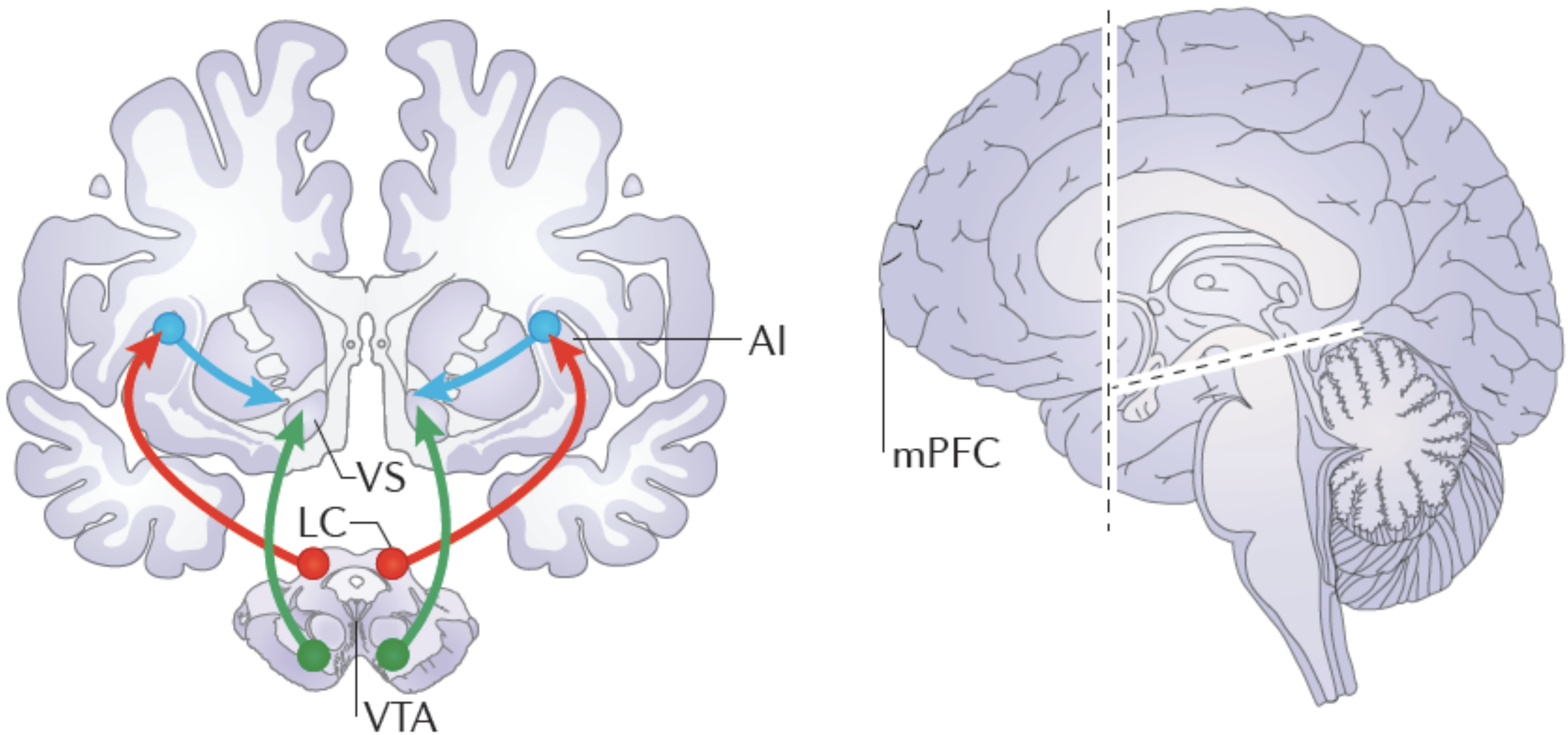
Johansen-Berg et al (2004), PNAS; Rae et al (2015), J Neuro; Leong et al (2018)

Applications

- Stimulant drug addiction and relapse
- Adolescent brain development

MacNiven, Leong, Knutson (2020) Science Adv; Leong et al (in press) DCN

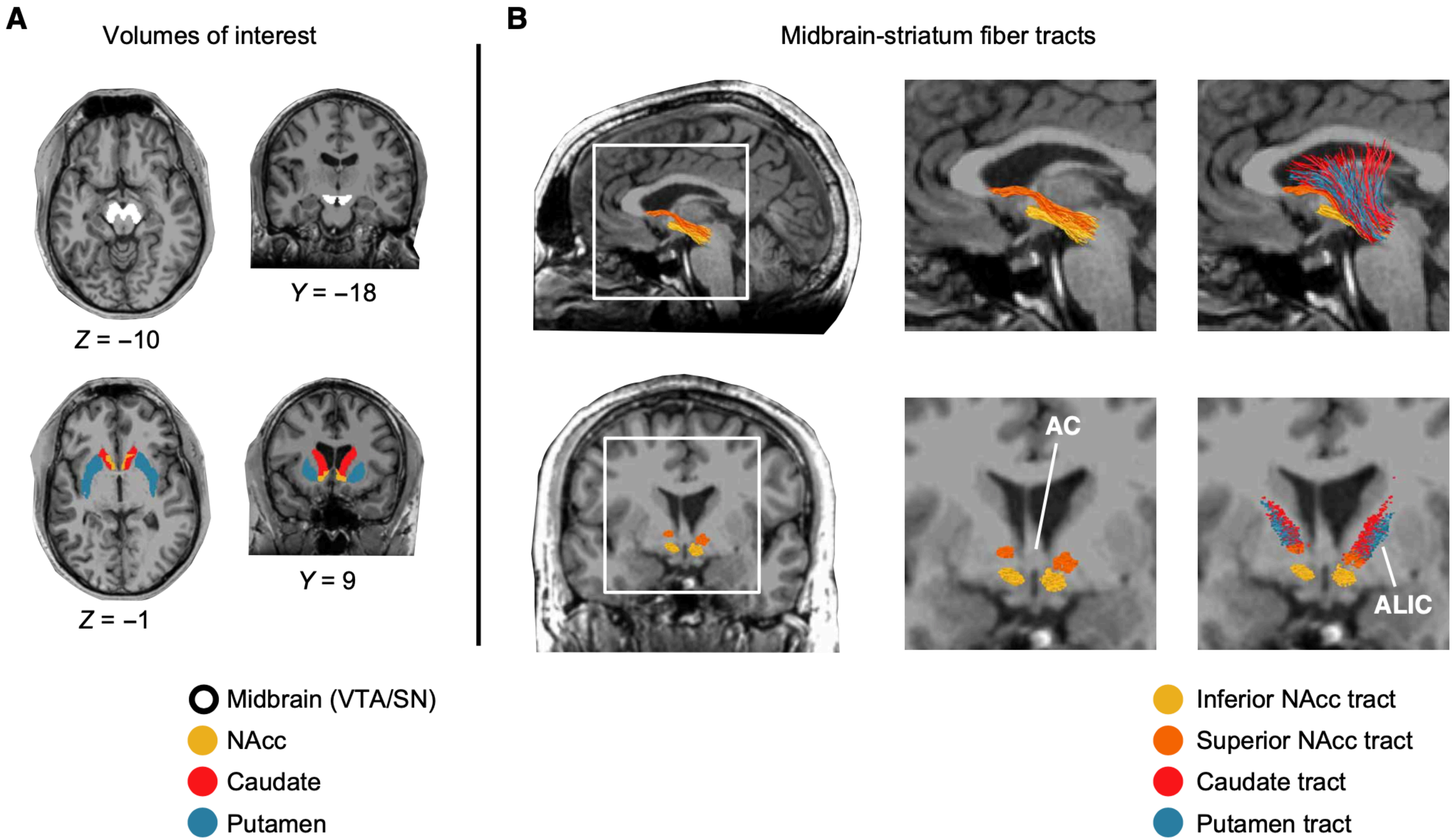
More targets in the brain



Ventral Tegmental Area

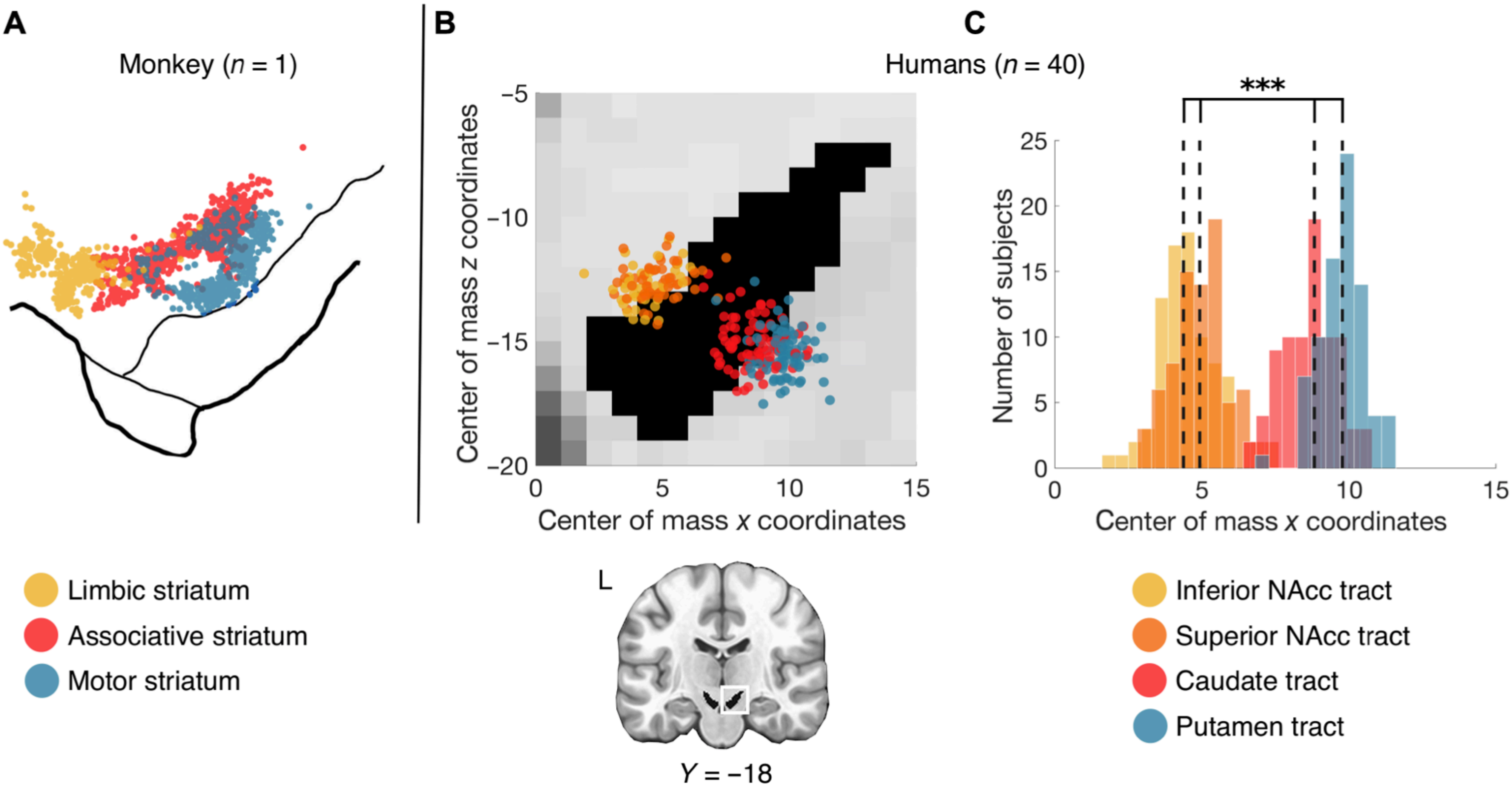
Samanez-Larkin & Knutson (2015), Nat Rev Neuro

