

Risky Behavior in Adolescents: The Role of the Developing Brain

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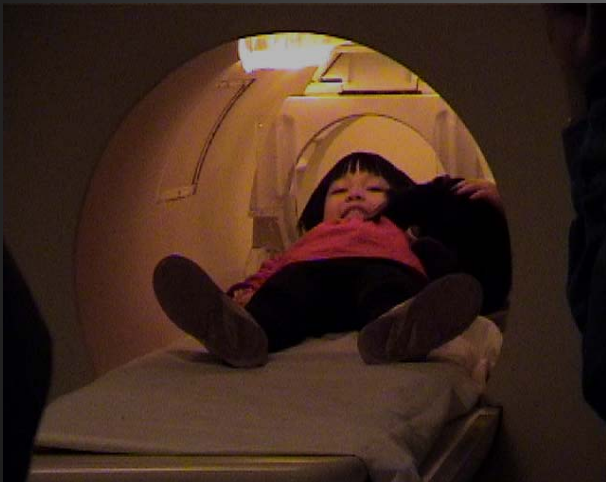


TROY:
THE MAKING
OF AN EPIC

Research is revolutionizing our
view of the adolescent mind—and
explaining its mystifying ways

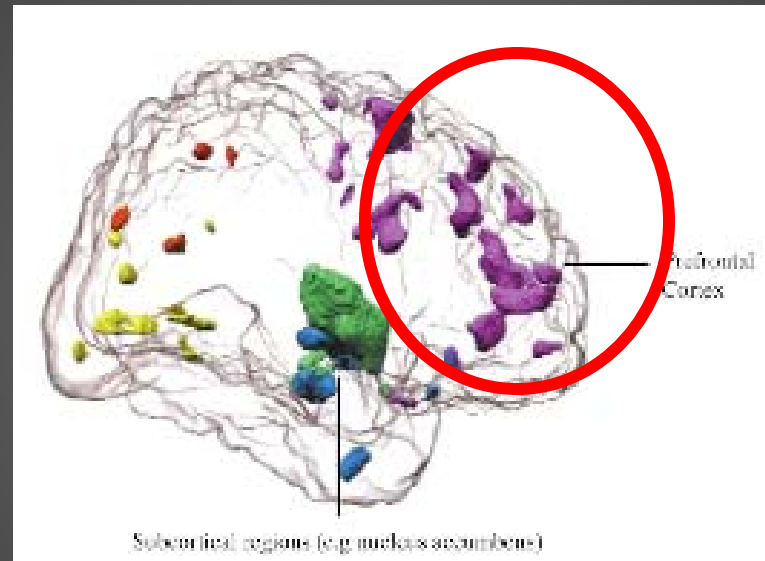
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What we know about brain development



- The brain is already about 90% of its adult size by the first grade
- The amount of gray matter increases until early adolescence (Giedd et al; Sowell et al)
- The amount of white matter, which helps brain increases until the mid-20s.

Brain regions that show the greatest structural changes during adolescence

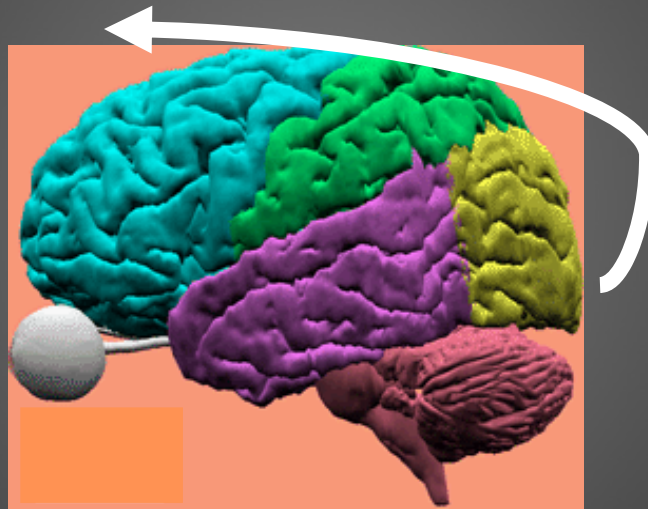


Sowell et al 1999

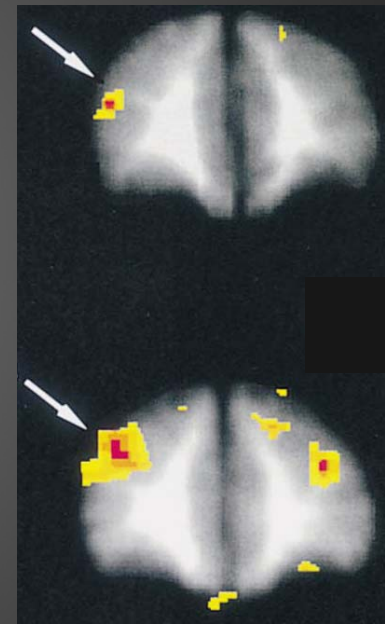
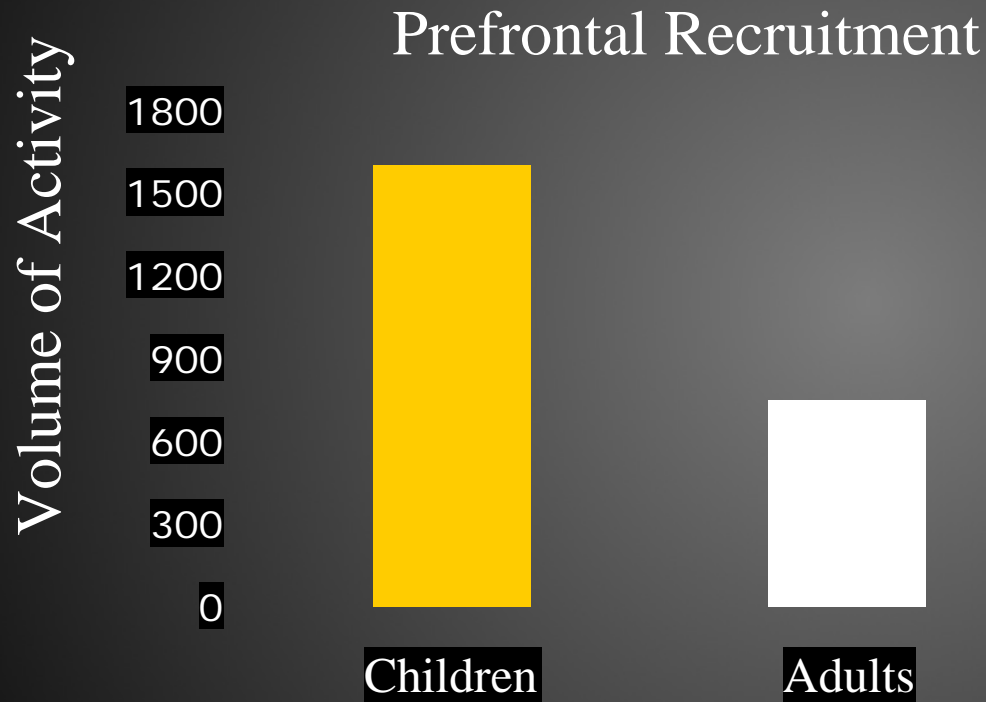
Prefrontal cortex is necessary for many cognitive functions:

- decision-making
- impulse control
- future planning
- goal-directed behavior
- appreciation of future outcomes

The part of the brain teens need the most to develop good judgment and decision-making “develops” last

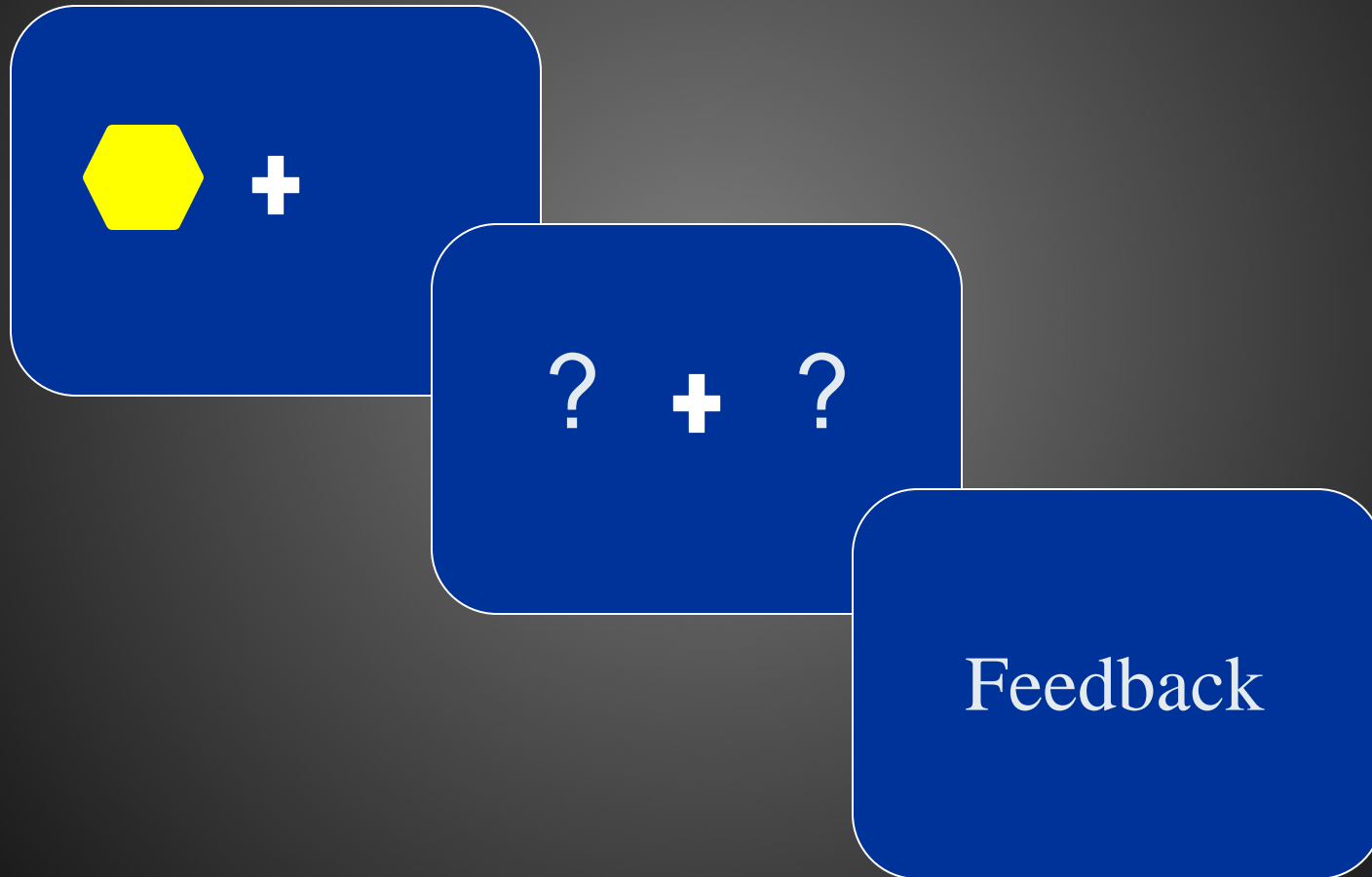


Children show greater activation in prefrontal regions to perform the same cognitive task

