

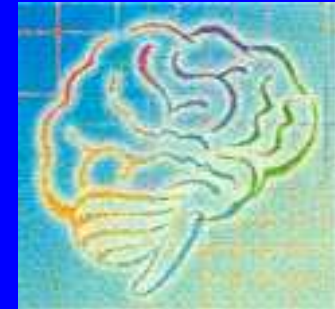
Adolescent Brain and Behavior: Impulsive or Risky?

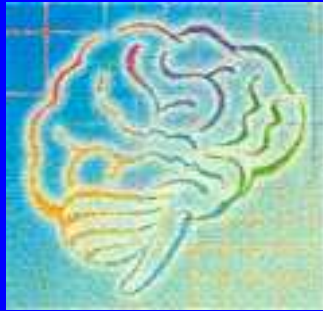
BJ Casey, Ph.D.,
Sackler Professor and Director

Sackler Institute for Developmental Psychobiology

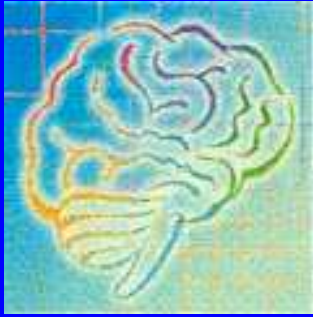


*Weill Medical College
of Cornell University*





*Sackler Institute for Developmental Psychobiology
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Key Take Home Points

- 1) Brain regions have different developmental courses that may influence or bias behavior.
- 2) Individual differences in development of these brain regions may put some teens at greater risk for substance abuse.

Suggests developmental windows of vulnerability that may be exacerbated by biological predispositions.

Brain Development from Conception to Adulthood

(based on post mortem human and animal studies)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Overarching Question

How is the brain changing with development that may explain behavioral changes and enhanced vulnerability to substance abuse during adolescence?

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Cornerstone of Behavioral Development

Ability to suppress inappropriate thoughts and actions in favor of goal oriented ones **especially in the presence of incentives.**

Delay of Gratification



Impulsivity or Reward Bias?

Mischel et al *Science*

MEASURE OF IMPULSIVITY IN THE LAB (Go/Nogo Task: Wack the Mole)

There is a sneaky mole digging up the garden. Your job is to bop him on the head to save the garden.

GO



NOGO





















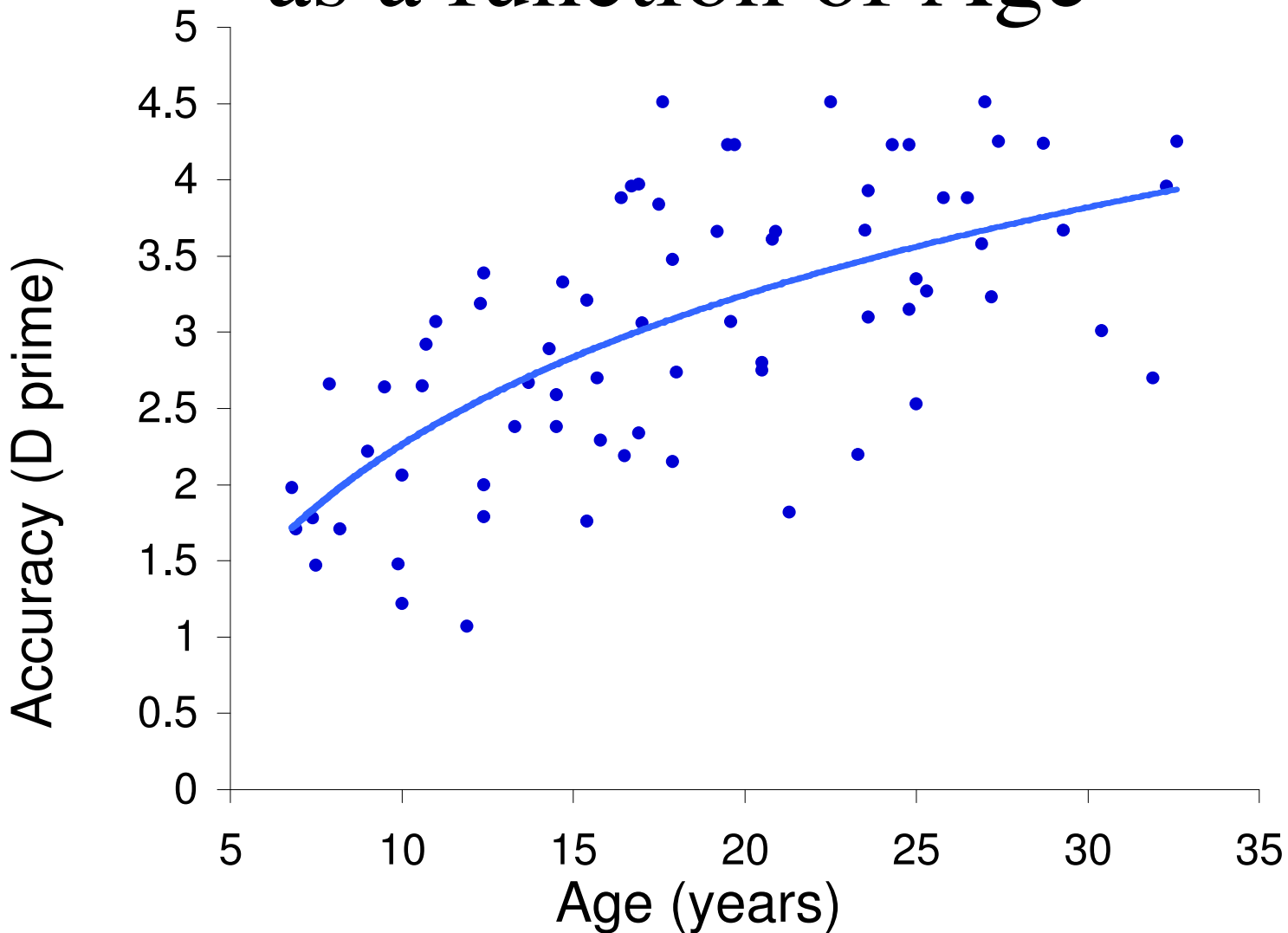








Impulse Control as a function of Age

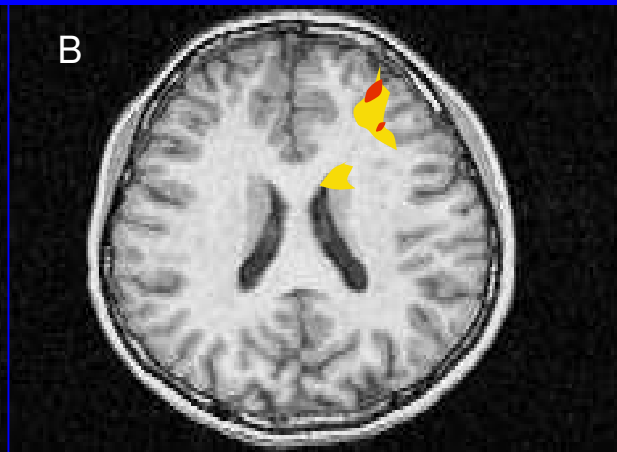


Hare et al 2007

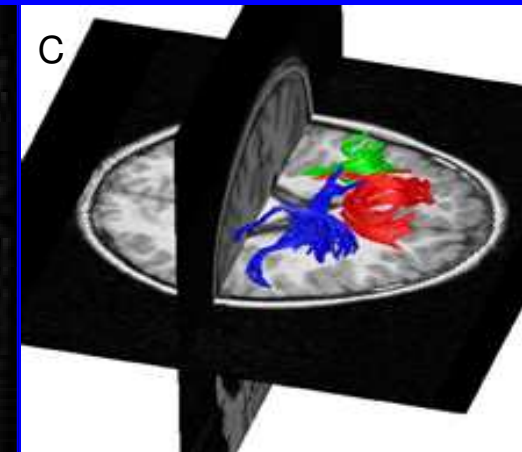
Measuring Changes in the Developing Human Brain with Magnetic Resonance Imaging (MRI)



Structural MRI to track changes in size and shape of neuroanatomical structures with development