Dopaminergic VTA-NAcc projections



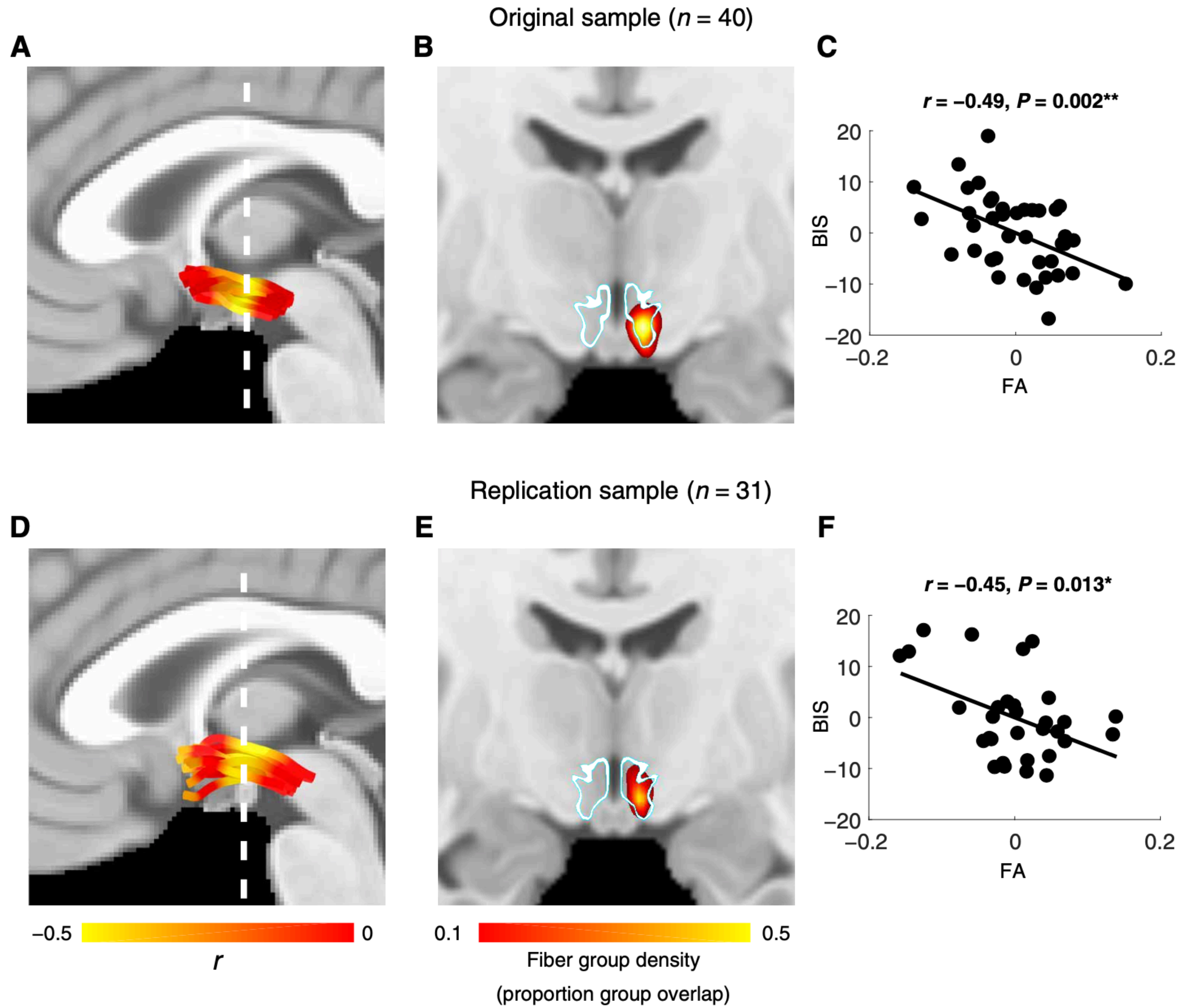
MacNiven, Leong, & Knutson (2020) Science Advances

Dopaminergic VTA-NAcc projections



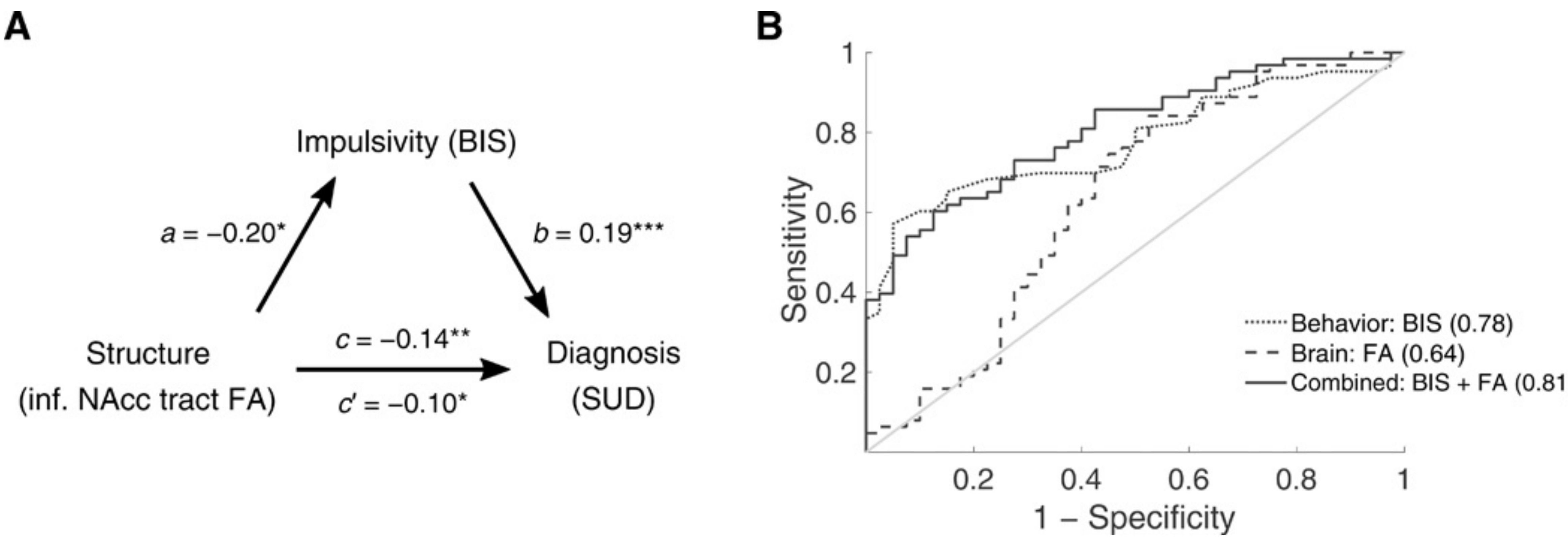
MacNiven, Leong, & Knutson (2020) Science Advances

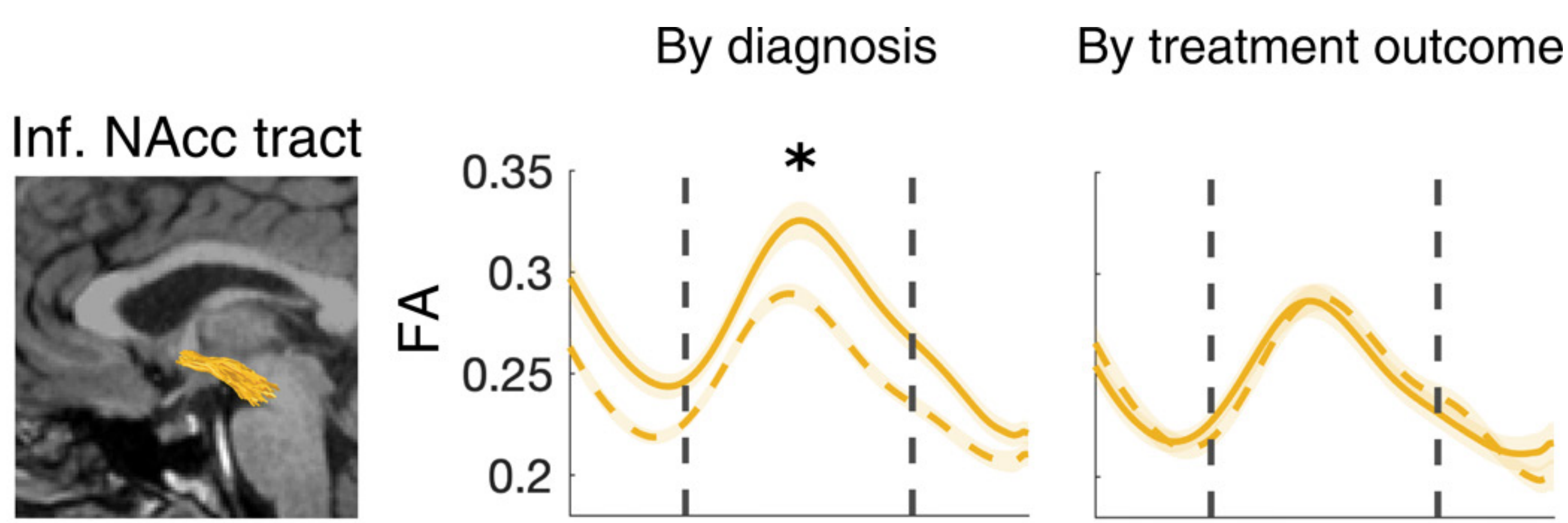
VTA-NAcc tract correlates with less impulsivity



MacNiven, Leong, & Knutson (2020) Science Advances

VTA-NAcc tract and trait impulsivity both predict stimulant use disorder





MacNiven, Leong, & Knutson (2020) Science Advances

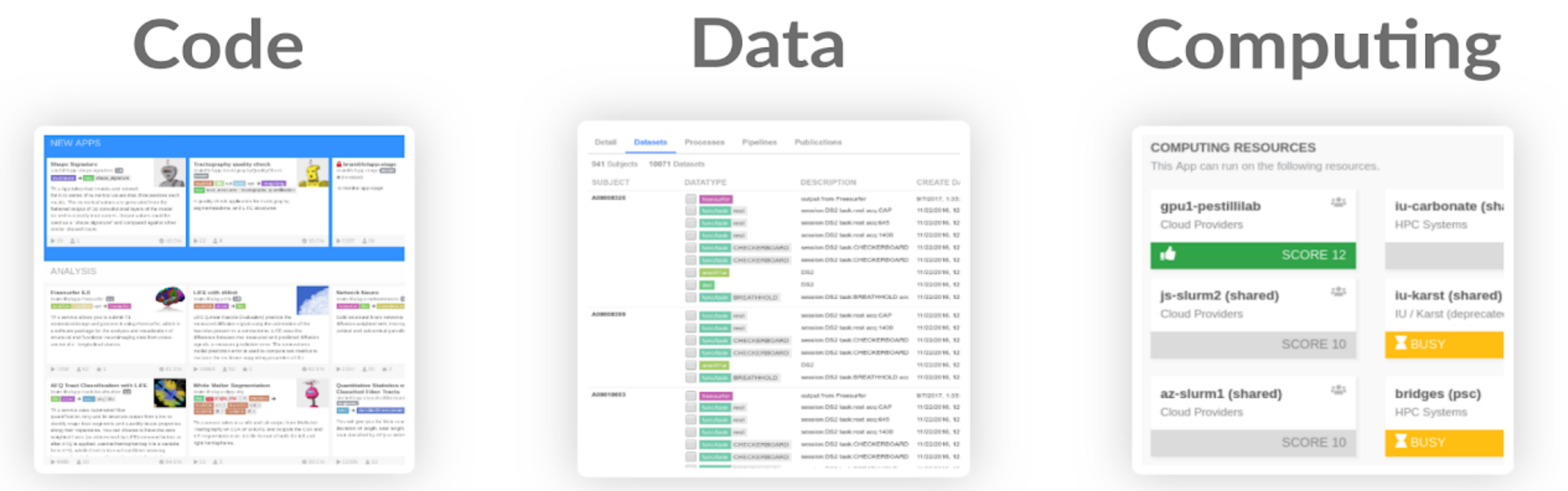
Adolescent brain development

- how to scale methods to large public datasets?
- Adolescent Brain Cognitive Development (ABCD) study
  - >10,000 subjects
  - 10-year longitudinal study
  - multimodal neuroimaging, genetics, behavior
- how to increase transparency and reproducibility of neuroimaging analyses?