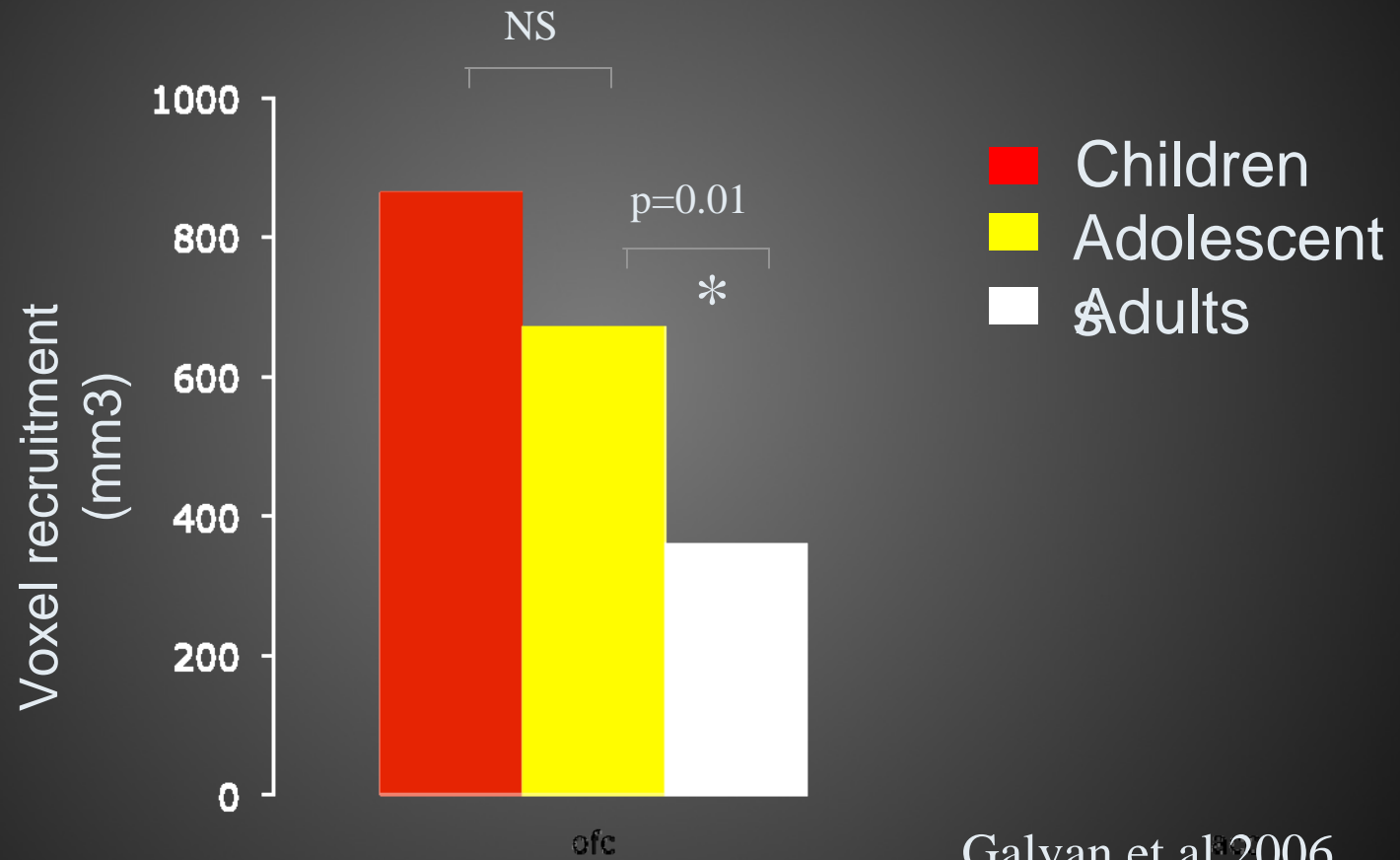


(Casey et al, 1997)

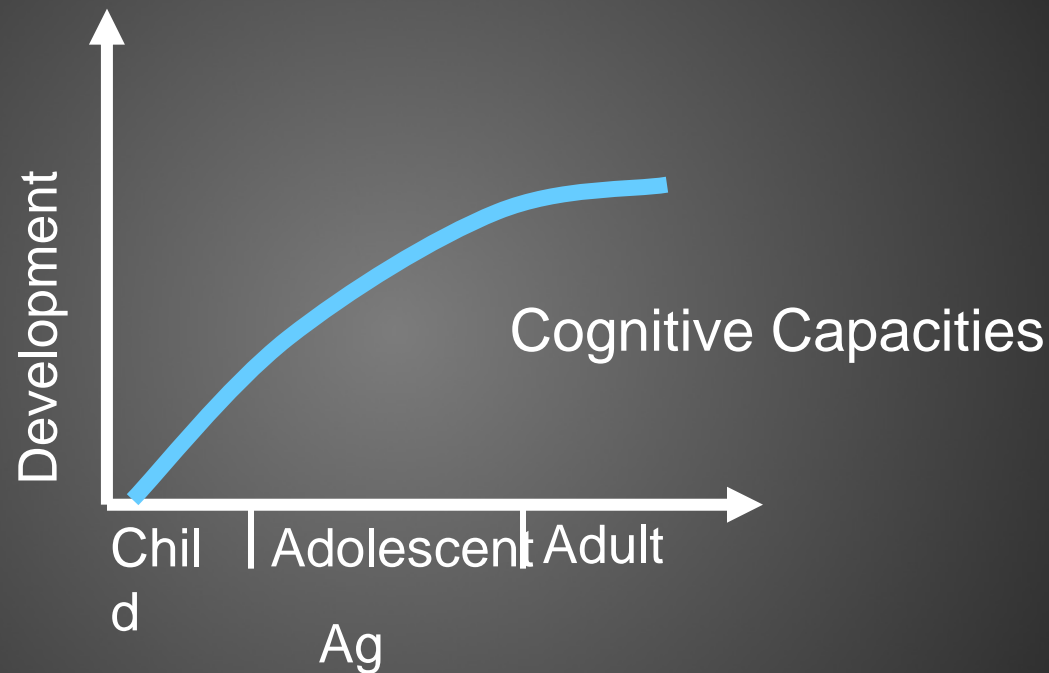
Cognitive Task



Prefrontal recruitment in adolescents parallels recruitment in children



Galvan et al 2006

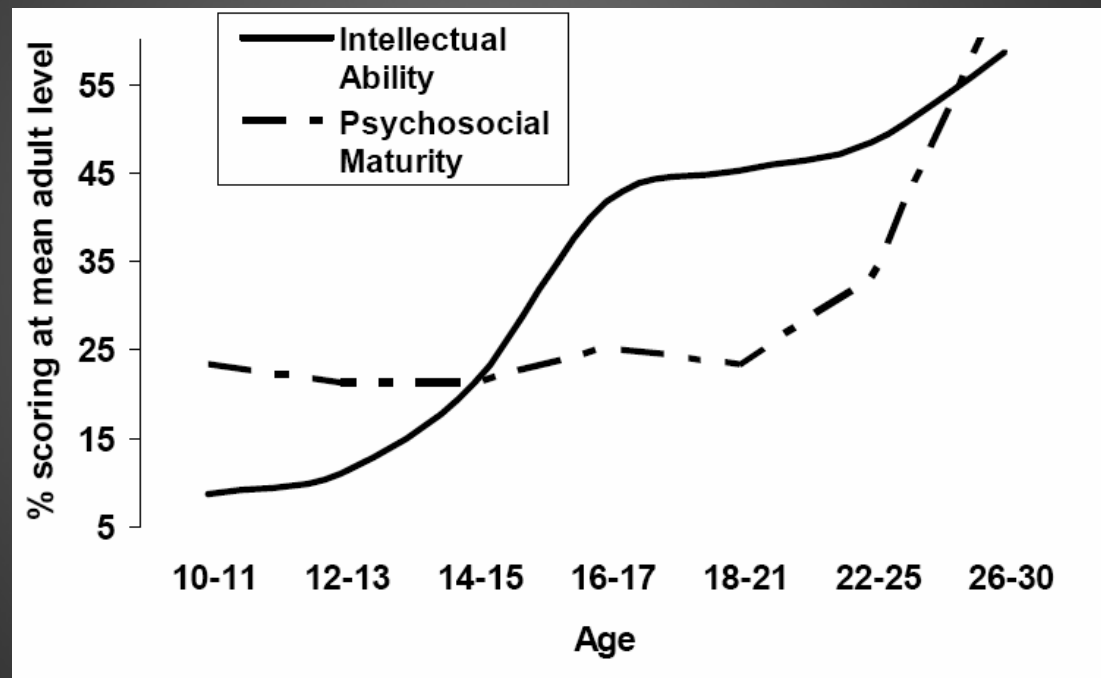


So why don't children also show the same levels of suboptimal decision-making as adolescents?

