

# Adolescent Brain Development



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# The Health Paradox of Adolescence

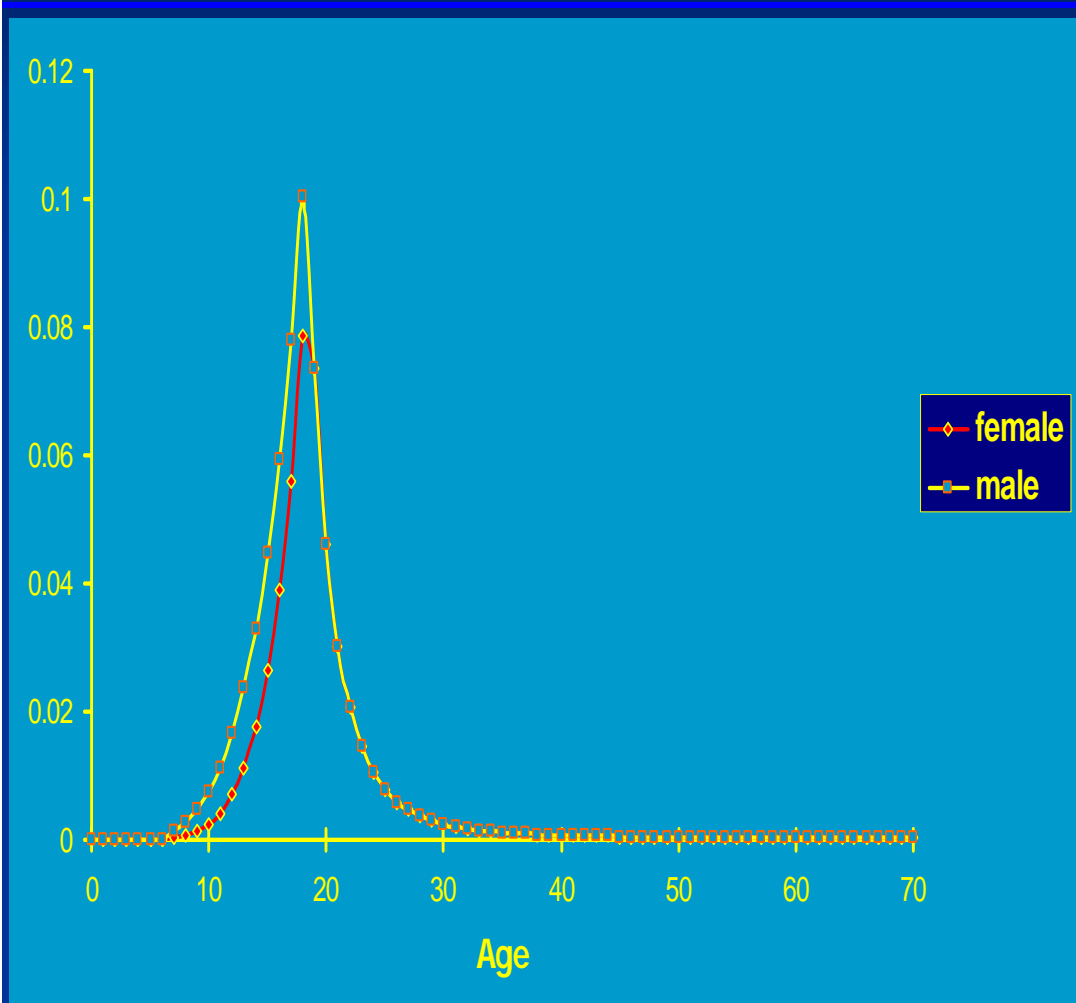
- Adolescence is (physically) the healthiest period of the lifespan: prior to adult declines; beyond the frailties of infancy and childhood:
  - Improvements in strength, speed, reaction time, reasoning abilities, immune function ...
  - Increased resistance to cold, heat, hunger, dehydration, and most types of injury ...
- *Yet: overall morbidity and mortality rates increase 200% from childhood to late adolescence*

# Morbidity & Mortality in Adolescence

Primary sources of death/disability are related to problems with *control of behavior and emotion*

- accidents, suicide, homicide, depression, alcohol & substance use, violence, reckless behaviors, eating disorders, risky sexual behaviors...
- risk-taking, sensation-seeking, and erratic (emotionally-influenced) behavior
- onset of problems with later health consequences

# Adolescence: an inflection-point in life course trajectory



## Probability of Smoking *Initiation*

- Alcohol use/abuse
- 95% of MJ use begins before 25
- Onset of initial depression episode
- Greatest risk of HIV exposure
- Rates of accidents related to violence and reckless behavior