Leong et al (in press) Developmental Cognitive Neuroscience

brainlife.io

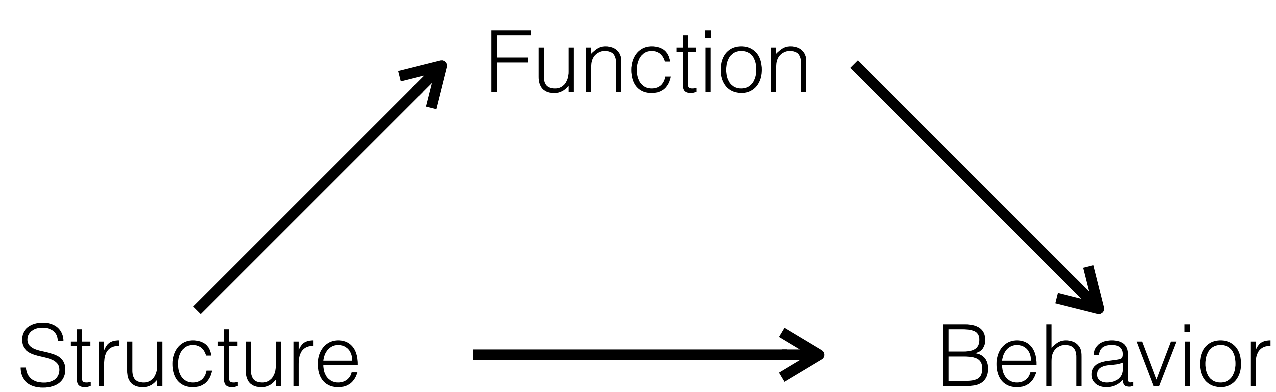
- neuroimaging analyses in internet web browser
- saves data provenance (hardware and software)
- free compute (campus clusters / cloud providers)



Summary

- Saw and measured the AIns—NAcc and VTA-NAcc tracts for first time in humans

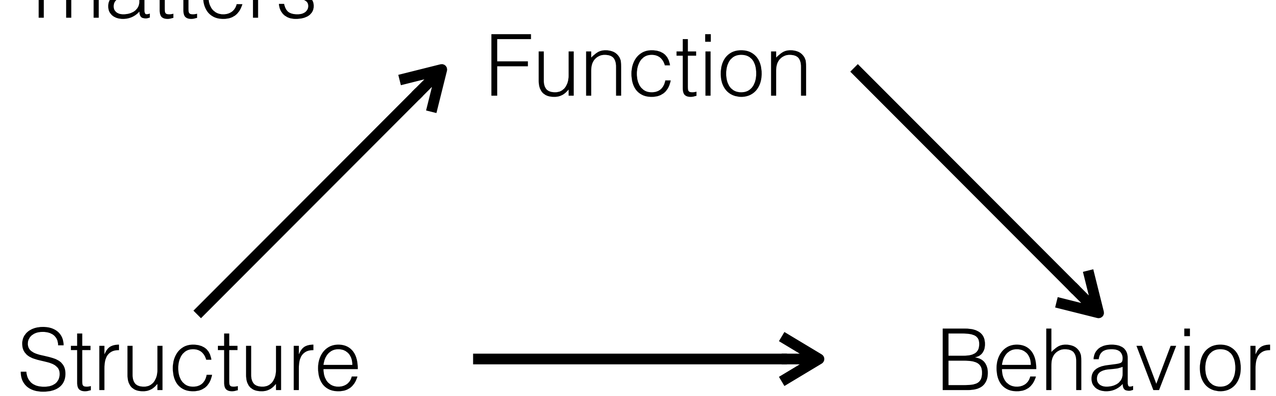
- Linked tract structural coherence to functional activity and incentivized inhibition behaviors



- Patients who abused stimulant drugs had less coherent tracts

Summary

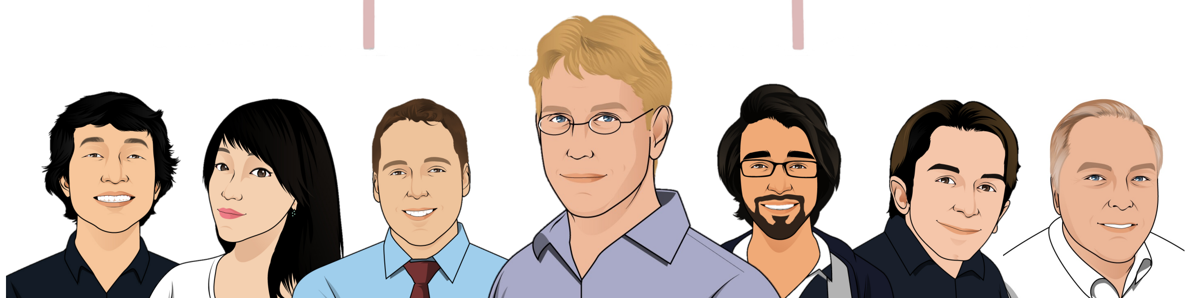
- Saw and measured the AIns—NAcc and VTA-NAcc tracts for first time in humans
    - measurement matters
- Linked tract structural coherence to functional activity and incentivized inhibition behaviors
    - anatomy matters



- Patients who abused stimulant drugs had less coherent tracts
    - reliable brain measures might predict real life outcomes

Thank you! Questions?

spanlab
NEURO-AVENGERS



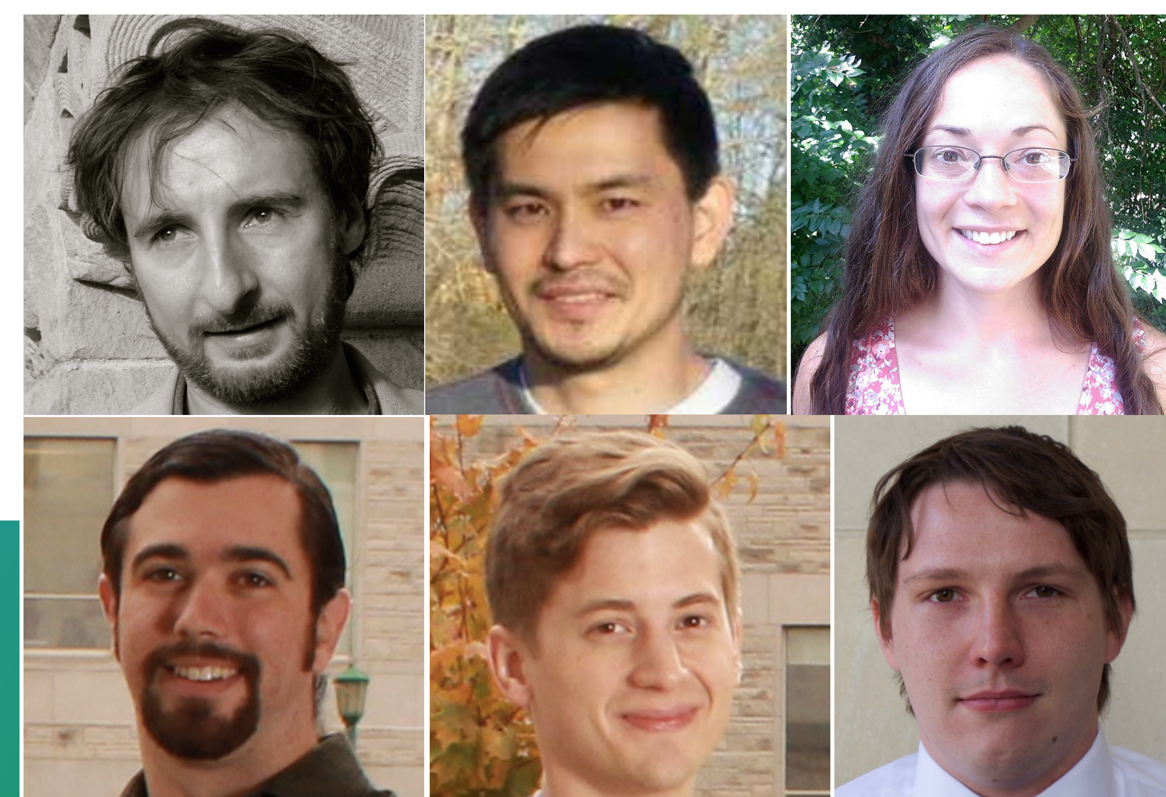
brainlife.io

Funds

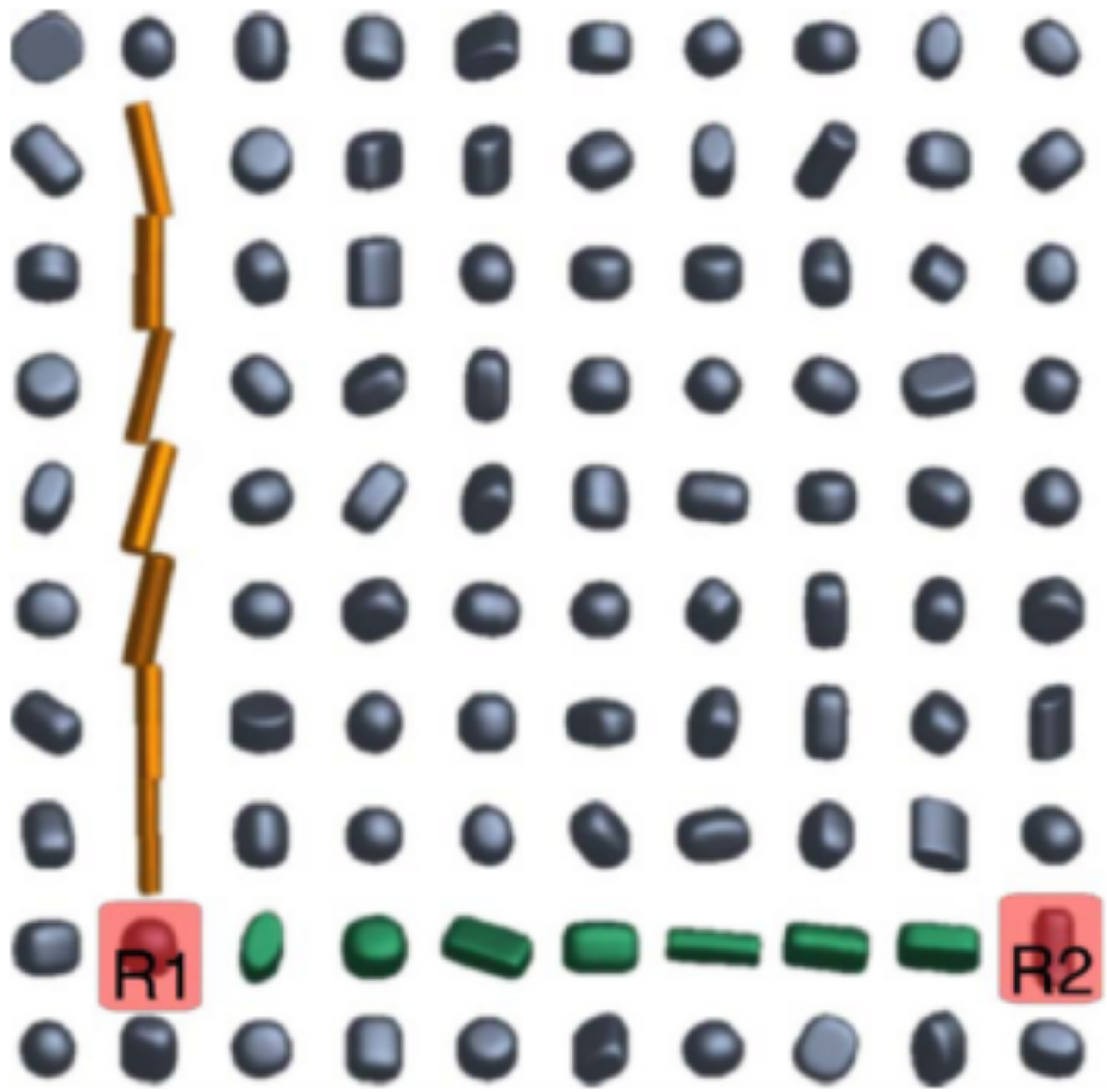
UArk Chancellor's Office
IU Pervasive Technology Institute
Stanford NeuroChoice Initiative
NIMH Affective Science Program