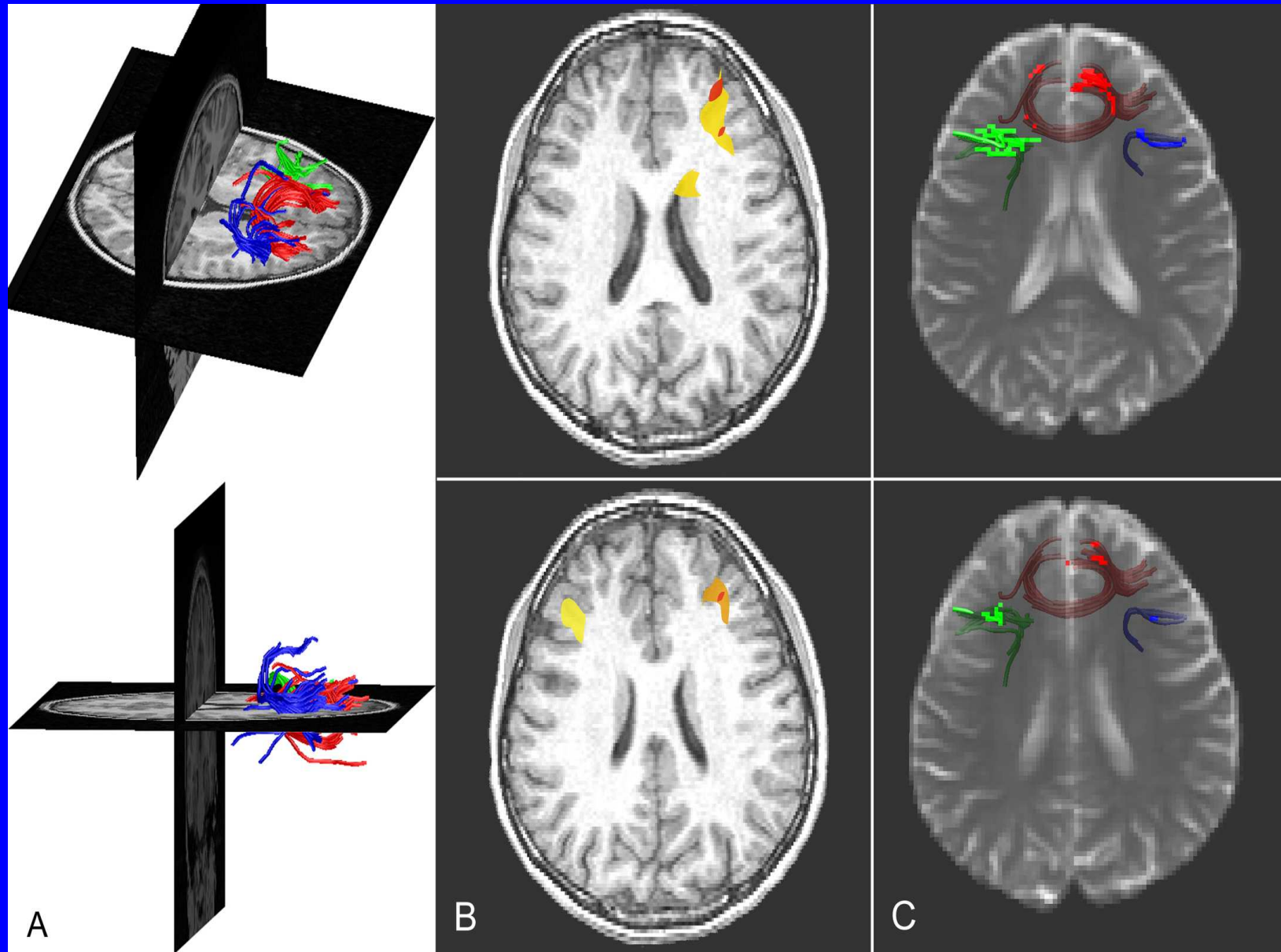


Functional MRI (fMRI) to track changes in brain and behavior with development

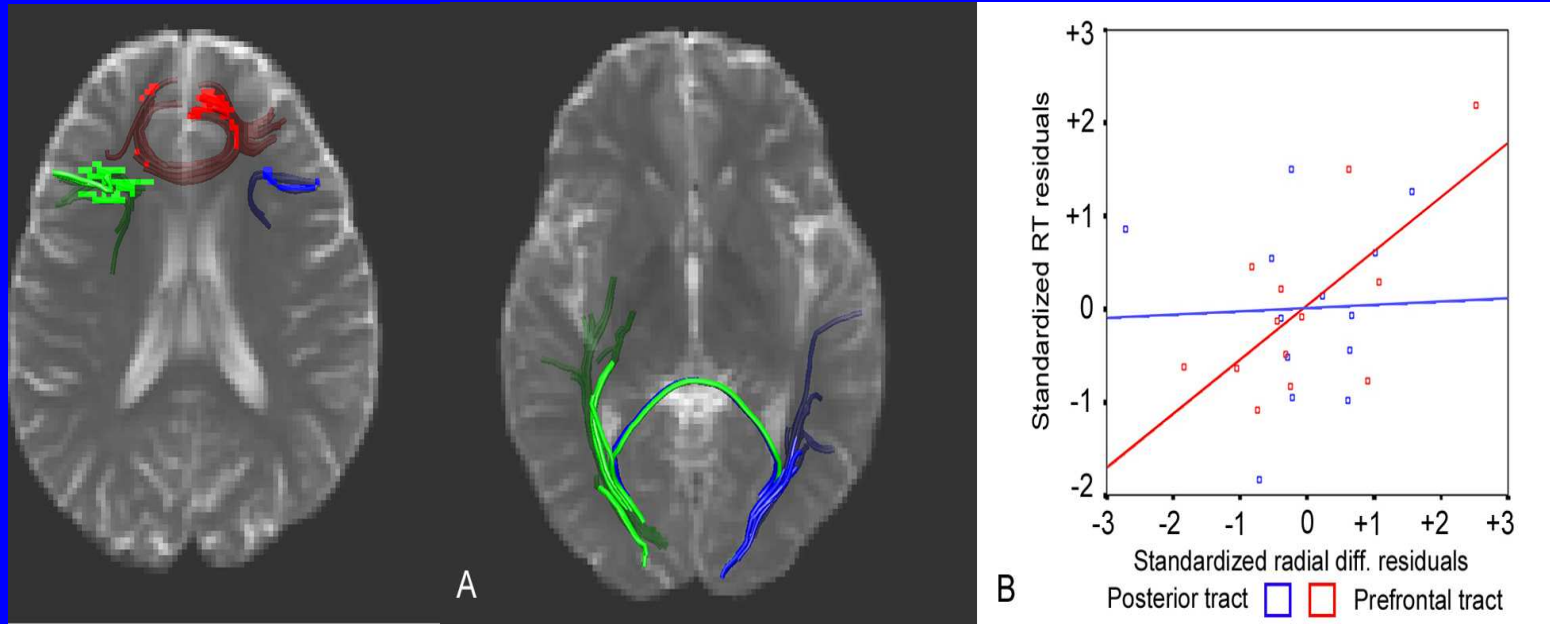


Diffusion Tensor Imaging (DTI) to track strengthening of brain connections with development