By mid-adolescence, teens have cognitive skills similar to adults (Fischhoff, 2008)

- Sensitive to future outcomes (Fischhoff et al 2000)
- No unique teen sense of invulnerability (Millstein & Halpern-Felsher, 2002)

Psychosocial maturity continues to develop into early adulthood, long after adolescents have become as “smart” as adults



Steinberg, 2007

In the lab, individuals
make decisions....

Alone

Under conditions of
low arousal

In hypothetical situations

In the real world, individuals
make decisions....

In Groups

Under conditions of
high arousal

In real-life situations

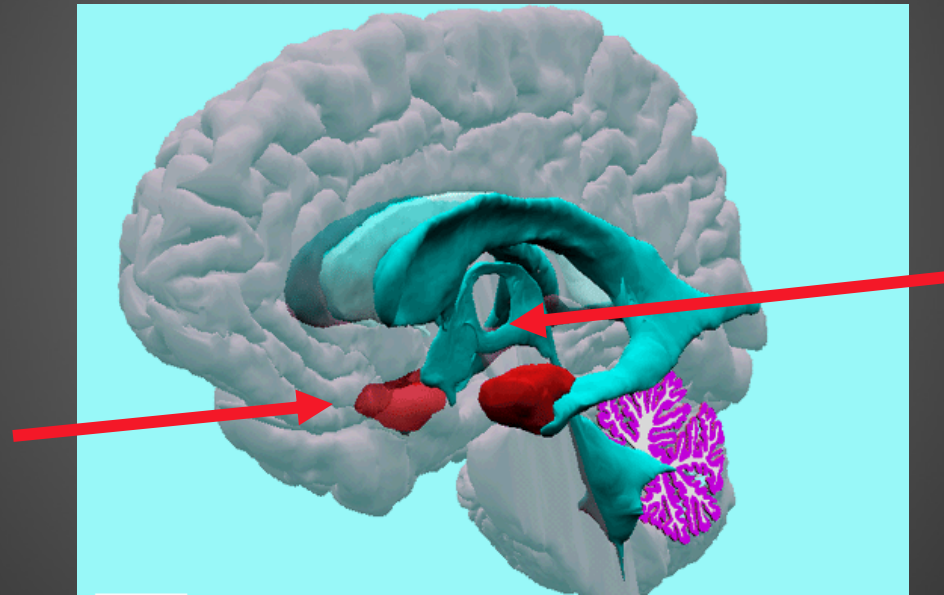
Contextual factors influence risky decision-making

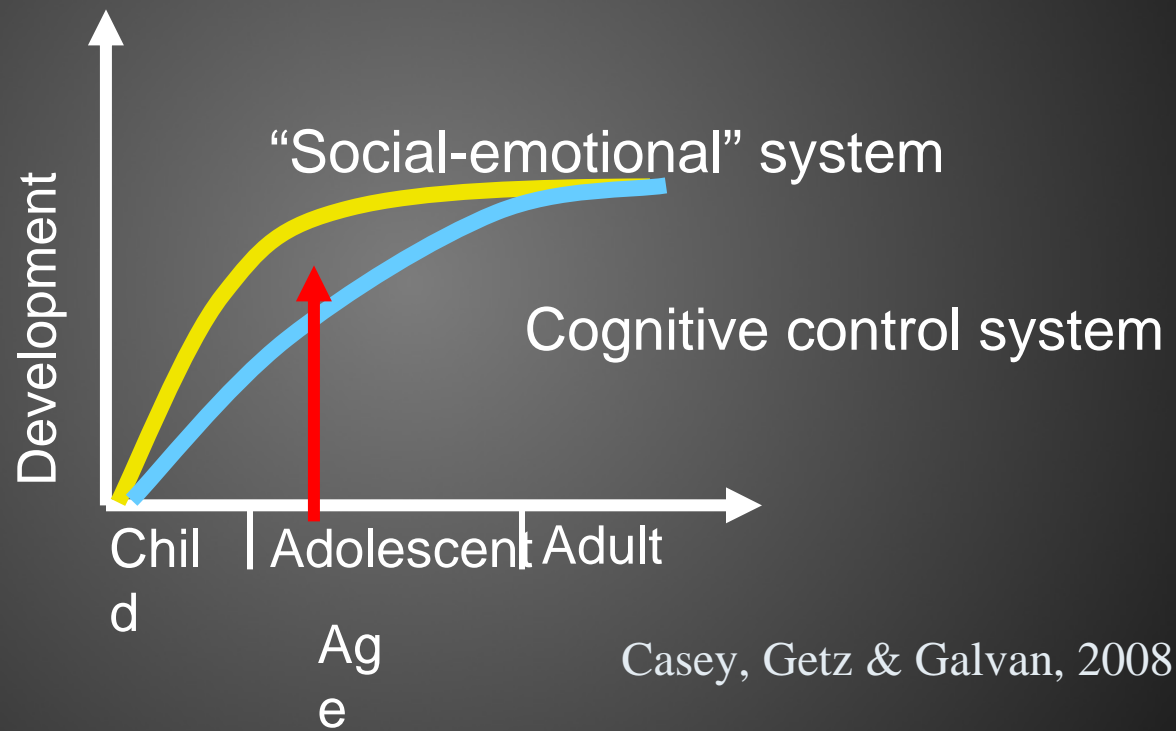
- Peers
- Curiosity
- Life Stressors
- Poor impulse control