# Tendency to excess based on individual differences in brain function



# EXECUTIVE FUNCTIONS

## Building blocks form in childhood

- Forethought
- Attention/Concentration
- Verbal Ability
- Abstract Reasoning
- Problem Solving
- Programming and Planning Goal Oriented Behavior
- Behavioral Inhibition
- Learning from Experience
- Interpreting Social Cues
- Using Socially Adaptive Behavioral Responses
- Avoiding Negative Consequences or Situations
- Regulating Emotional Responses
- Sensitivity to Penalties

# Focal Point: Prefrontal Deficits

- Inability to accurately interpret social cues
- Permits negative emotions to dominate
- Heightened sensitivity to rewards
- Impulsivity and Inattention
- Insensitivity to Consequence

\* Doesn't connect until after adolescence!!!

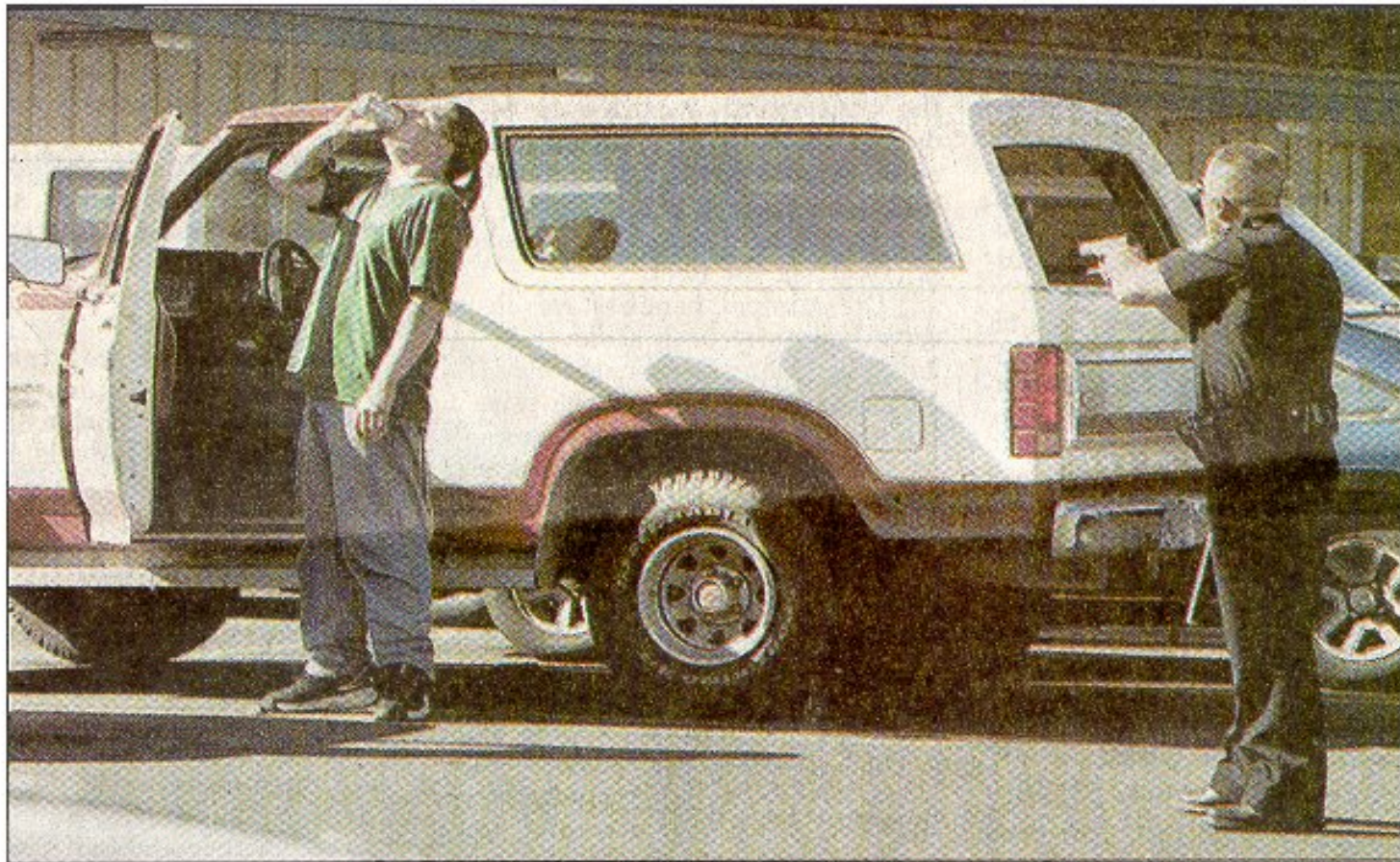
Frontal lobes



- Memory, planning, problem solving
- Gray matter volume peaks ~ age 12
- Change with experience = *plasticity*



## Pardon Me, Officer, While I Finish My Beer



*Associated Press*

Despite the fact that an officer is pointing a gun at him, a passenger from a stopped vehicle decides to finish his beer. Police stopped the vehicle because they thought it was stolen; it wasn't, but another passenger was taken into custody on an outstanding

warrant and was also charged with resisting arrest. Five people were in the vehicle, and drinking was obviously occurring, but the police didn't arrest anyone else. The incident occurred in Klamath Falls, Ore., on Wednesday.