Prefrontal Circuitry involved in Impulse Control

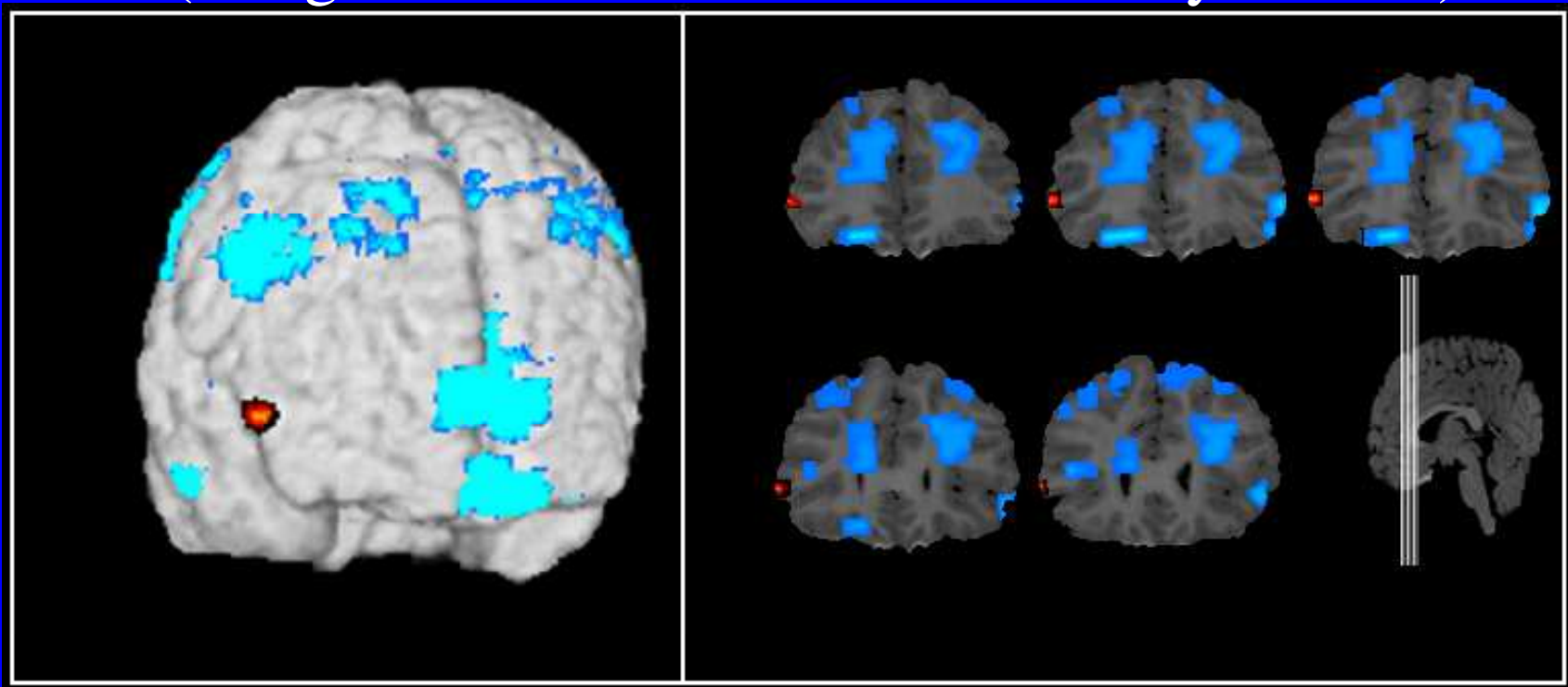


DTI-based Prefrontal Connectivity correlates with Impulse Control



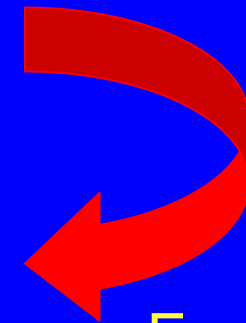
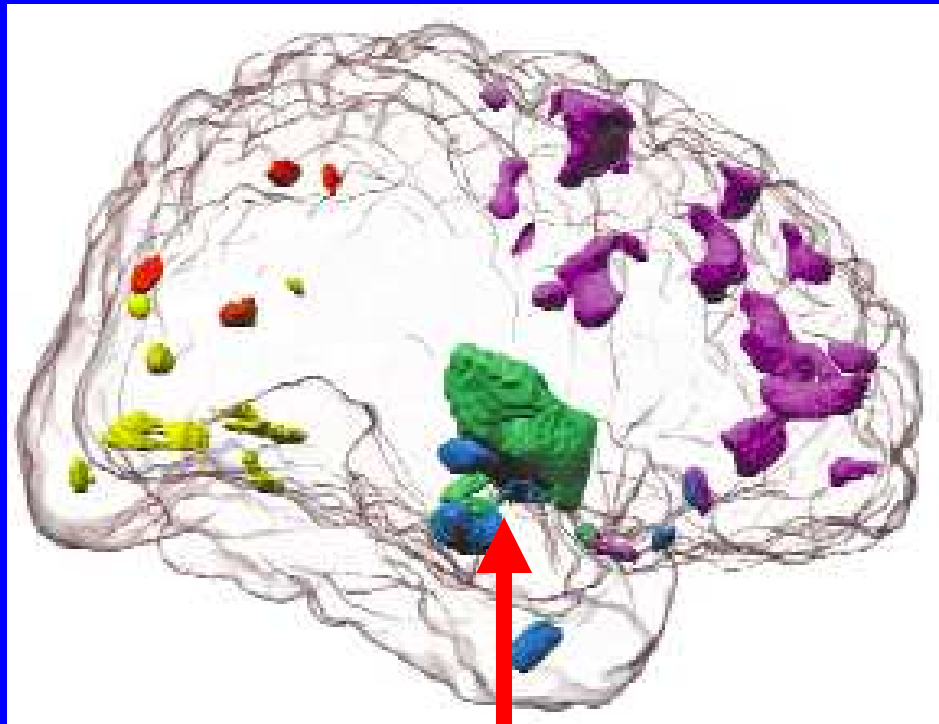
Impulse Control involves the fine-tuning of Prefrontal Cortex

(Longitudinal fMRI data from 7-14 year olds)



Cortical regions that are recruited more (in red) and less (in blue) with development

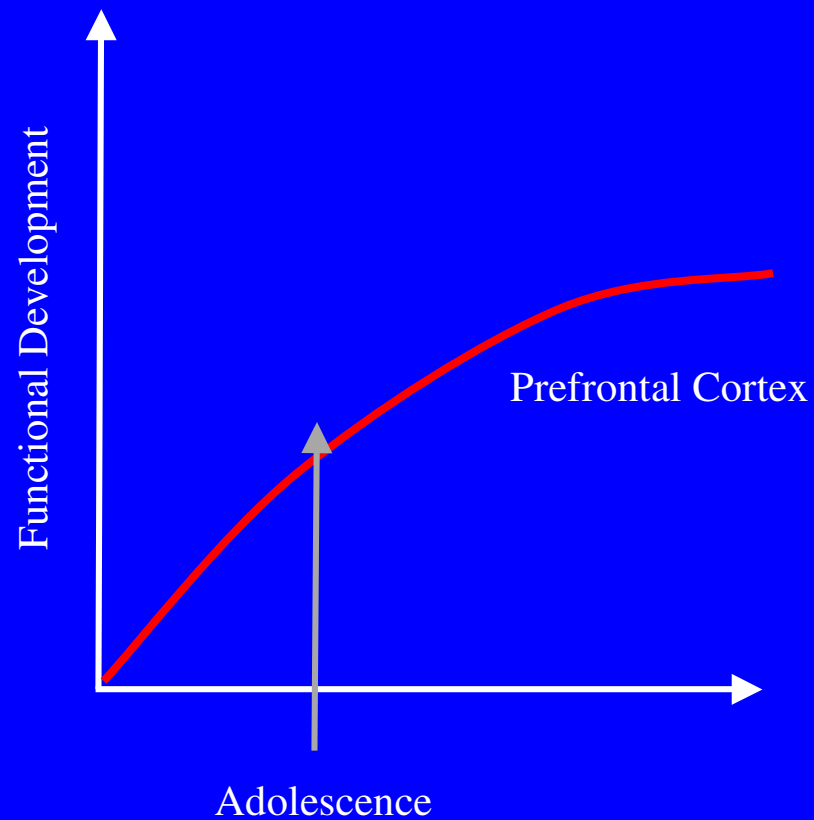
MRI Studies: Dramatic developmental changes in prefrontal and subcortical regions during childhood and adolescence



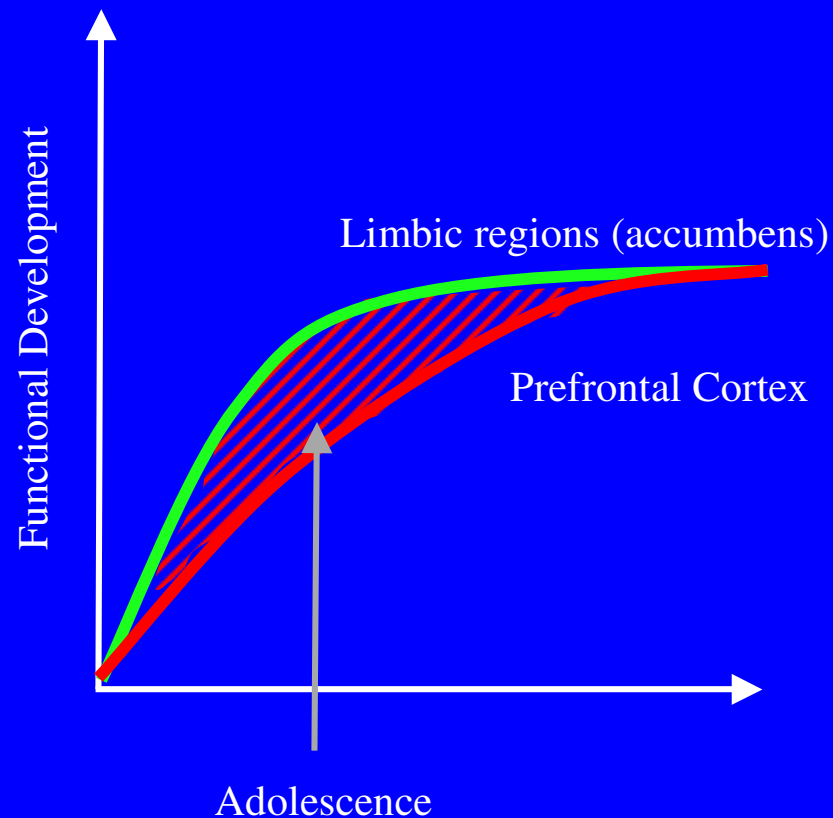
Focus has typically been on prefrontal cortex (PFC)

Subcortical limbic regions involved in desire, fight, flight.