Code

github.com/fullstackneuro
github.com/spanlab
github.com/vistalab

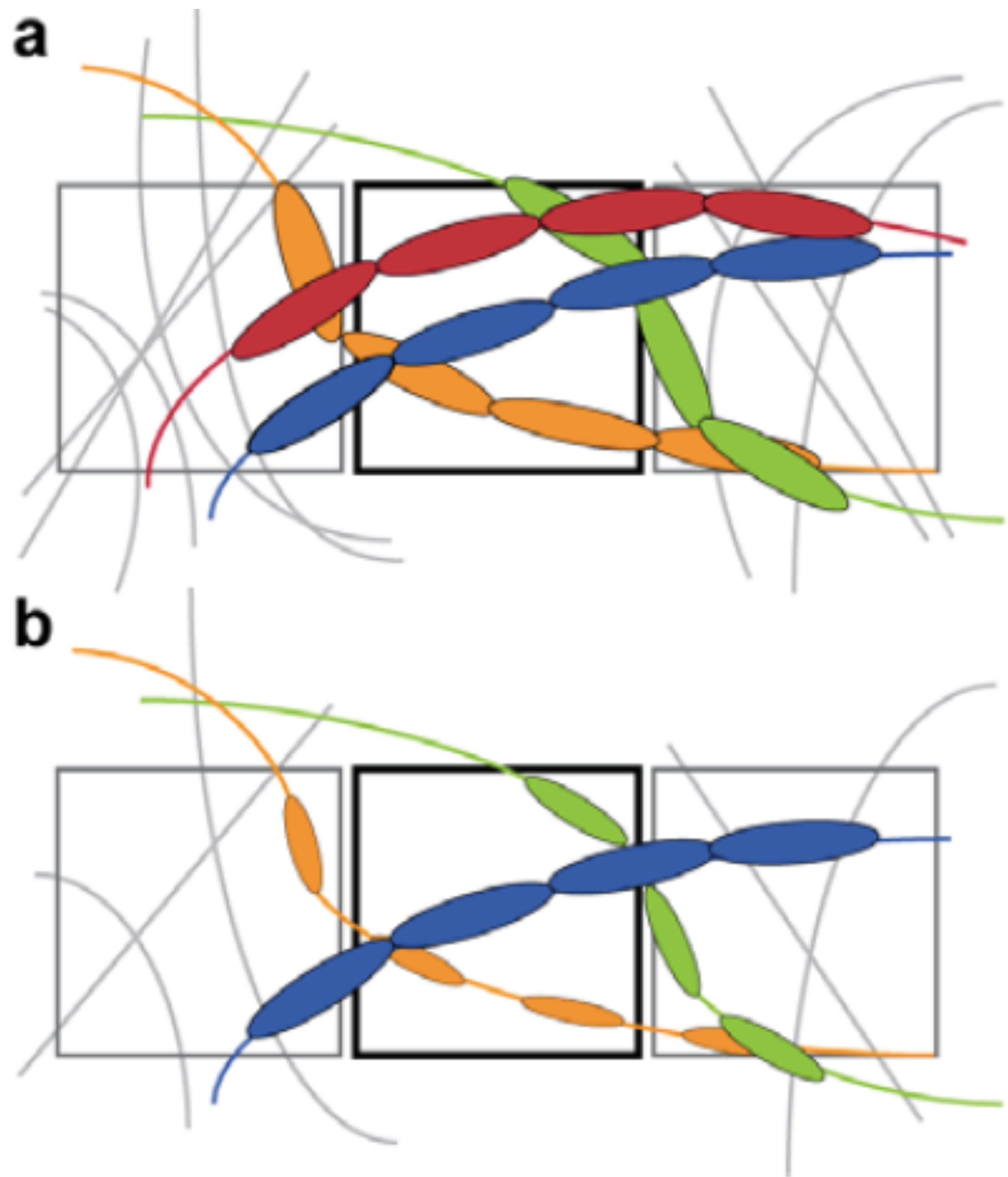


Probabilistic tractography



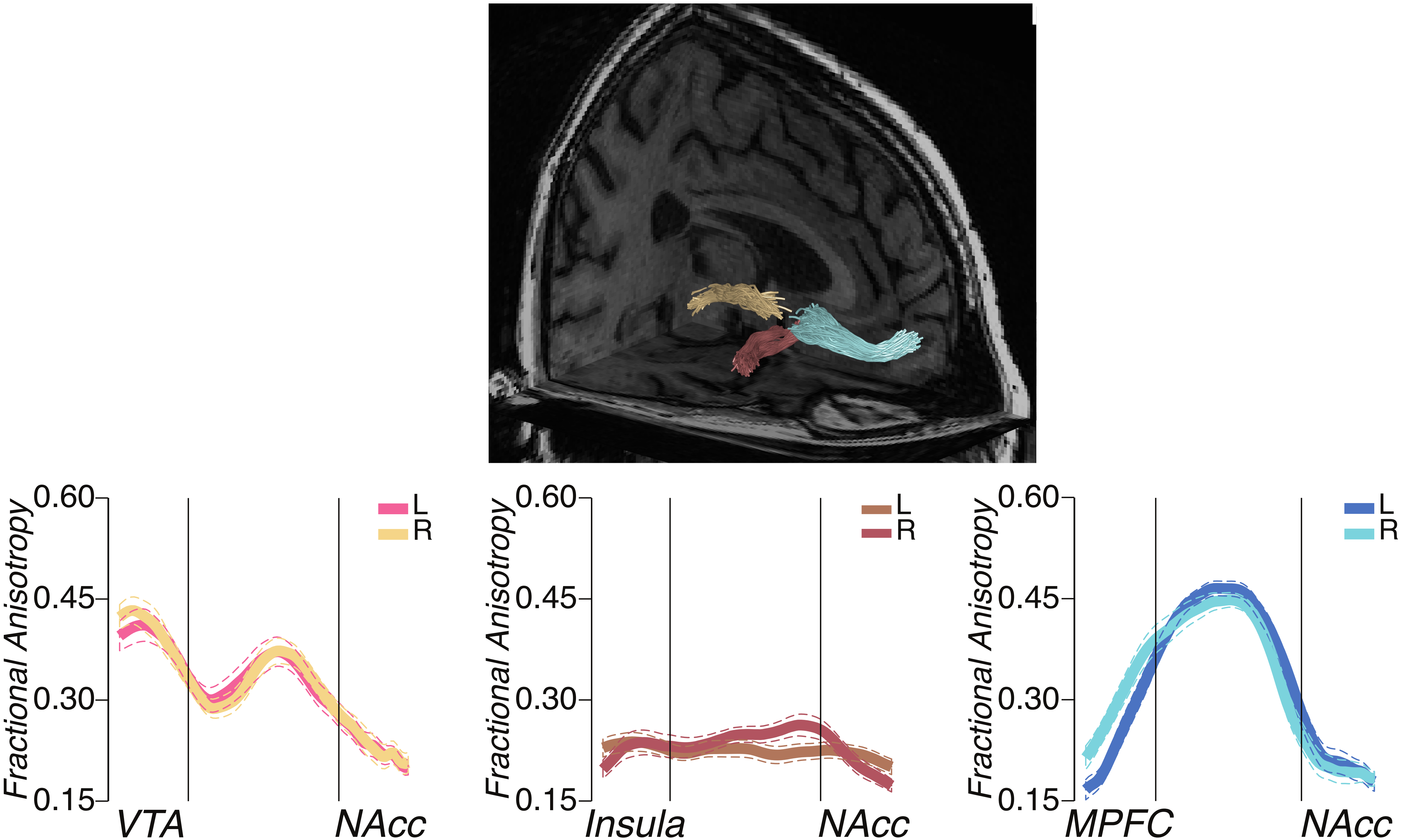
Tournier et al (2007), NeuroImage; Sherbondy et al (2012)

Improve tract coherence measures?