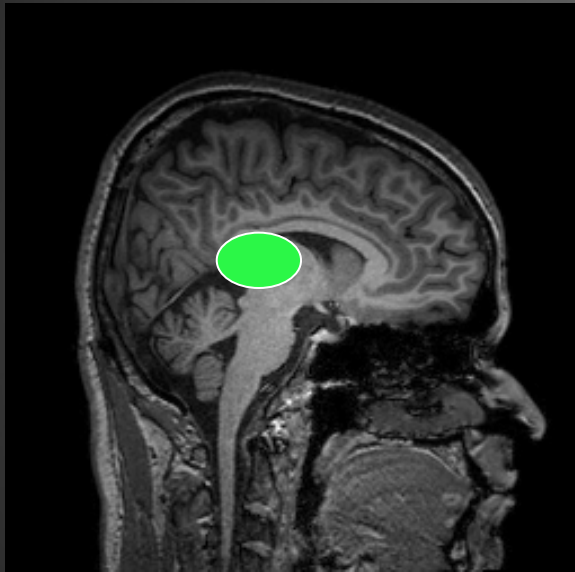
Emotion

Brain regions that are active during emotion processing





Dual brain systems involved in decision-making and judgment



“Social-emotional”
system mainly involves
limbic regions

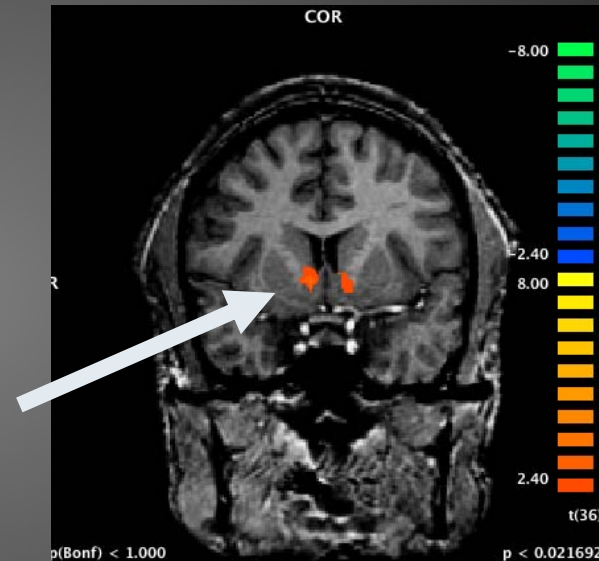


“Cognitive control”
system mainly involves
cortical regions

Does the influence of each neural system on risk and decision-making change with development?

How does reward influence neural recruitment in adolescents?

- 13 Children
(7 female; mean age: 9)
- 12 Adolescents
(6 female; mean age: 16)
- 12 Adults
(6 female; mean age: 25)