Protracted Development of Prefrontal Control Regions alone can't explain adolescent behavior



Protracted Development of Prefrontal Control Regions Earlier Development of Subcortical Limbic Regions



Casey, Getz & Galvan, in press
Developmental Review

**How do incentives bias our behavior?
How are they represented in the brain?
How does this change with development?**



Developmental Differences in Neural Response to Incentives

- **Participant (n=37)**

12 adults, 12 teens 13 children

- **Reward Task**

Validated in Nonhuman Primates
(dopamine neuronal firing to
changes in reward magnitude)

Cue



Reward



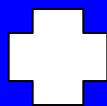
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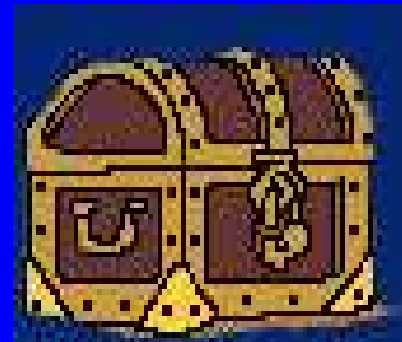
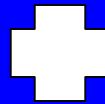
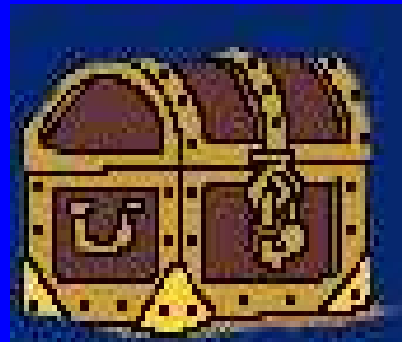
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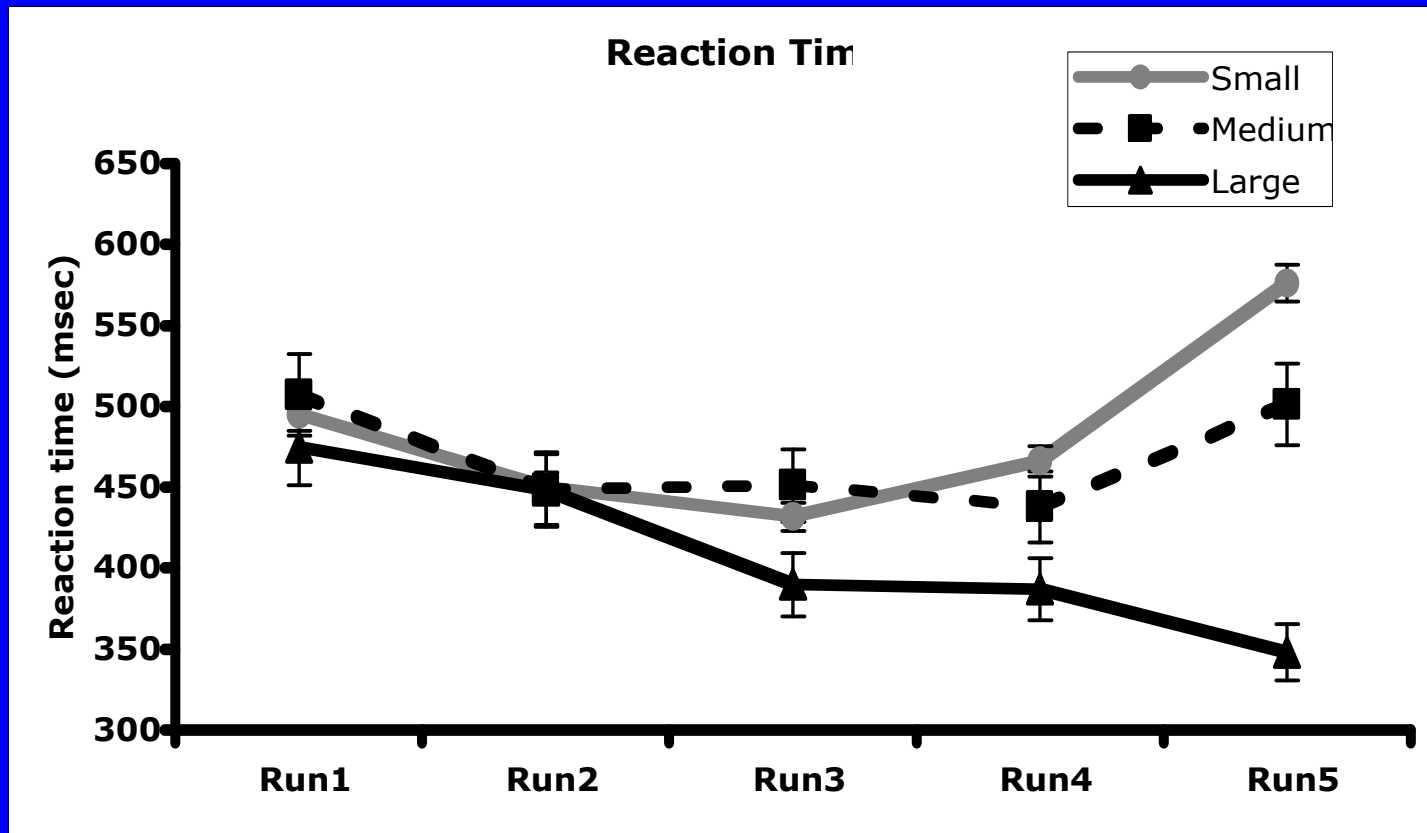








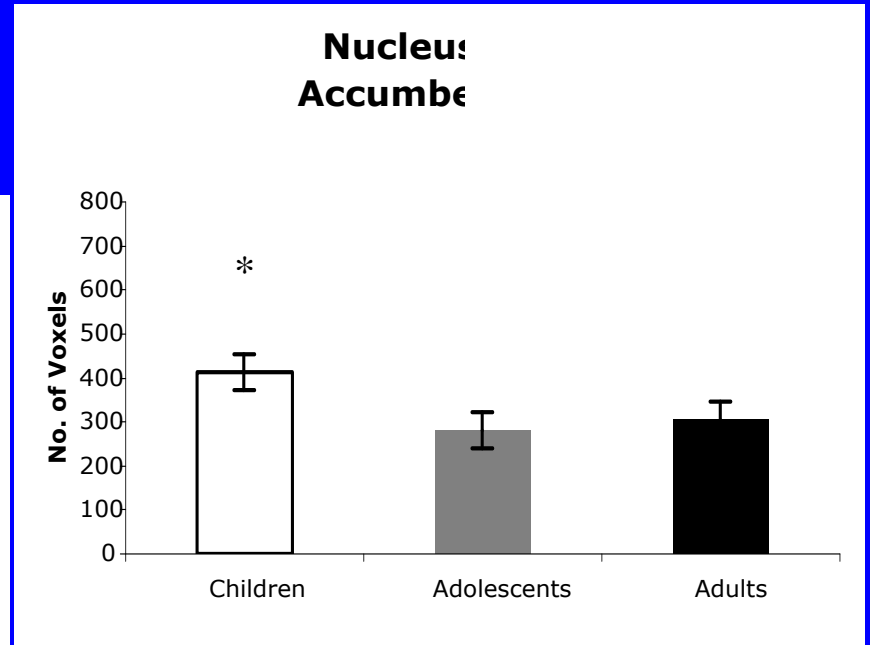
Participants are faster on trials that give the largest reward.



Developmental Imaging Results

Adolescents are similar to adults in extent of nucleus accumbens activity

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



Developmental Imaging Results

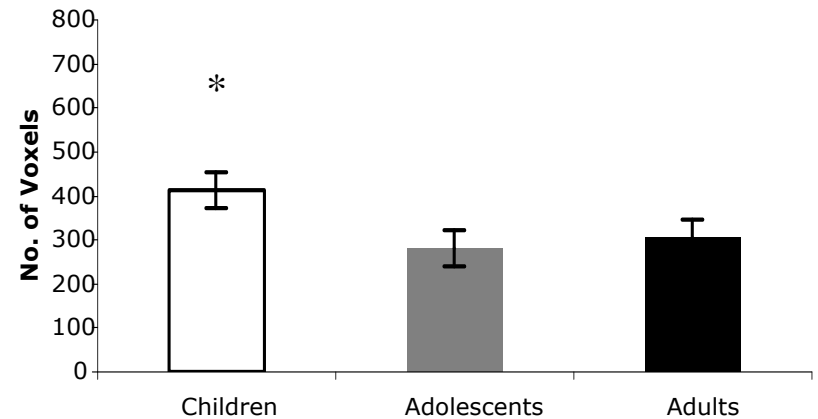
Adolescents are similar to adults in extent of nucleus accumbens activity

BUT similar to children in prefrontal activity.

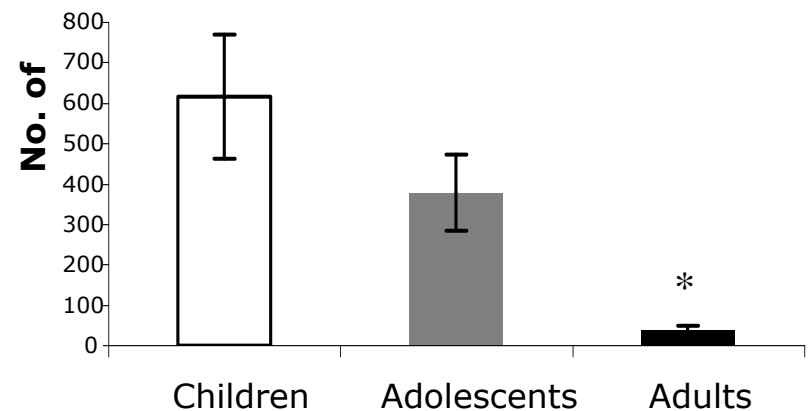
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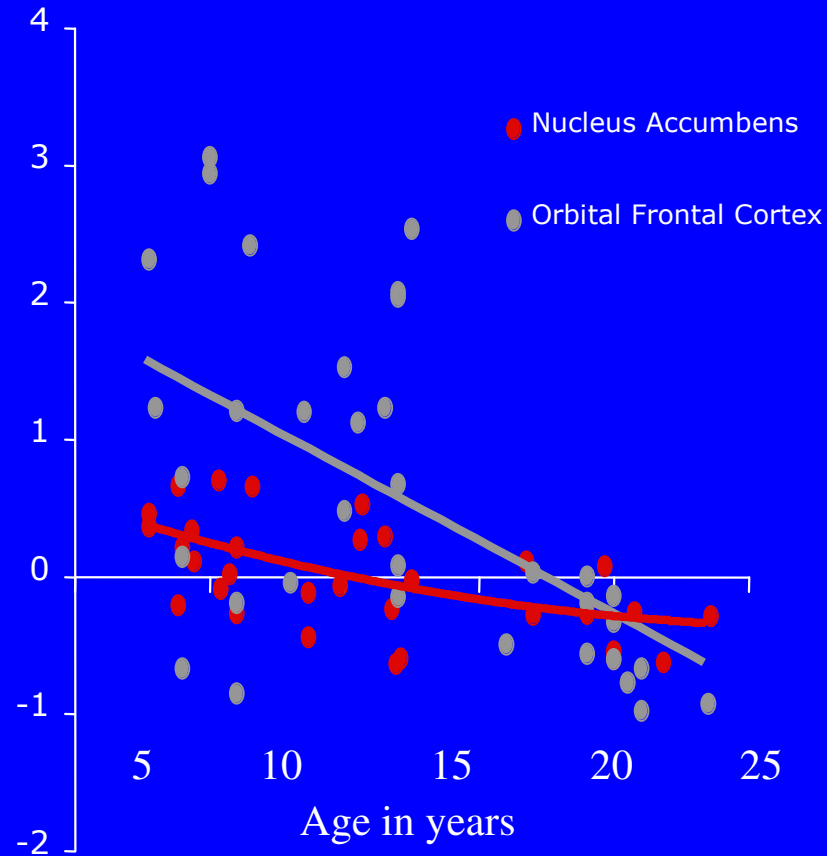
Nucleus Accumbens