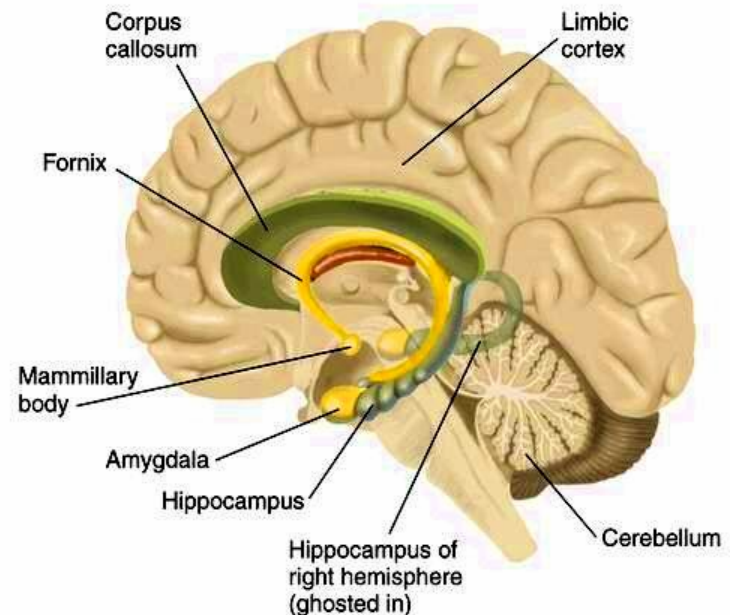


# Emotional Regulation

## Prefrontal cortex controls lower functions of limbic system

- Motivation and emotion
- Assigns feeling to incoming stimuli
- Emotional drives
- Stress responses
- Provides for rewarding and addictive properties of drugs and seeking

► Major Components of the Limbic System



# Breakdown in Brain's Regulatory System may Heighten Risk

Regulatory neural circuitry b/t prefrontal cortex and limbic system vulnerable to:

- genetic defects
- developmental delays
- injury
- metabolic errors
- stress and adversity
- drug and alcohol use

# The Adolescent Brain

**Particularly vulnerable to external inputs:**

- Environmental exposures
- Psychosocial stressors
- Drug and alcohol use
- Protective factors

**Prefrontal cortex not fully developed until early adulthood**

- Unique stage of change in metabolism, pruning, and increased efficiency in prefrontal function

**Emotional centers (limbic) without checks and balances**

- Greater sensitivity to rewards, less inhibition
- Seek altered states of consciousness

**Effects are longstanding**

# Fundamental Imbalance in Puberty

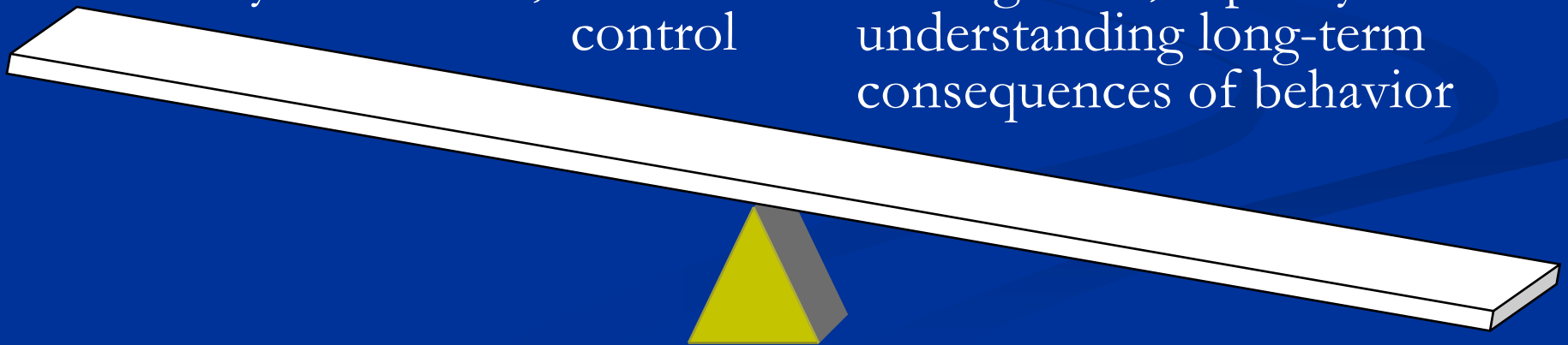
- Rapid physical, endocrine, and social changes that create *early* affective motivations and challenges
- Gradual, *later* development of affect regulation and maturation of cognitive/self-control skills