Small
Reward

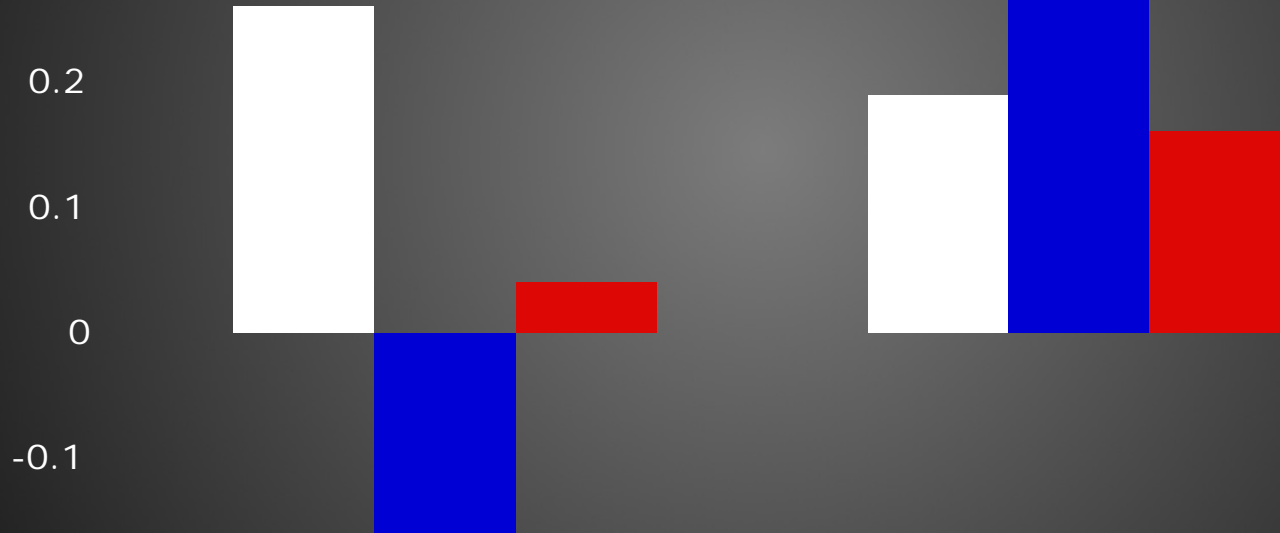


Large
Reward

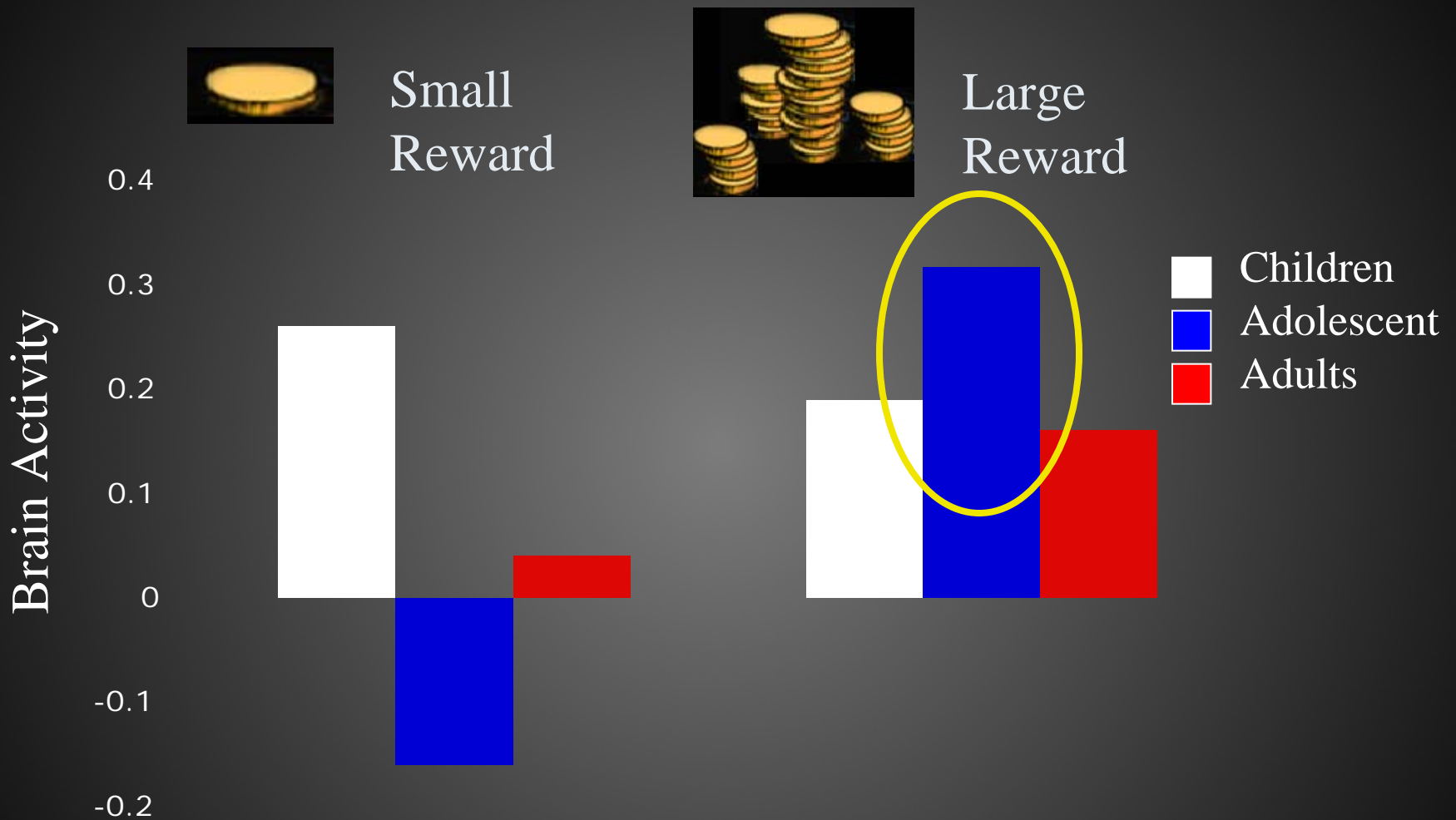
Brain Activity

0.4
0.3
0.2
0.1
0
-0.1
-0.2

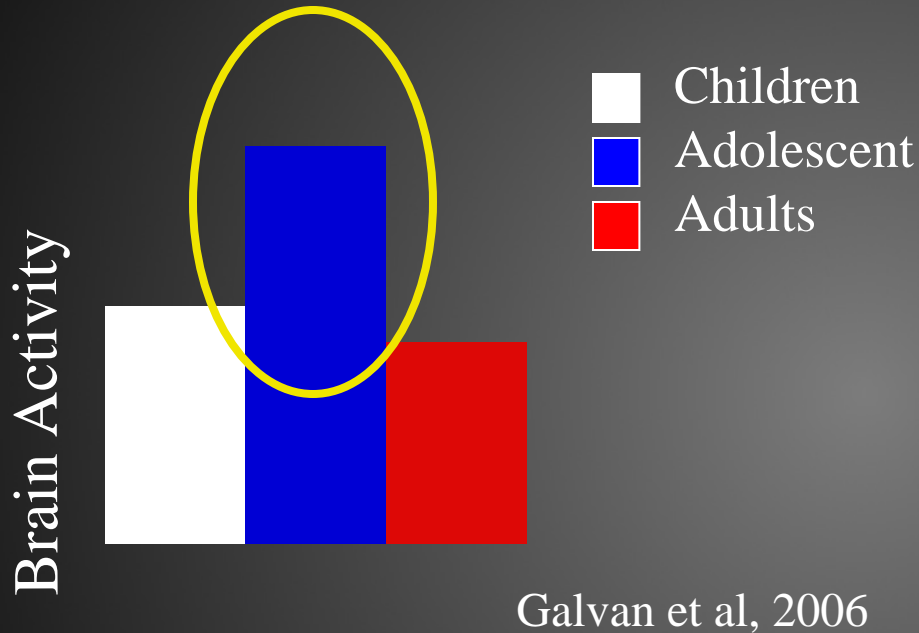
Children
Adolescent
Adults



Galvan et al, 2006

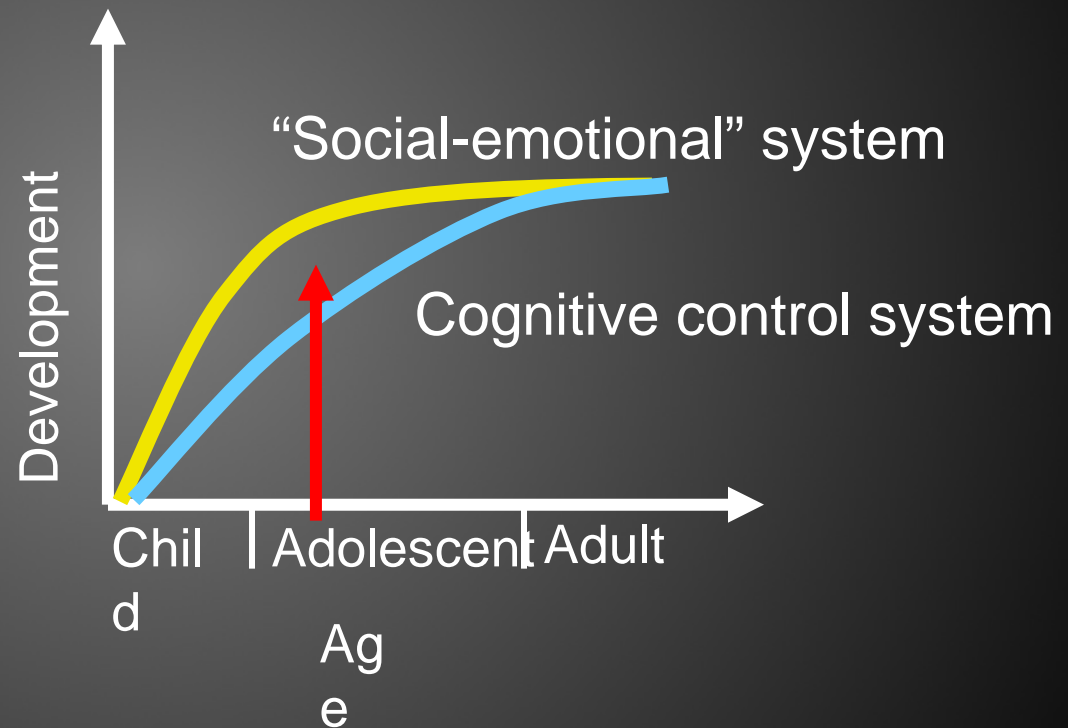


Galvan et al, 2006



Decision-making under the influence of positive feeling states occurs more quickly and efficiently than under neutral states (Rivers et al 2008, Bodenhausen et al 1994)

Adolescents show heightened brain activity to incentives/rewards while cognitive control systems are still relatively immature.