Lateral Orbital Frontal Volume of Activity

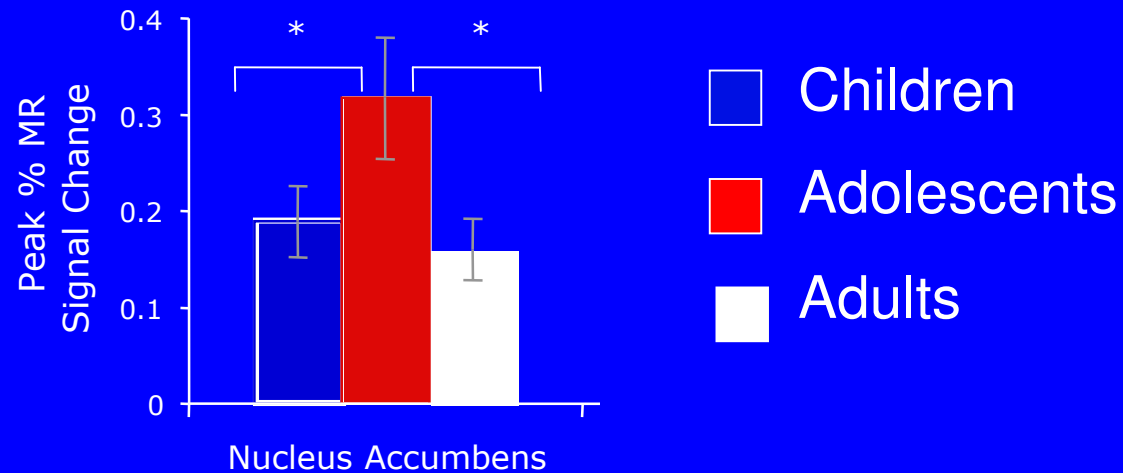
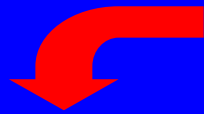


Protracted development of the prefrontal cortex relative to the accumbens

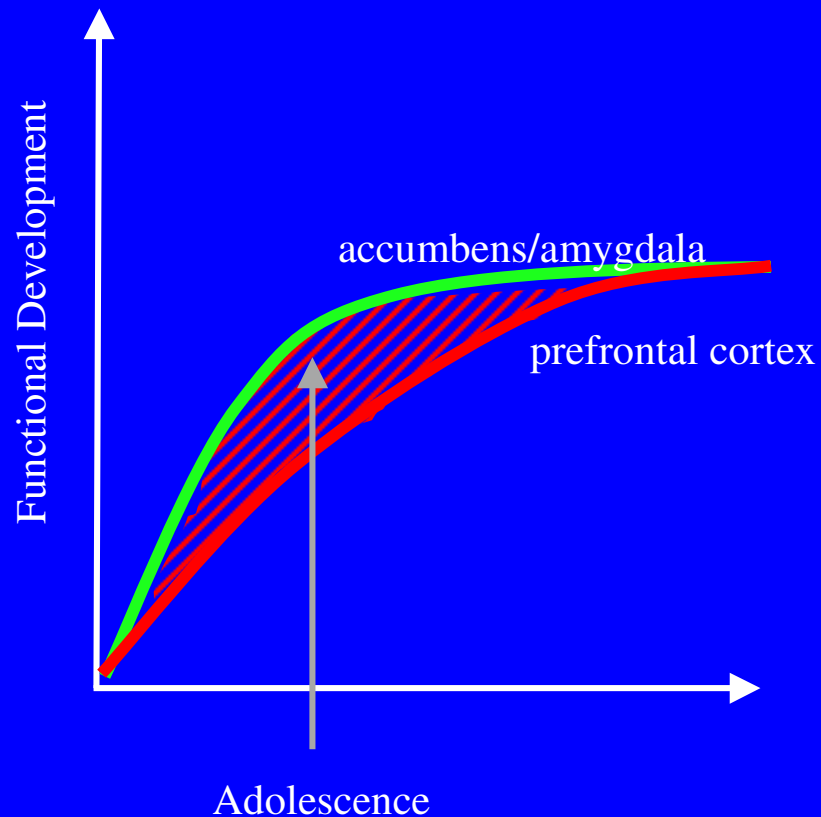


Galvan et al 2006 J Neuroscience

Neural recruitment differs by region for age groups and corresponds to enhanced activity in the accumbens in adolescents.



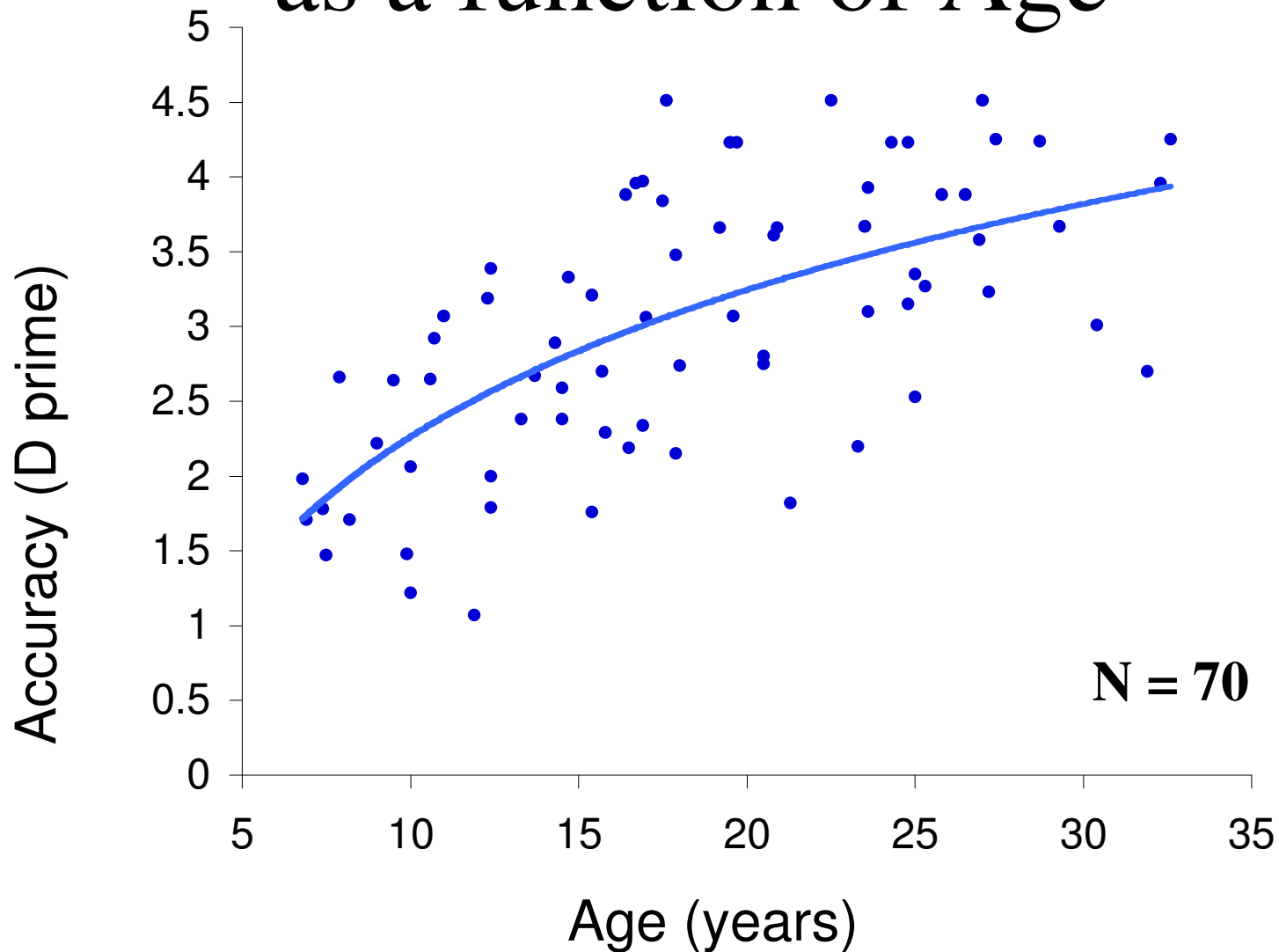
Different Developmental Trajectories



-Differential development of subcortical relative to prefrontal control regions may explain increased engagement in incentive driven behaviors.