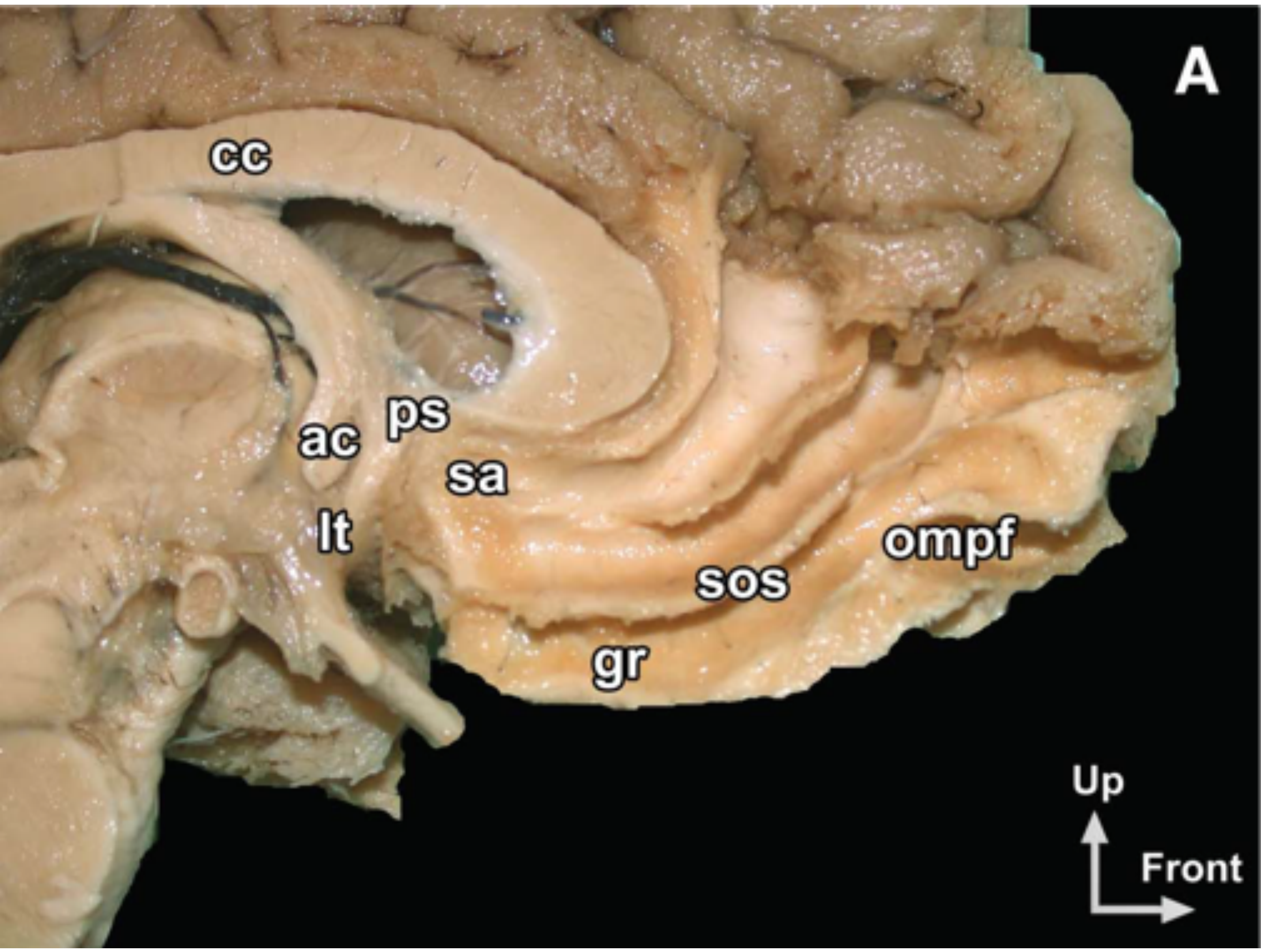
Pestilli et al (2014), Nature Methods

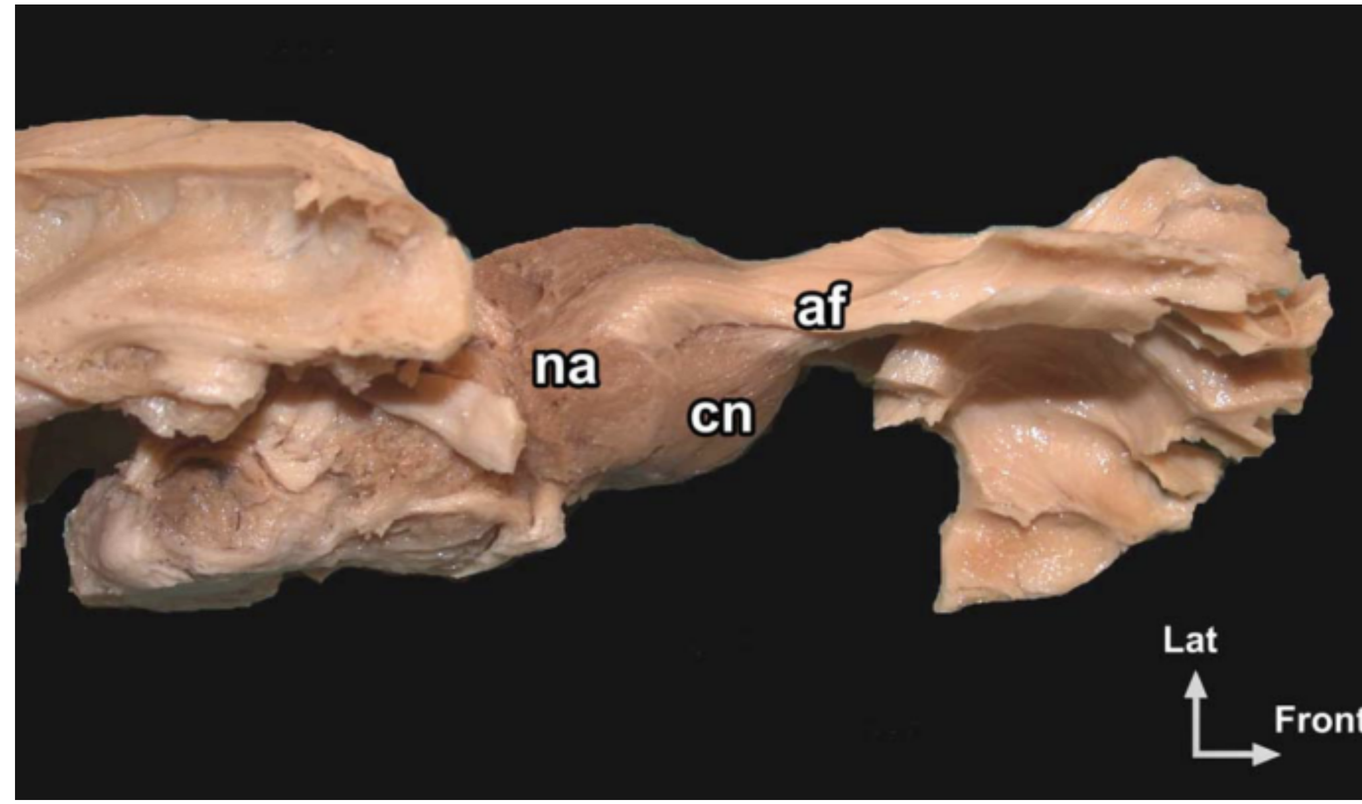
Control tracts: MPFC & VTA—NAcc

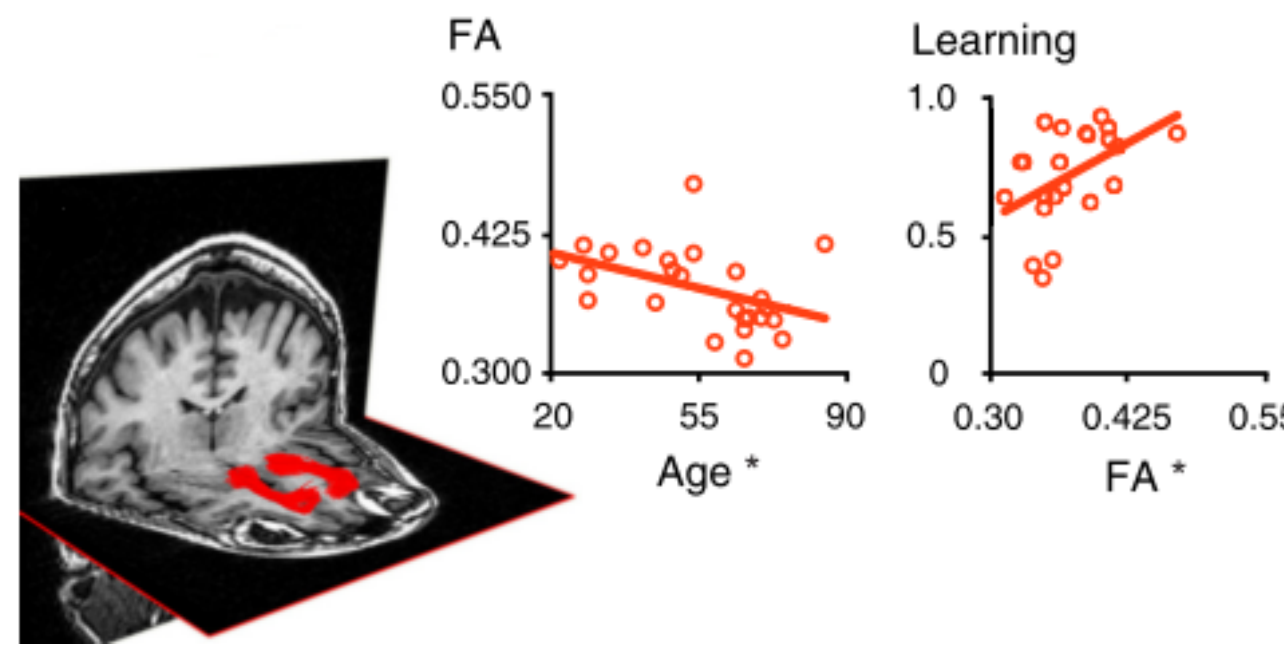


Leong et al (2016), Neuron

MPFC—NAcc replication

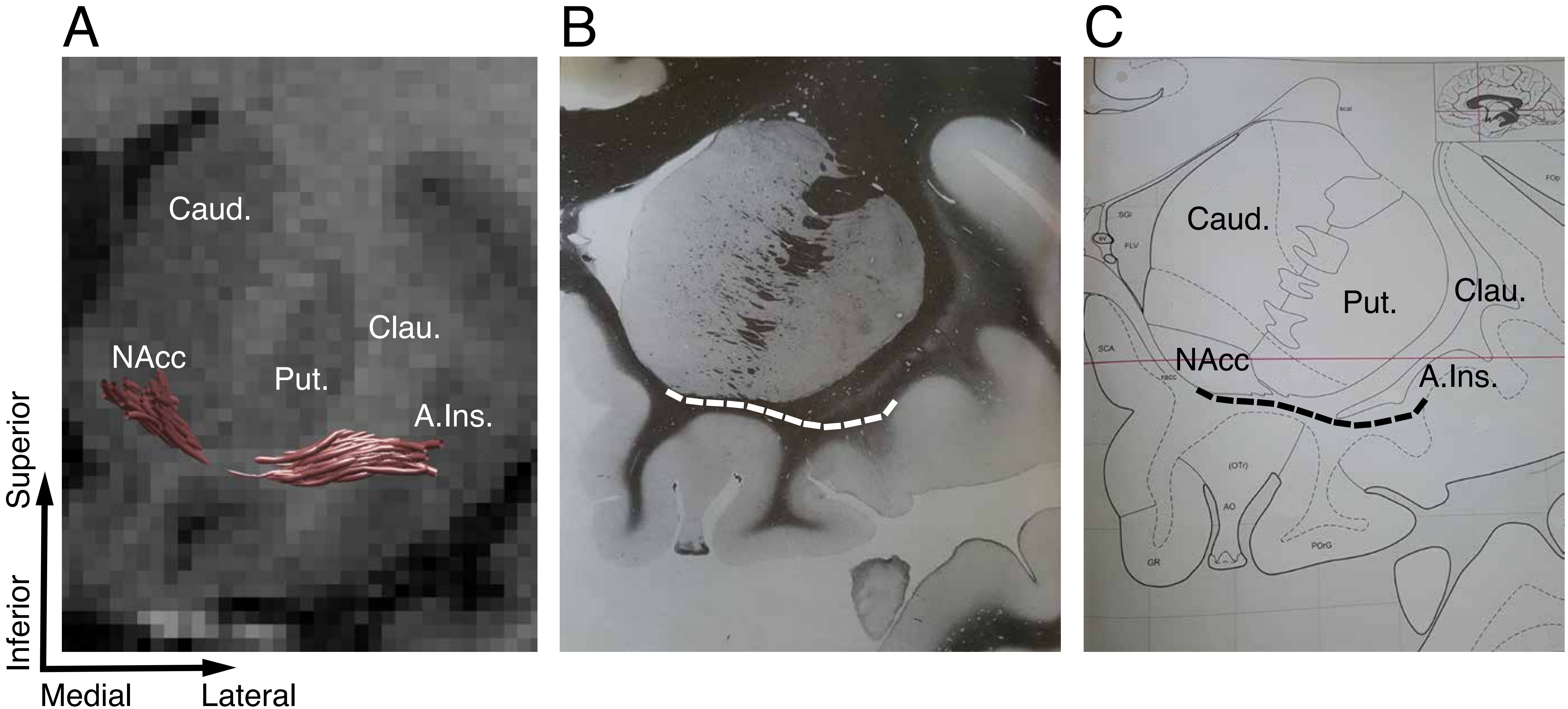






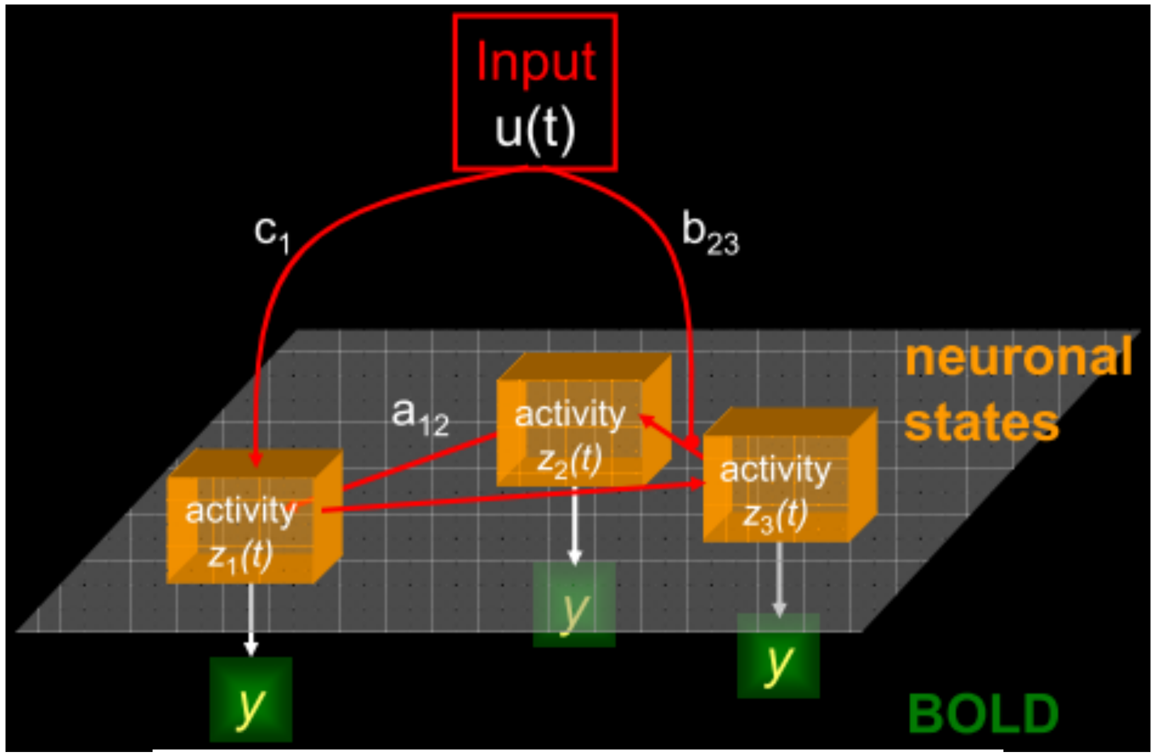
Rigoard et al (2011), J Neurosurg; Samanez-Larkin et al (2012), J Neuro

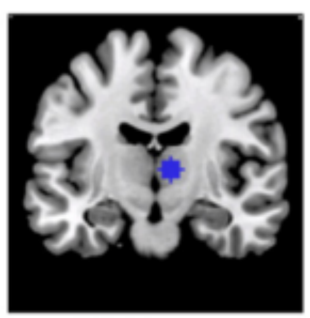
Compare with atlas



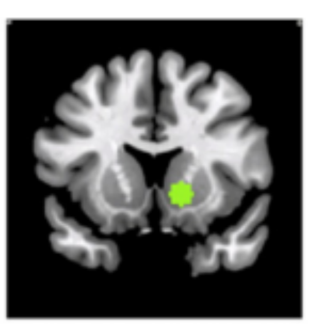
Leong et al (2016), Neuron

"Effective connectivity"