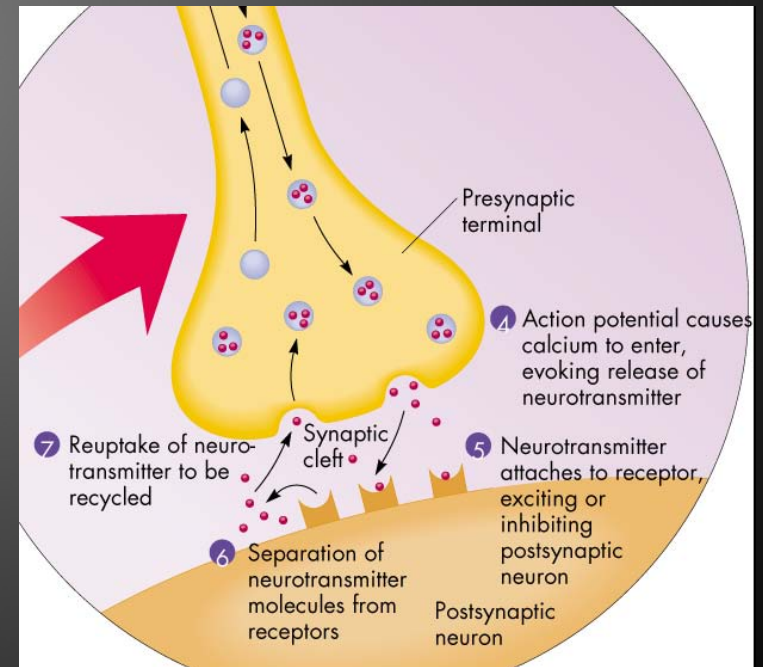


Not all adolescents make bad decisions

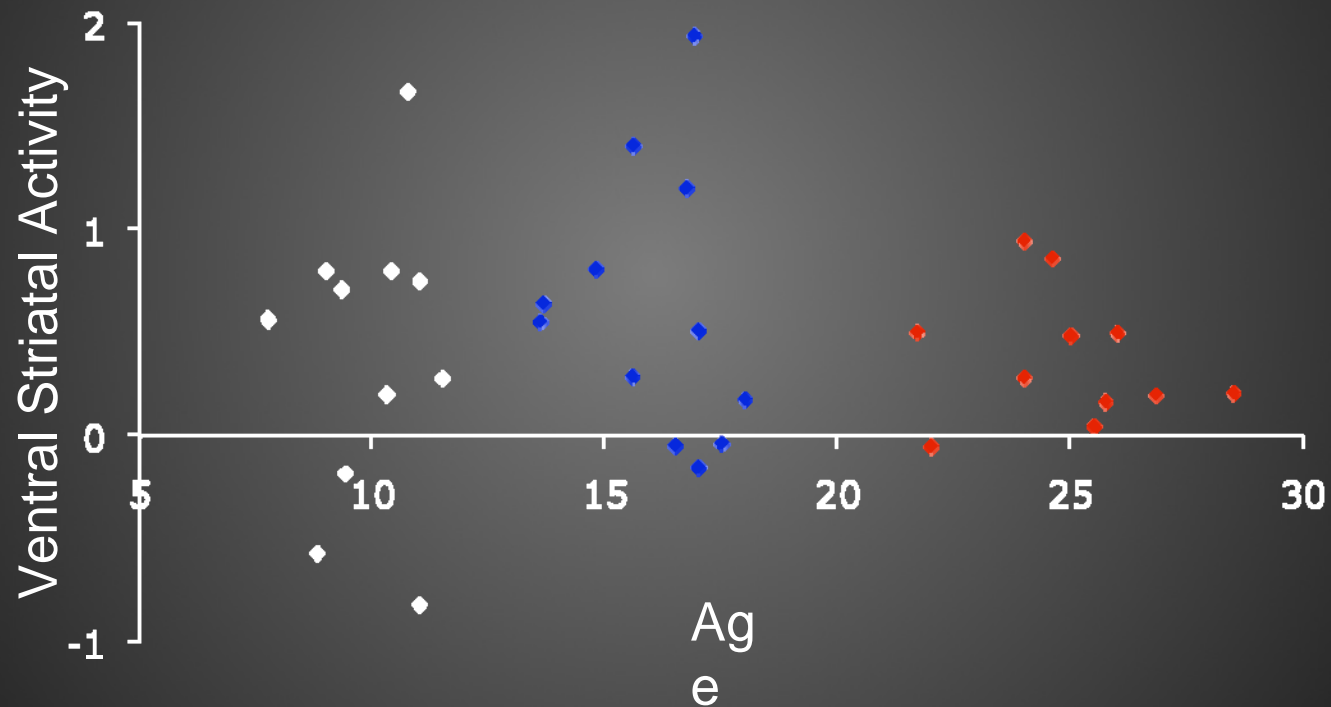
but a lot of bad decisions are made
during adolescence

Individual differences

- Are there individual differences in how neural sensitivity to affect/reward relates to actual risk-taking choices?
- Individual differences in dopamine transmission might relate to the propensity to engage in risky behavior (e.g. O'Doherty, 2004)



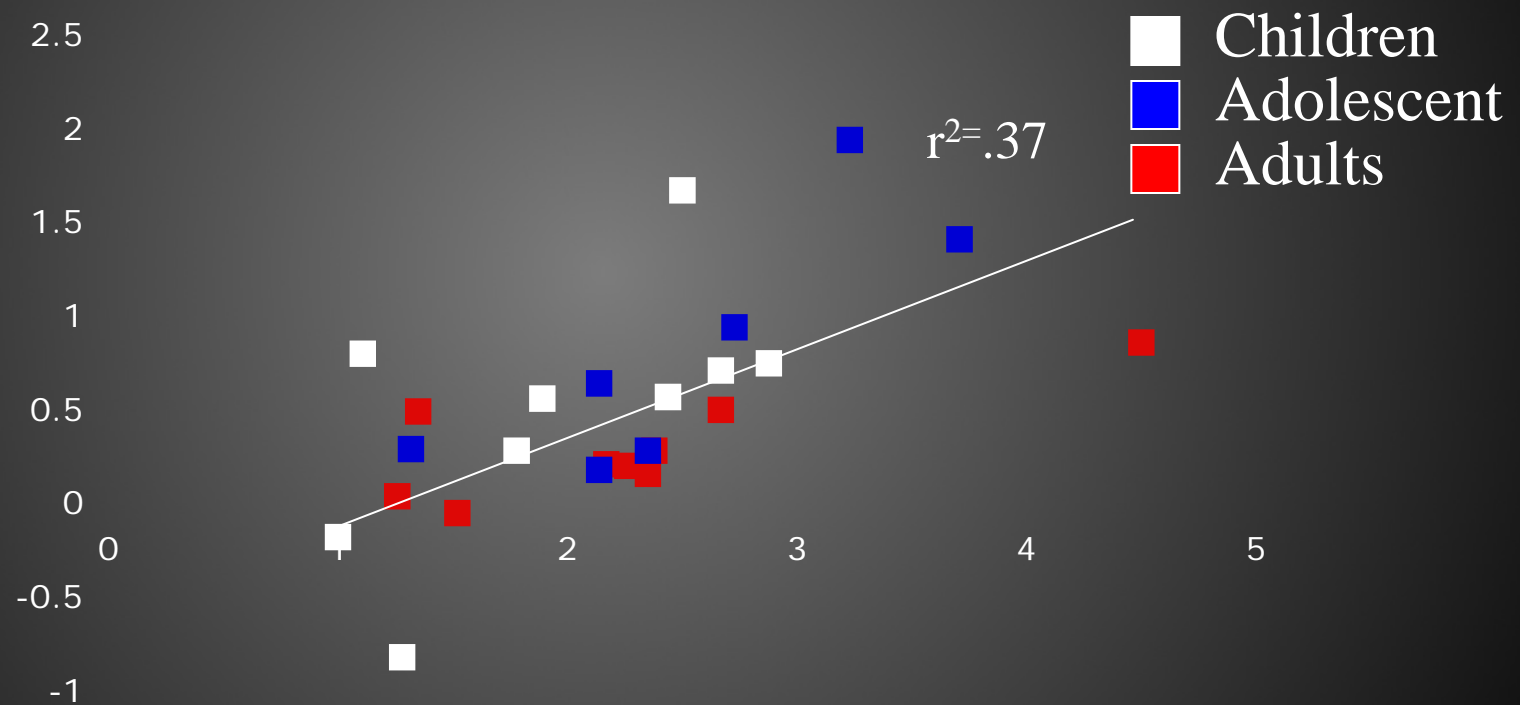
Extensive variability in ventral striatal activation across development