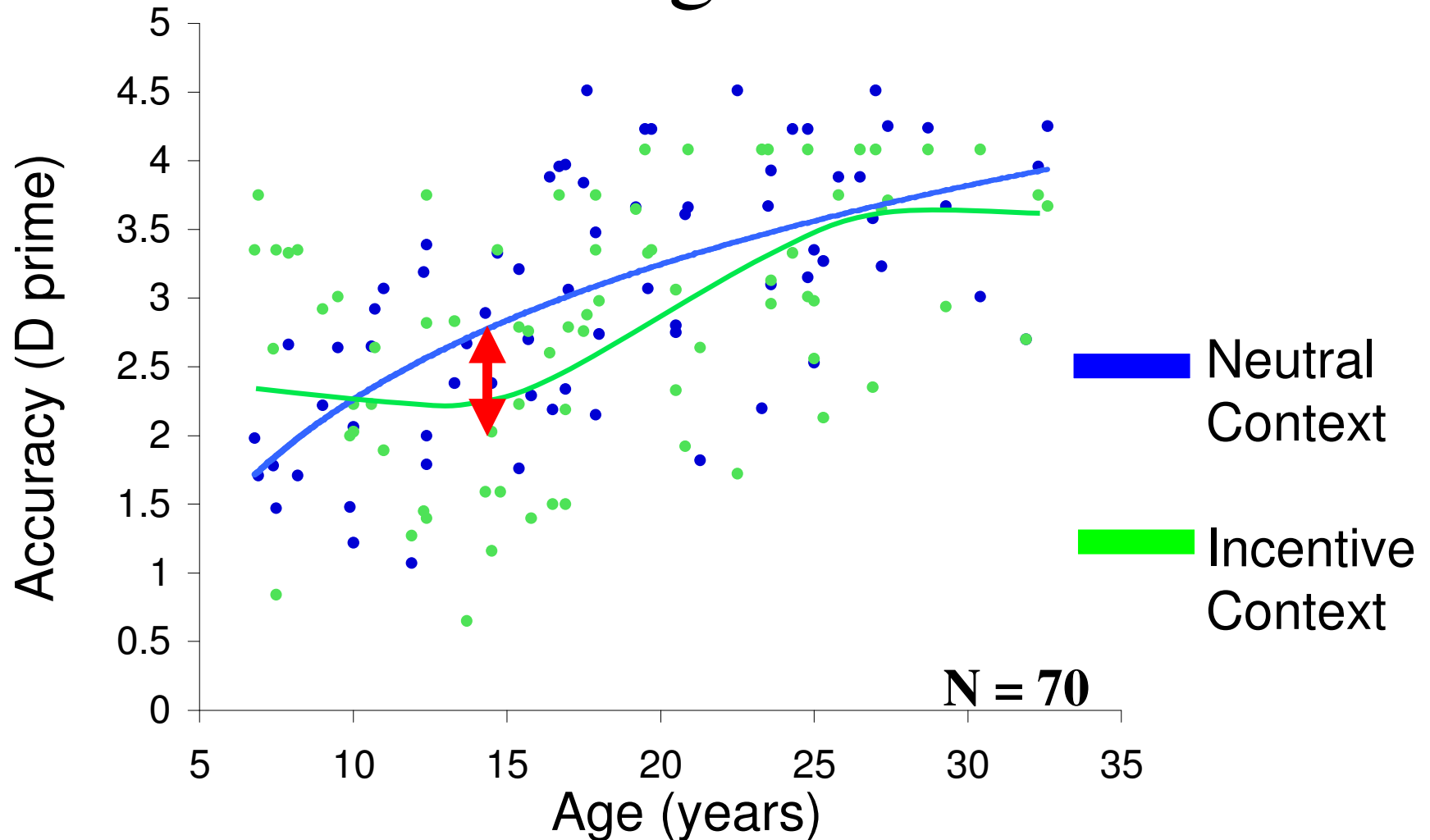
BUT do incentives differentially bias behavior across development?