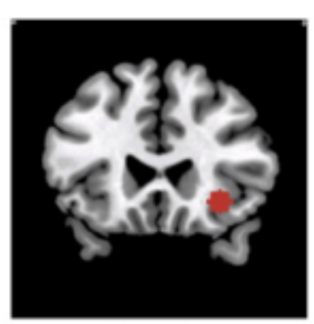




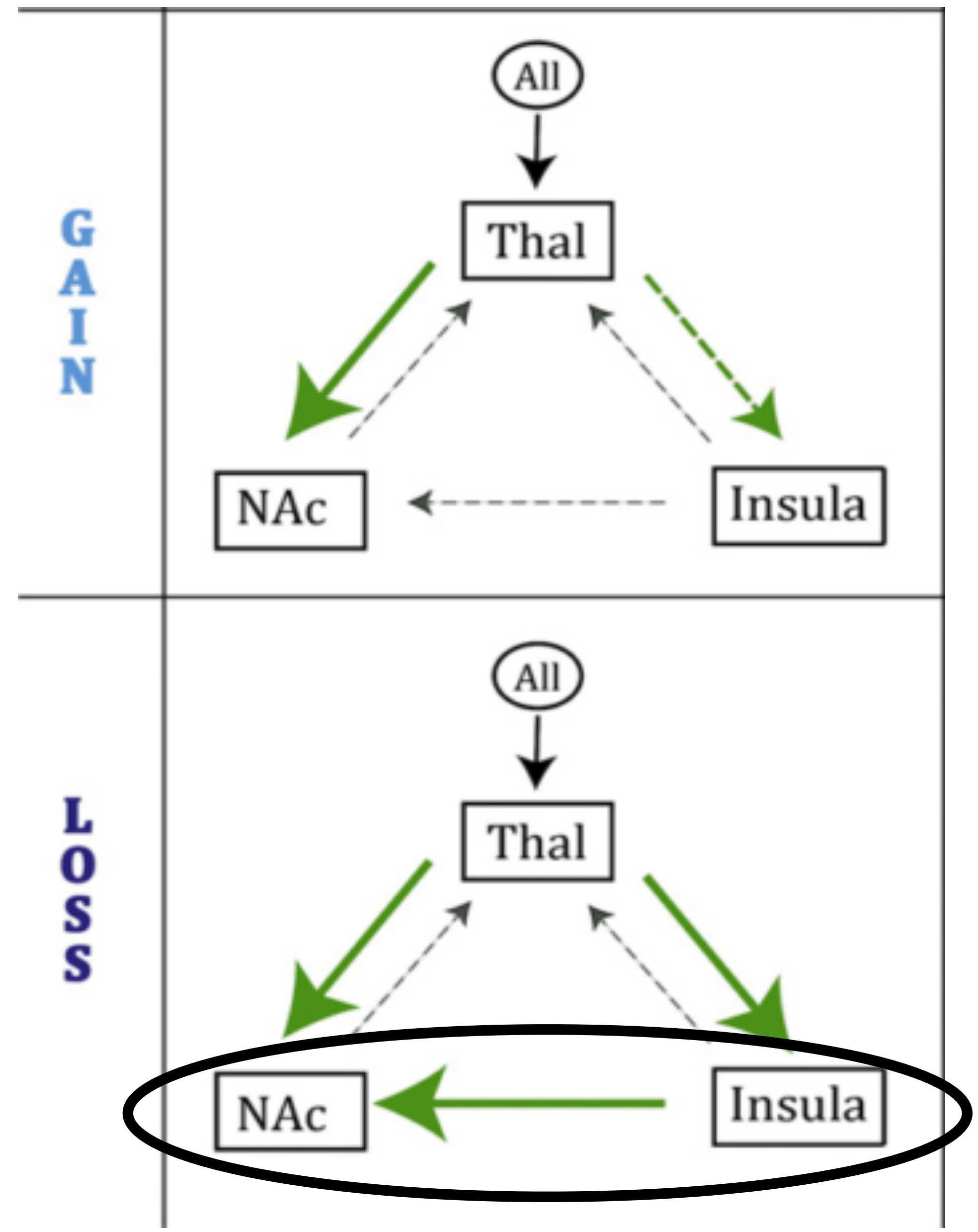
Thalamus
(8, -12, 6)



Nucleus Accumbens
(14, 14, -4)



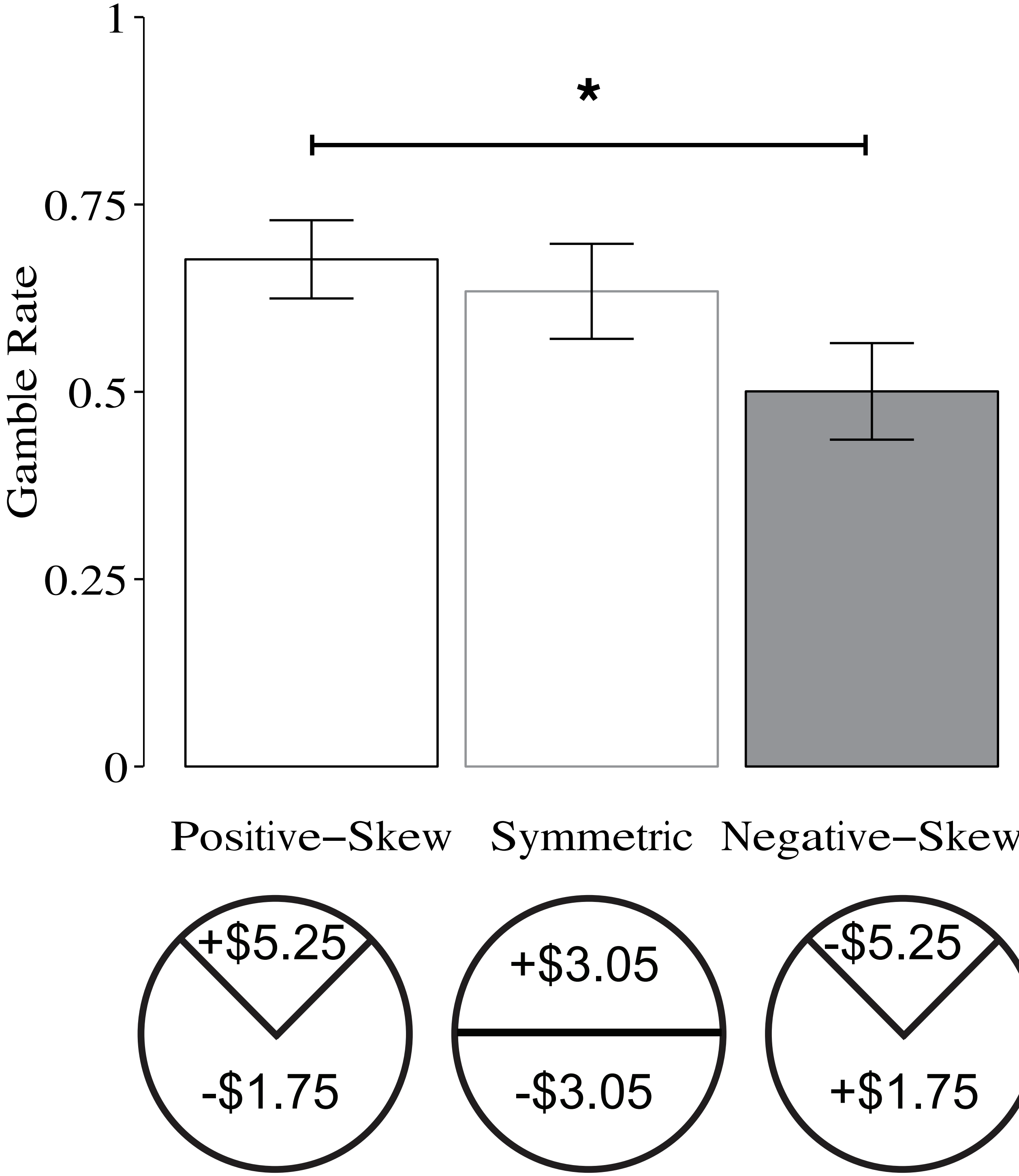
Insula
(32, 24, -8)