Self-report of risky behavior

- Cognitive Appraisal of Risky Events (CARE) for Adults and Adolescents (Fromme et al 1997)
- CARE for Children (modified version)
- Likelihood of engaging in the following behaviors in the near future:
Example items:
 - Leaving a social event with someone I just met
 - Driving after drinking alcohol
 - Skydiving
 - Gambling
 - Smoking marijuana

Brain activity associated with increased likelihood of risky behavior



Likelihood of Risky Behavior

Galvan et al, 2007

Risk-taking fMRI Task (BART)

- Increasing risk accompanies increasing potential reward
- On each trial, subjects chooses between sure outcome (rejecting the gamble) and risky outcome (accepting the gamble)

Risk-taking fMRI Task (BART)

- Increasing risk accompanies increasing potential reward
- On each trial, subjects chooses between sure outcome (rejecting the gamble) and risky outcome (accepting the gamble)

TOTAL GAIN = \$1.00
(GOES INTO BANK)



\$0.25

<ACCEPT>



\$0.50

<ACCEPT>



\$0.75

<ACCEPT>



\$1.00

<REJECT>

Consequences to Accepting Risk

Balloons explode randomly according to a uniform distribution over # of presses
- when balloon explodes, no money is gained for that trial (but money in bank is safe)

TOTAL GAIN = \$0.00



\$0.25

<ACCEPT>



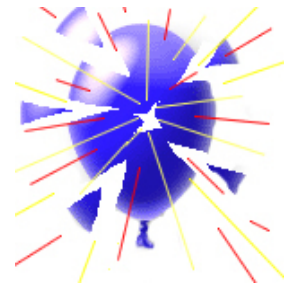
\$0.50

<ACCEPT>



\$0.75

<ACCEPT>



Control trial allowed subtraction of basic sensorimotor-related brain activation

CONTROL TRIAL



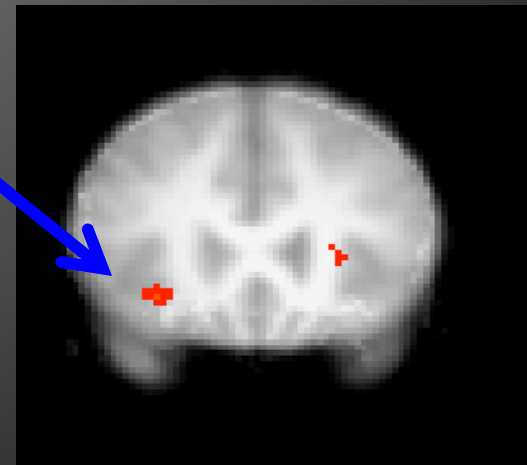
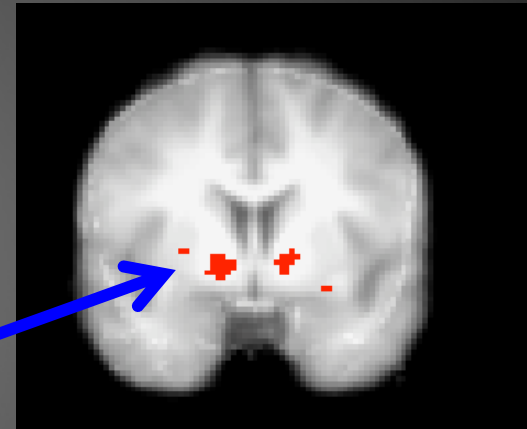
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Brain activation during risky choices in teens

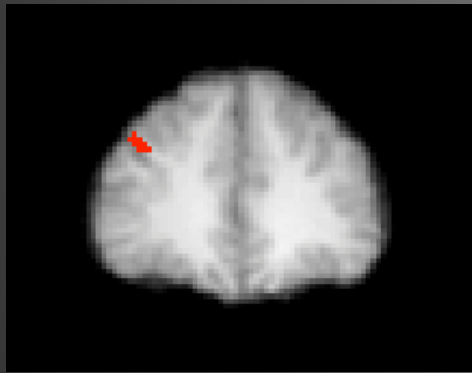
- N=18 (12 females)
- Ages 16-19 years (mean: 17 years)
- Greater ventral striatal and OFC activation during decision to take gamble relative to decision to cash-out



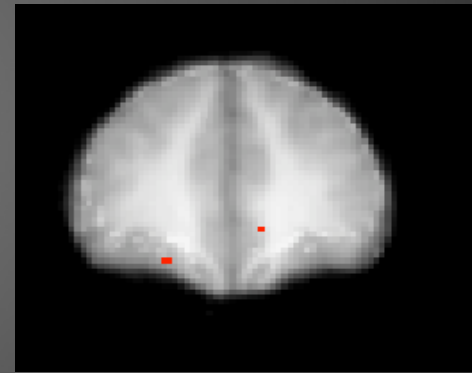
Brain activation during risky choices in risk-taking teens (smokers)

- N=28 (10 smokers)
- Ages 16-20 years
(mean: 18 years)
- fMRI during BART
and Stop-Signal Task
(measure of response
inhibition)

Stronger correlation between prefrontal brain activation during gamble (BART) and poor response inhibition in smokers, but not in nonsmokers



Smokers



Nonsmokers

Conclusions

- Protracted development of regions critical for cognitive control is not the sole reasons adolescents make poor choices; a dual-systems approach to understanding neurobiological underpinnings of adolescent decision-making is necessary.
- Development of brain regions sensitive to emotion and reward is distinct from development of regions involved in judgment and decision-making.
- These developmental changes can be exacerbated by individual differences in brain activity of affect-related regions.
- Adolescent risk-takers show distinct neural recruitment than adolescents who are less risk-taking.

Implications

- Context plays a crucial role in how decisions will be made: Risky choices made in emotional circumstances differ from those made non-emotional circumstances.
- Individuals prone to risky behavior may be at further risk during adolescence when neural systems underlying risky behaviors undergo significant development.
- Prevention/treatment approaches should not be ‘one size fits all’
- Policy should take advantage of the natural tendency of youth to explore new opportunities, become emotional engaged, influence their peers, and respond to immediate rewards (and disincentives).

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