Impulse Control as a function of Age



Hare et al 2007

Incentives differentially affect Impulse Control during Adolescence

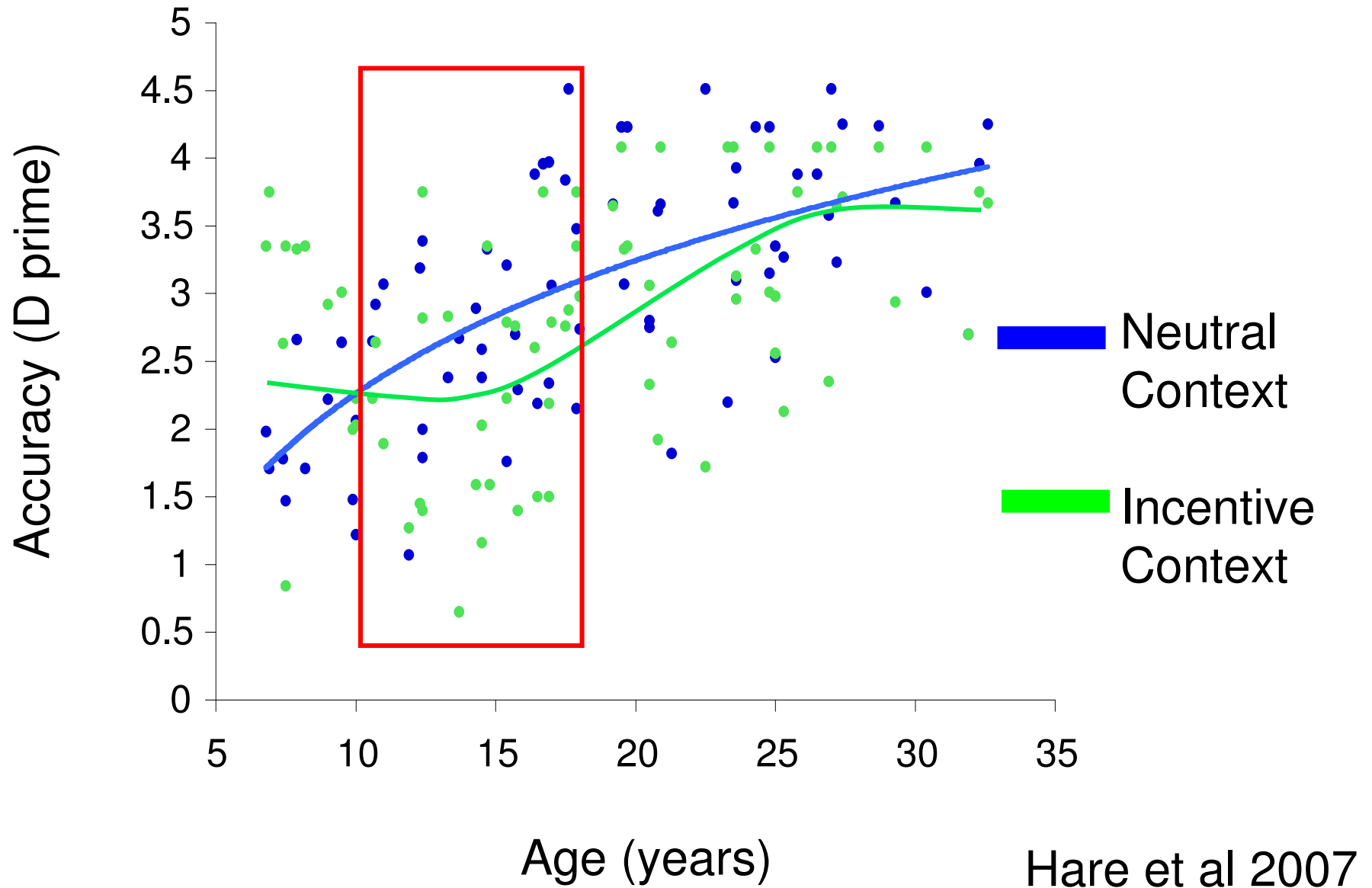


Incentive: Happy faces

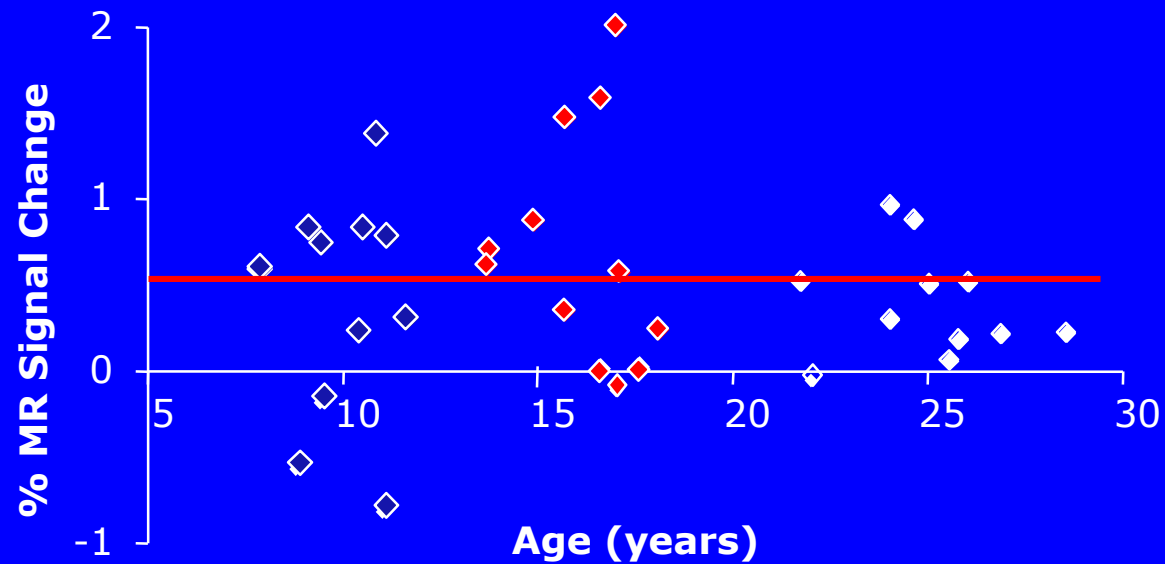
Arguably simplest form of social interaction

Hare et al 2007

Individual Variability



Individual variability in accumbens activity to incentives across development



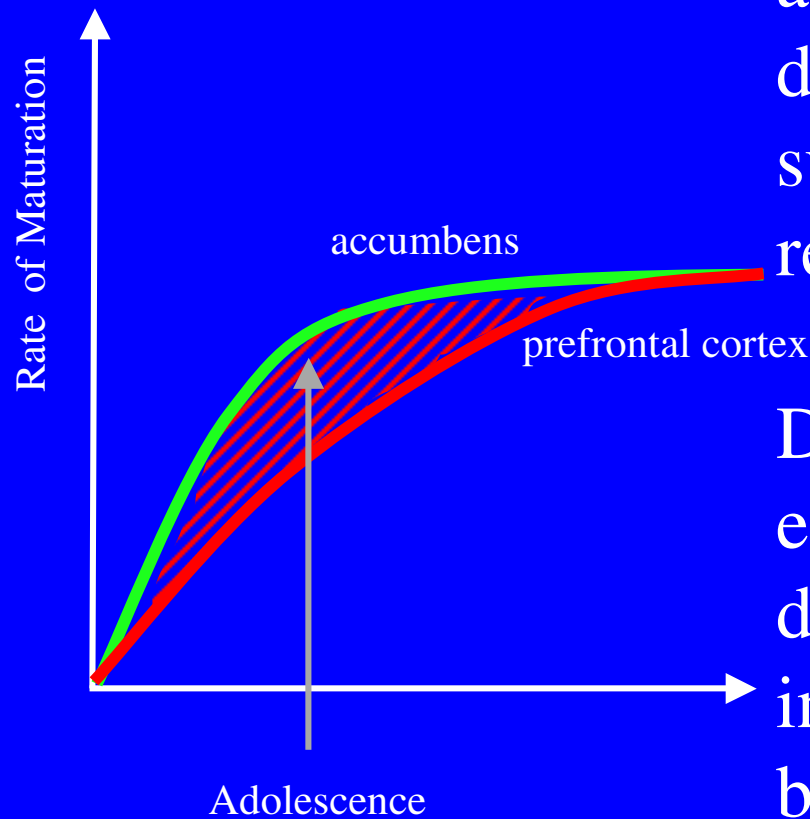
Accumbens activity is correlated with risky behavior

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Note: Accumbens activity not correlated with impulsivity (Conners)

Galvan et al 2006 *Developmental Science*

The Adolescent Brain

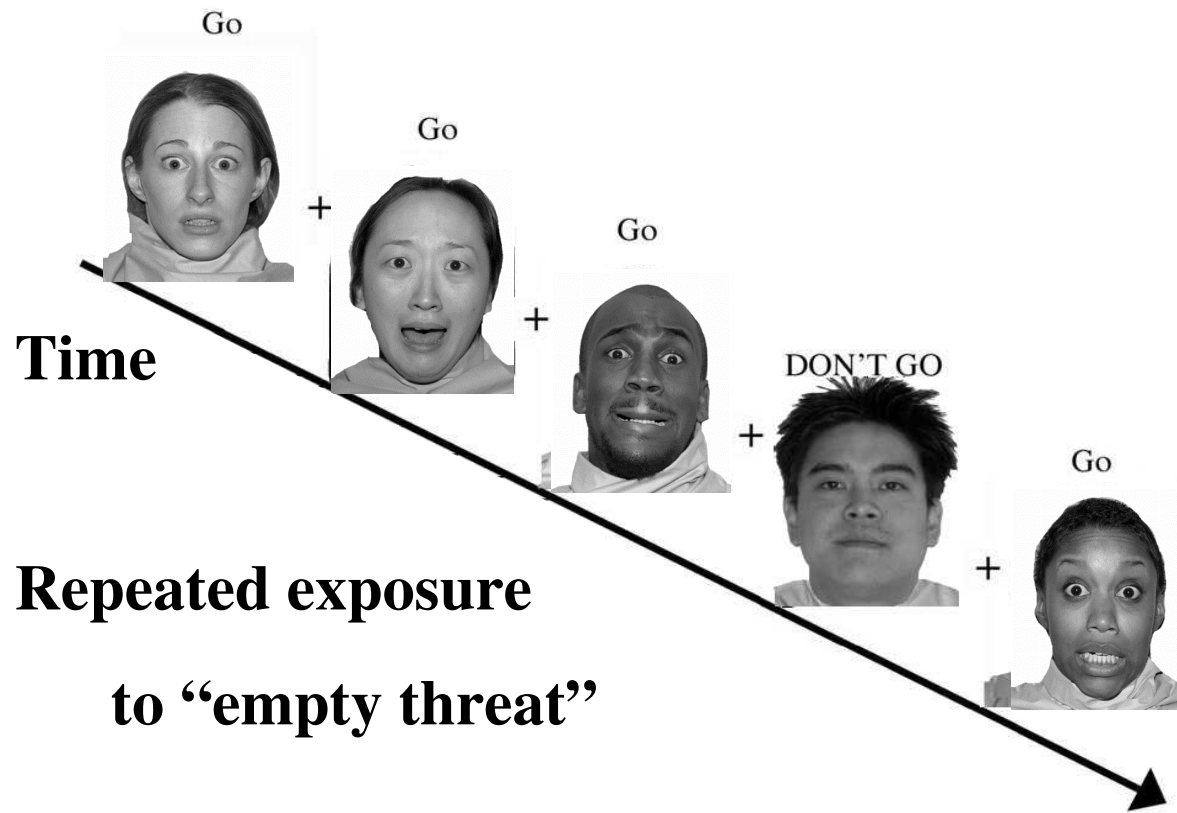


Increased risk-taking behavior in adolescence may be related to differential development of limbic subcortical vs. cortical control regions (imbalance).