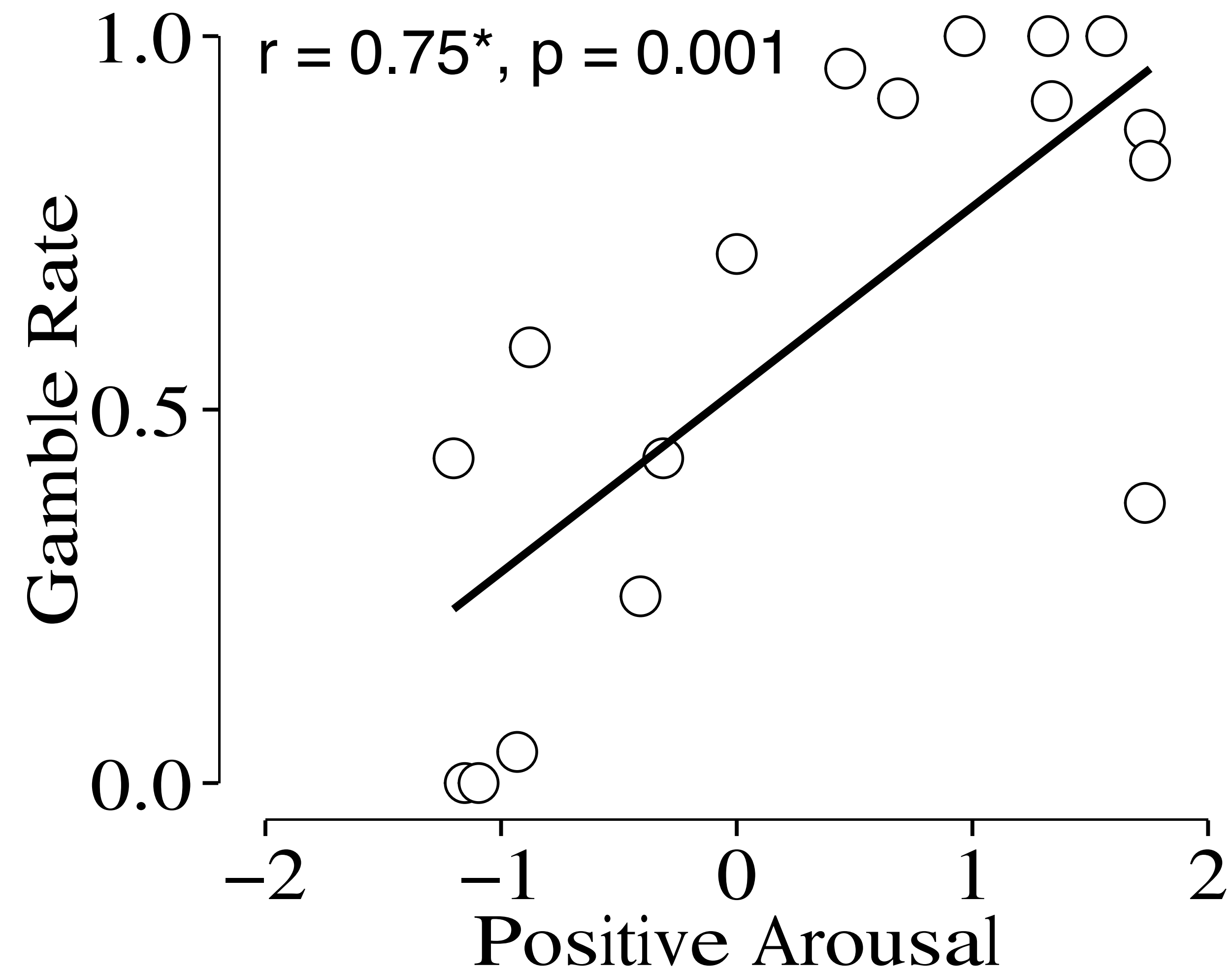


Friston (2002); Cho et al (2012), NeuroImage

Gambling and affect

Positive arousal correlates with positive-skew gambling



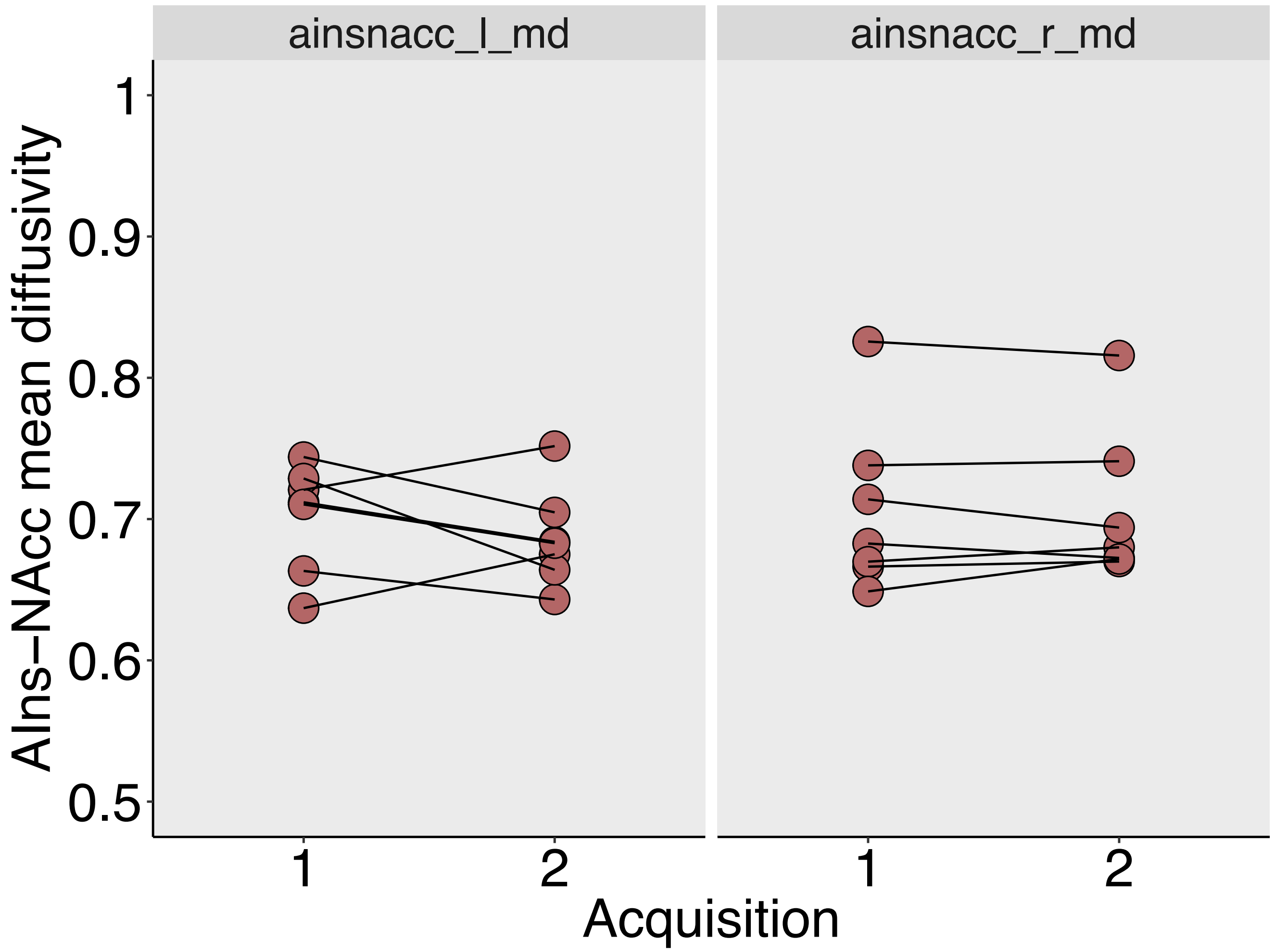


Positive Arousal =
(Valence + Arousal) / $\sqrt{2}$

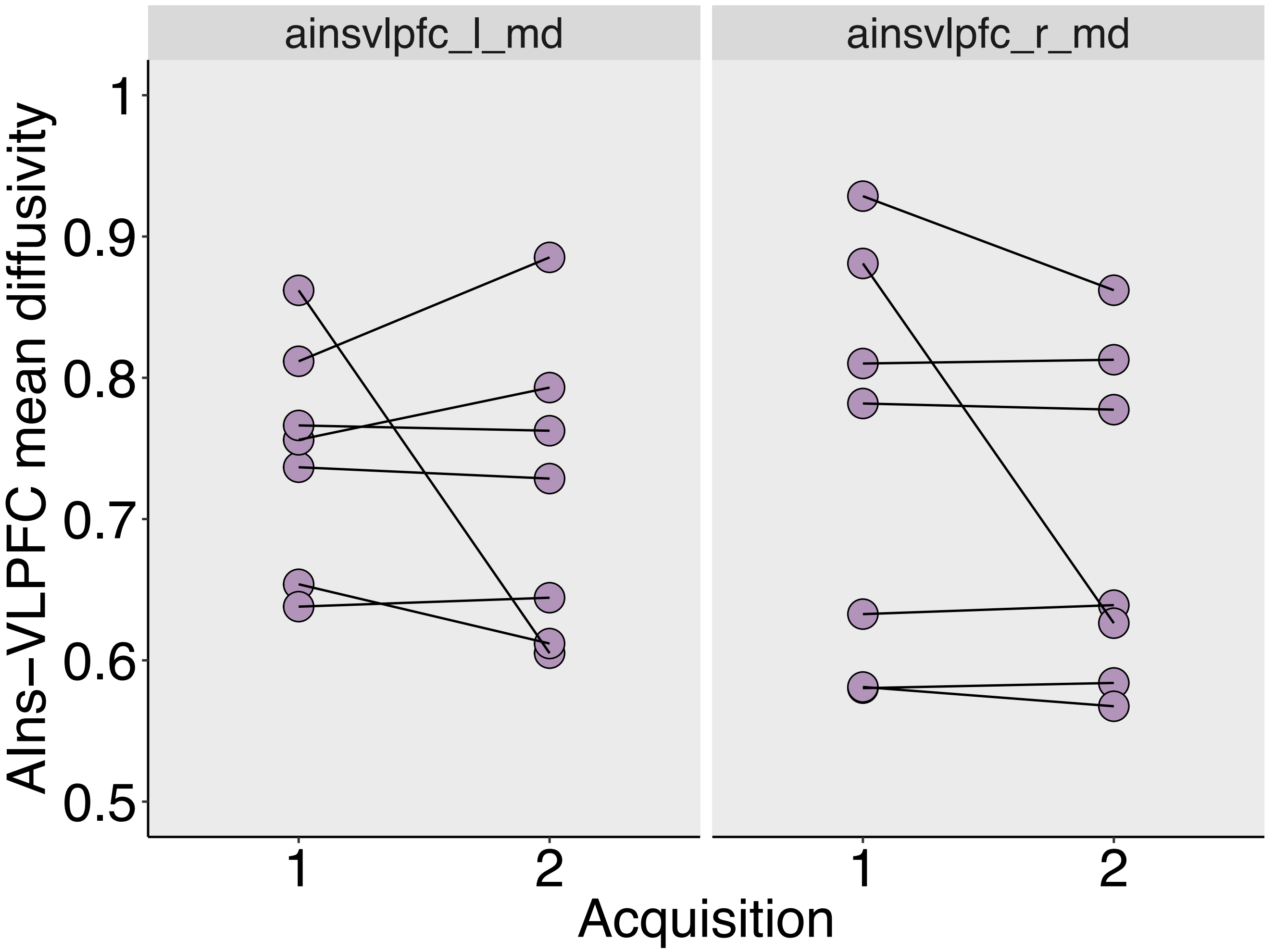
*$p<0.05$

Test-retest reliability of tract measures (mean diffusivity)

- "measure twice, cut once"

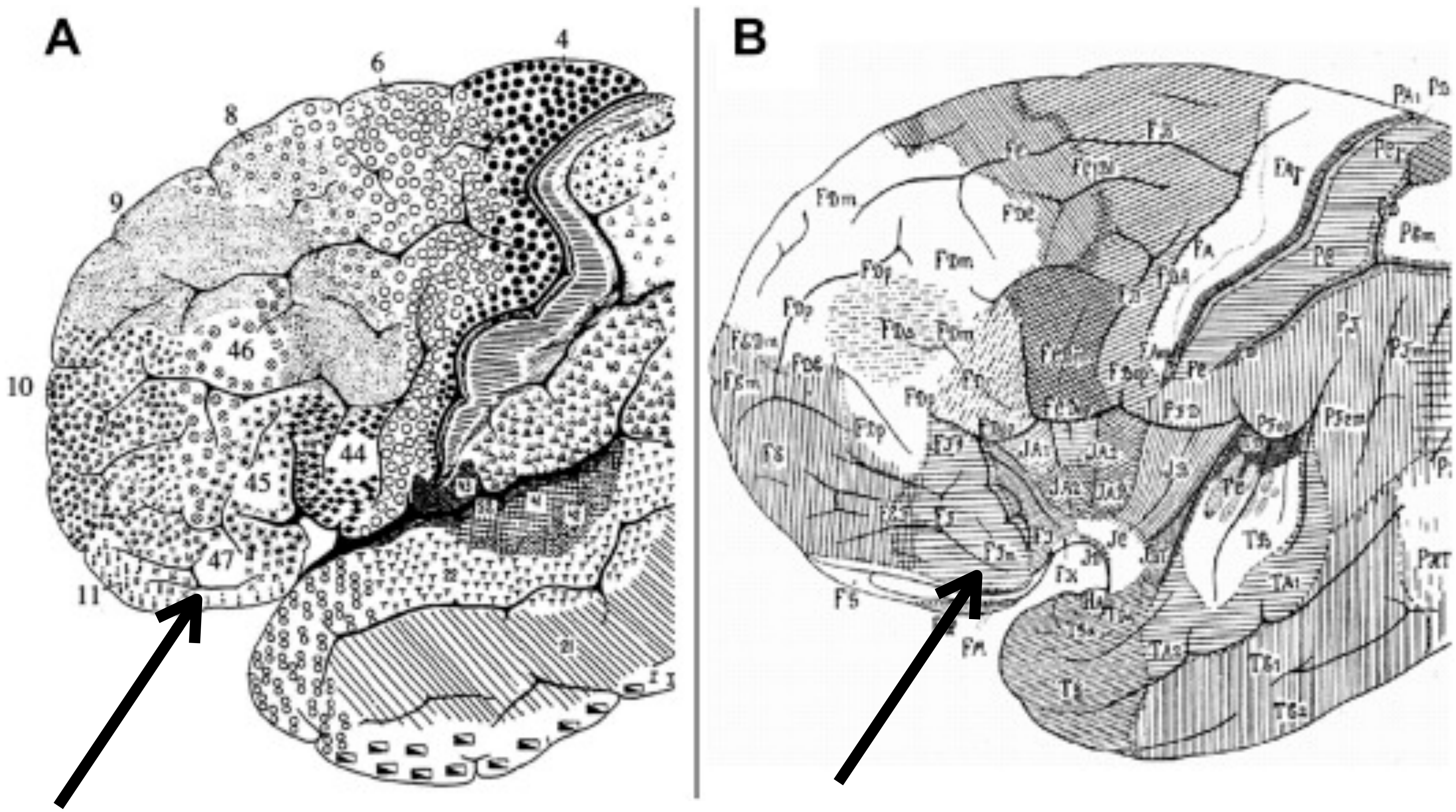


Right: ICC2k = 0.99, p < 0.001
Left: ICC2k = 0.63, p = 0.12



Right: ICC2k = 0.84, p < 0.05
Left: ICC2k = 0.52, p = 0.21

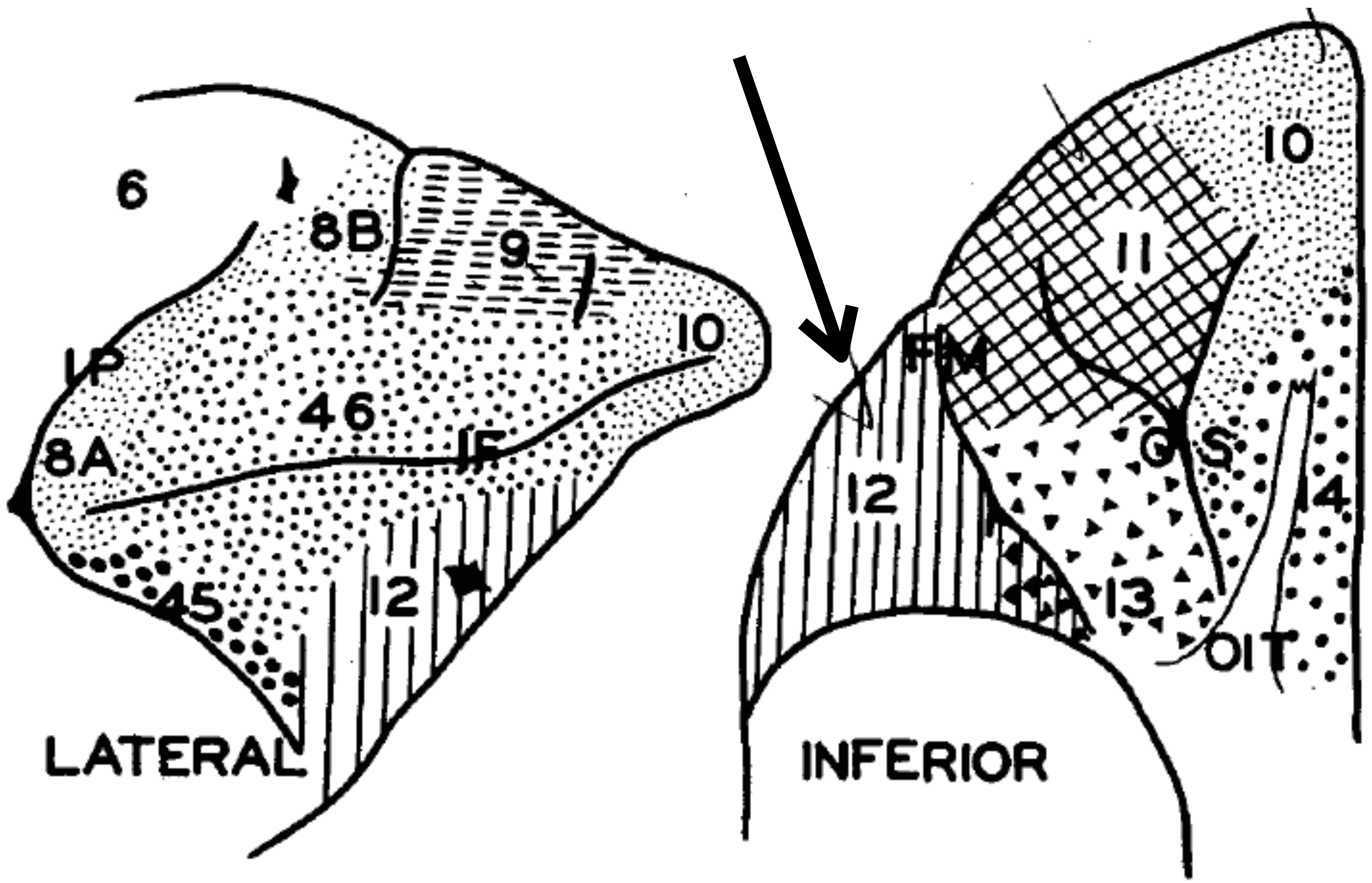
Mapping ventrolateral PFC



Brodmann area 47 (1909)

Economo and Koskinas
"FE" (1925)

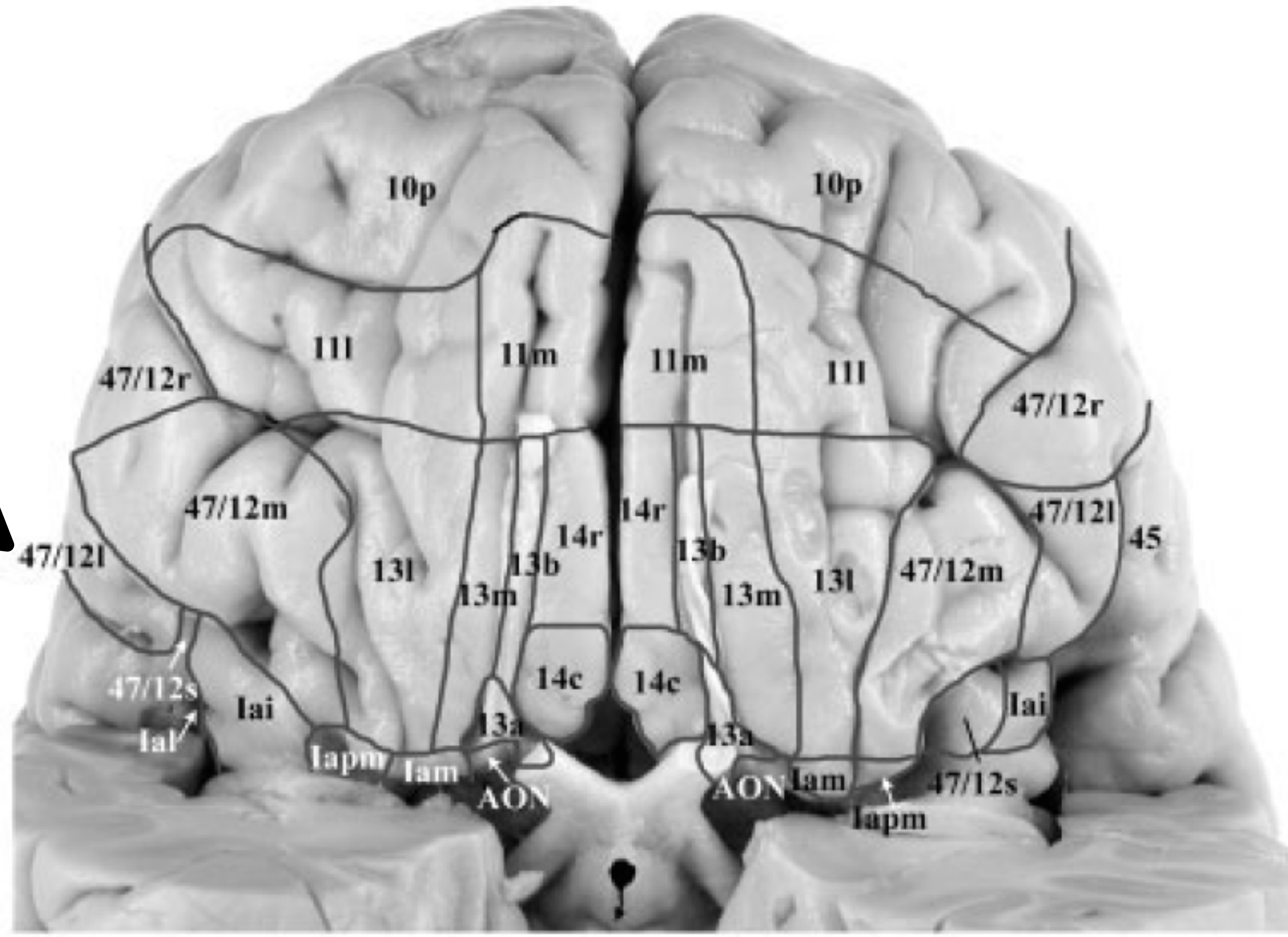
Mapping ventrolateral PFC



Walker mistook it for area 12 (1940)

Area 47/12 or ventrolateral PFC

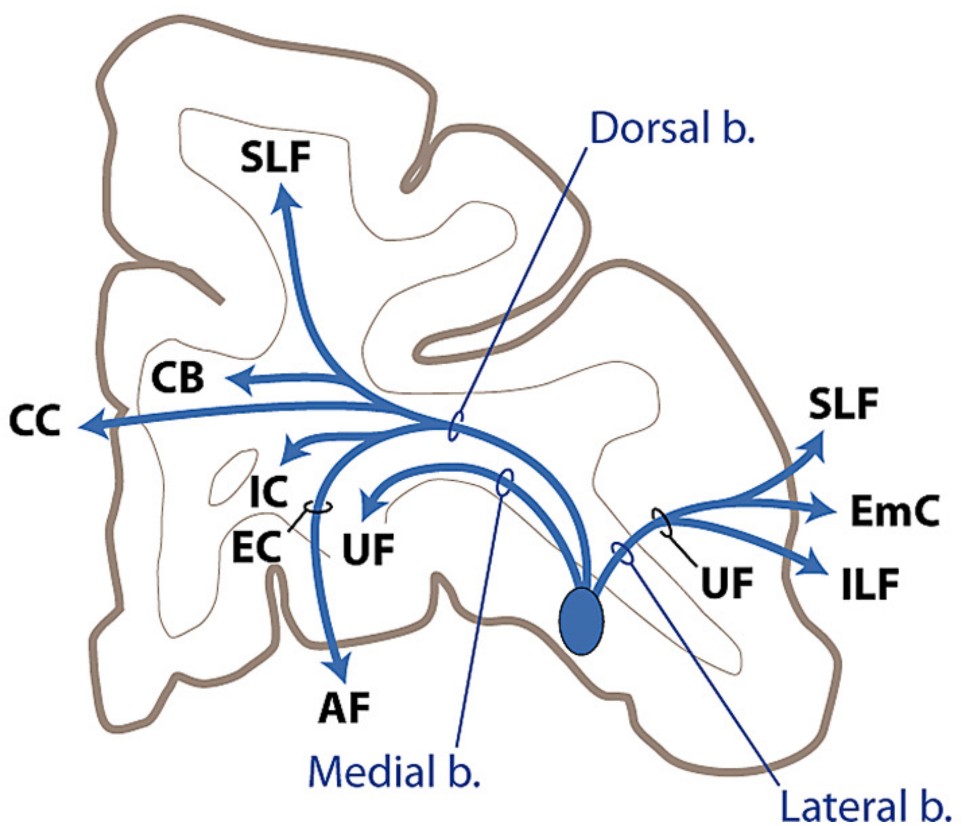
“47/12”
VLPFC

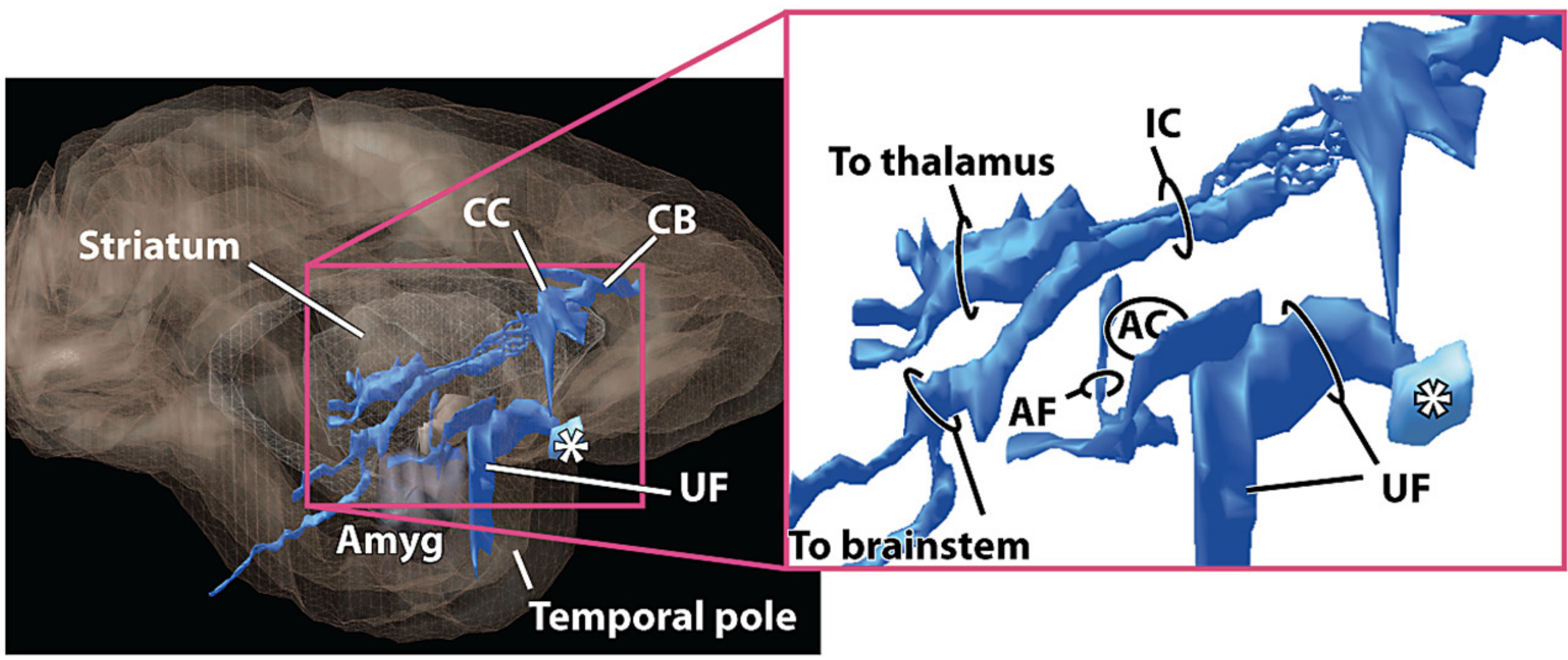


Petrides & Pandya (1994); Ongur et al (2003)

Guidance from monkey research

“Axons from the lOFC include the UF fibers traveling to the temporal cortex and those that enter the EmC to terminate in the insula.”





Lehman, Haber, et al (2011), J Neuro