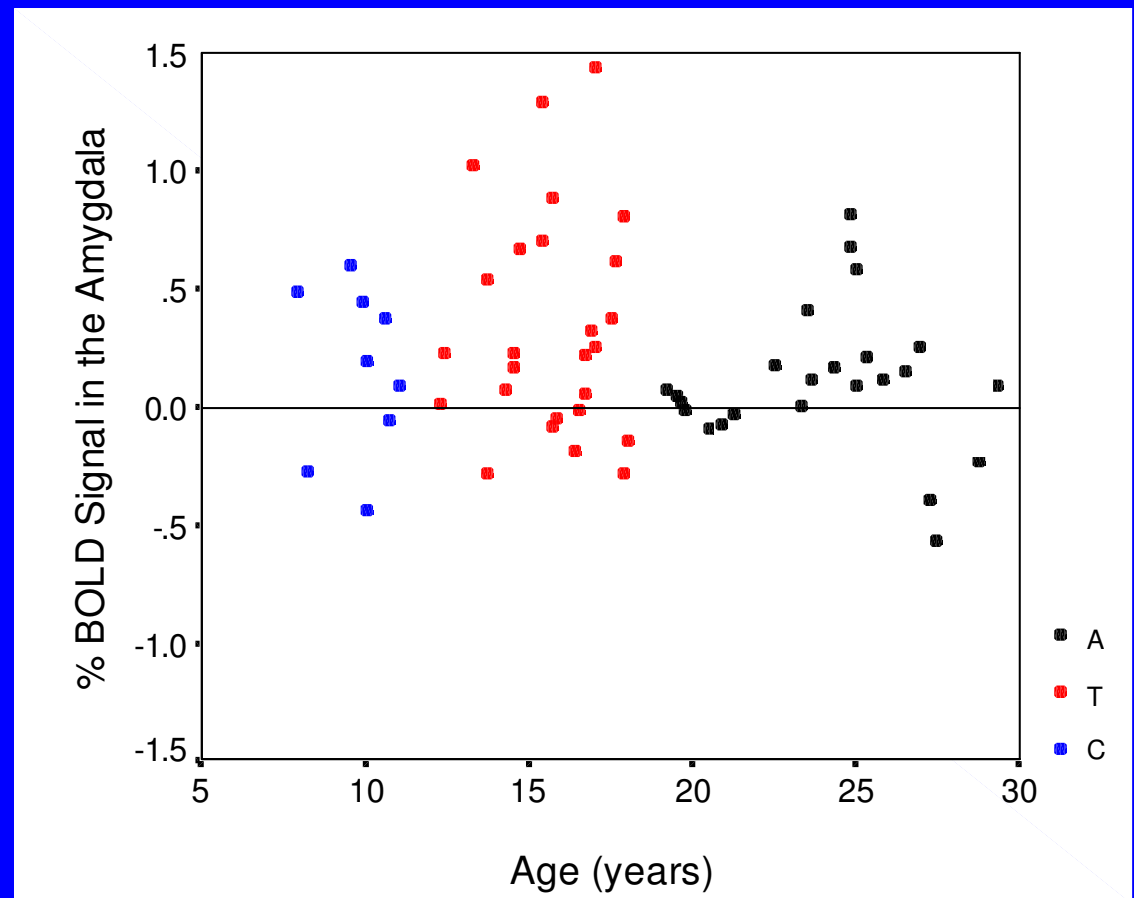
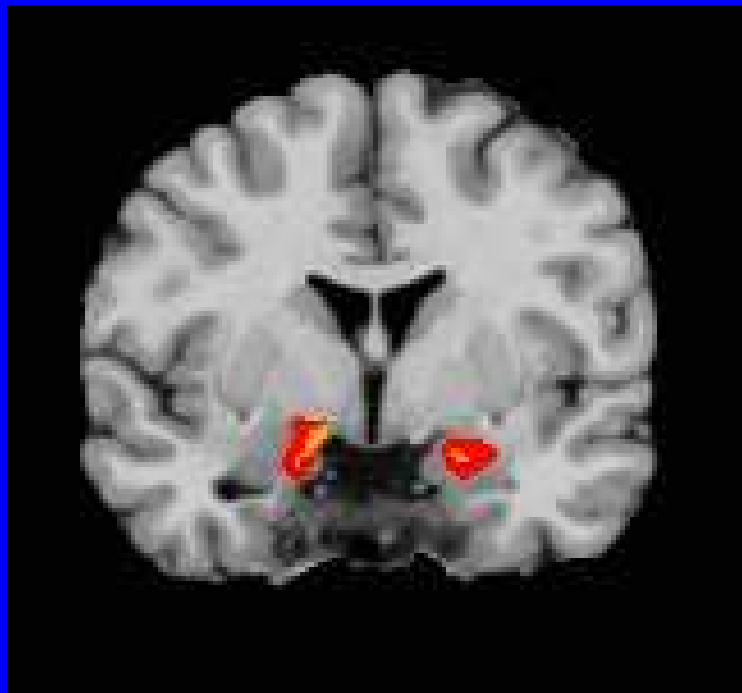
Developmental changes may be exacerbated by individual differences (genetic/environmental) in tendency to engage in risky behavior.

Note: stress effects on PFC

Influence of Negative Emotion on Behavior (triggers)



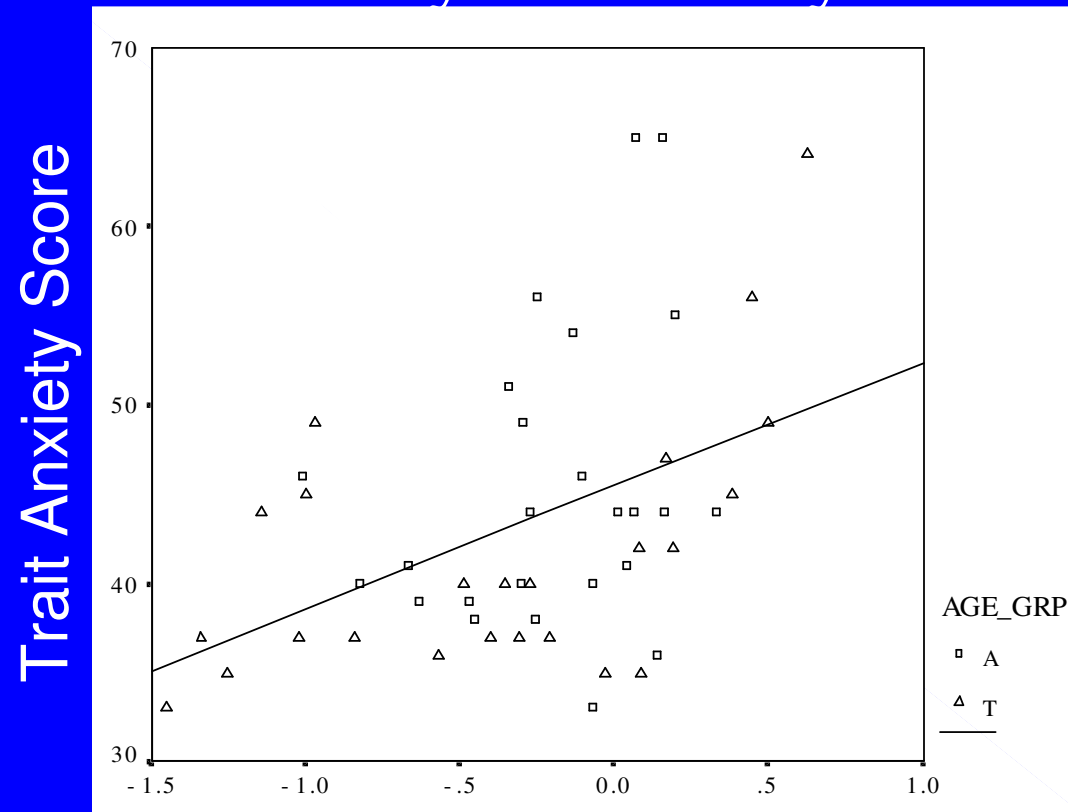
Emotional Reactivity to Negative Emotions is exaggerated in Adolescents relative to children and adults



Hare et al. 2007

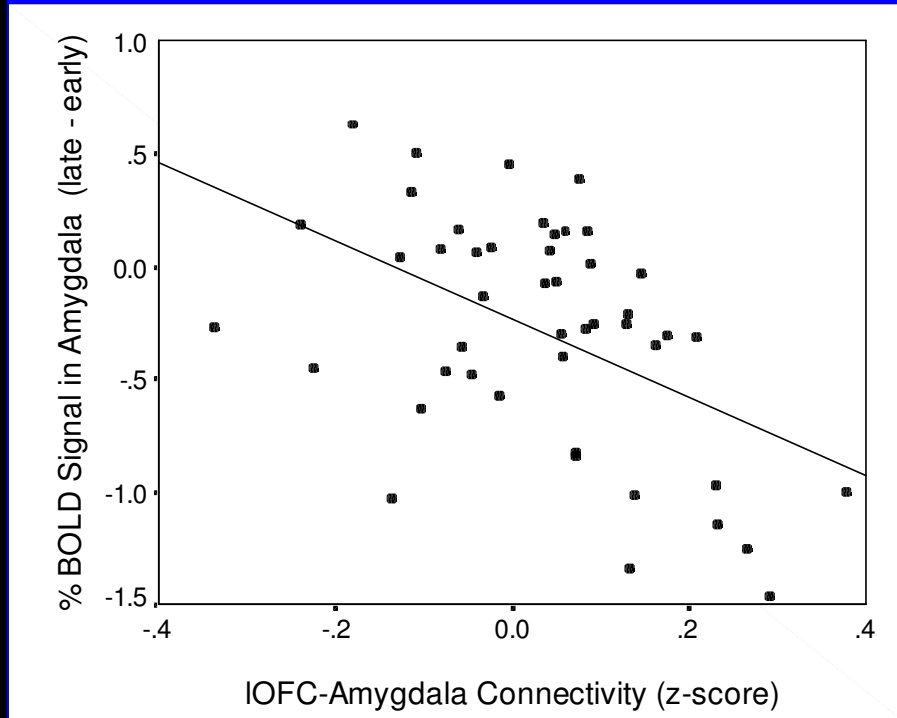
Habituation of Amygdala Response to repeated exposures of empty threat correlated with ratings of Trait Anxiety

(i.e., decrease in activity from early to late trials)



Sustained amygdala activity
(late - early trials)

Functional Connectivity Between Prefrontal Regions and Amygdala is associated with Habituation of Amygdala Response



Conclusions

- 1) Brain regions have different developmental courses that may influence or bias behavior.
- 2) Individual differences in development of these brain regions may put some teens at greater risk for substance abuse and poor outcome.

Suggests developmental windows of vulnerability that may be exacerbated by biological predispositions.

Implications

Heightened response and/or rewarding effects of substances may be at an all time high because of the heightened responses in reward areas during adolescence.

Context is incredibly important when considering adolescent behavior and brain development (e.g. public policy).