## Emotional Capacity

Pubertal drives and emotions; sensation seeking; risk taking; sensitivity to rewards, low self control

## Cognitive Capacity

Planning; logic; reasoning, inhibitory control; problem-solving skills; capacity for understanding long-term consequences of behavior



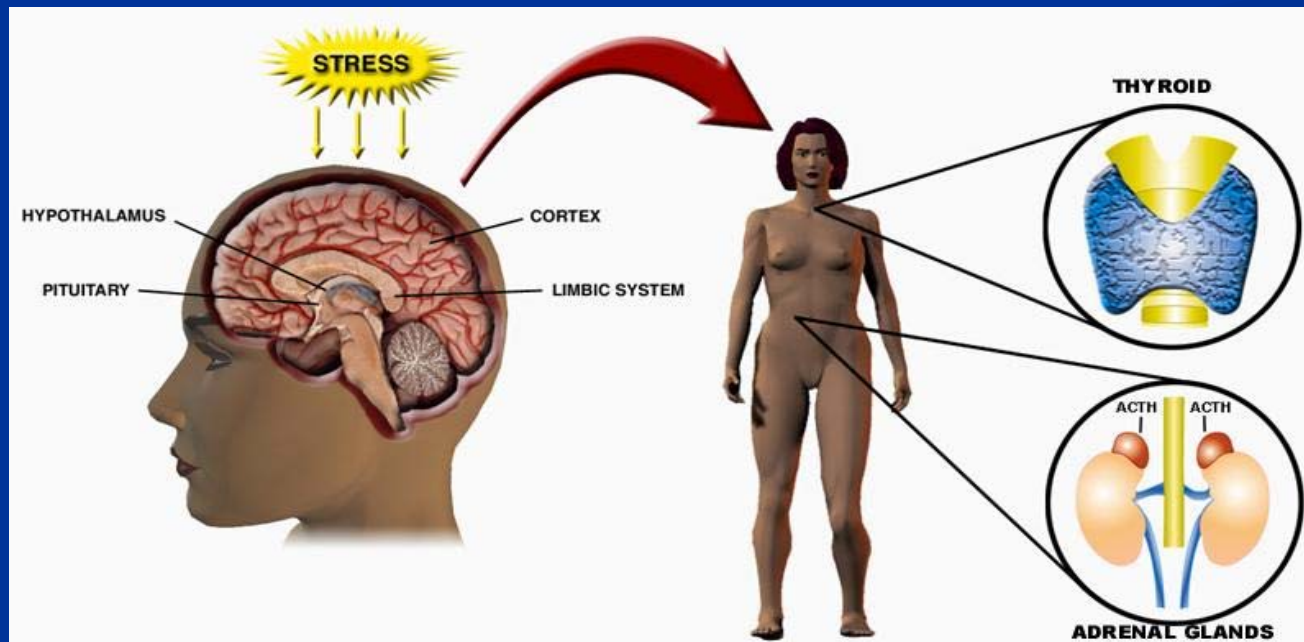
# The Adolescent Brain is *Plastic*

- Plasticity research shows that experience changes neural patterns for better or for worse.
- Creates unique opportunities for emotional-motivational learning
  - sculpts connections *between* cognitive control and emotional systems to create lasting changes
- Scaffolding/social support
- Relevance to prevention, early intervention and policy



# \*\*\*Chronic stress primes the brain for novelty seeking and drug use\*\*\*

- Alters brain function, disengages coping mechanisms, and compromises ability to execute rational choices
- Increases the likelihood of psychopathology
- Genetic vulnerabilities affect behavioral outcomes
- Positive attributes of person or environment = protection



# Alcohol and the Adolescent Brain

- More vulnerable to long term damage to memory and other systems
  - Prevents changes in neural circuits involved in learning and attention
  - Disrupts function of the hippocampus: reduces size
  - Prone to seizures after binge drinking
  - Less brain activity overall
- Less vulnerable to perceived negative effects: motor coordination and sedation
- Delays in normal brain development over time
- Causes reduced testosterone in adulthood

The brain images below show how alcohol may harm teen mental function. Compared with a young non-drinker, a 15-year-old with an alcohol problem showed poor brain activity during a memory task. This finding is noted by the lack of pink and red coloring.

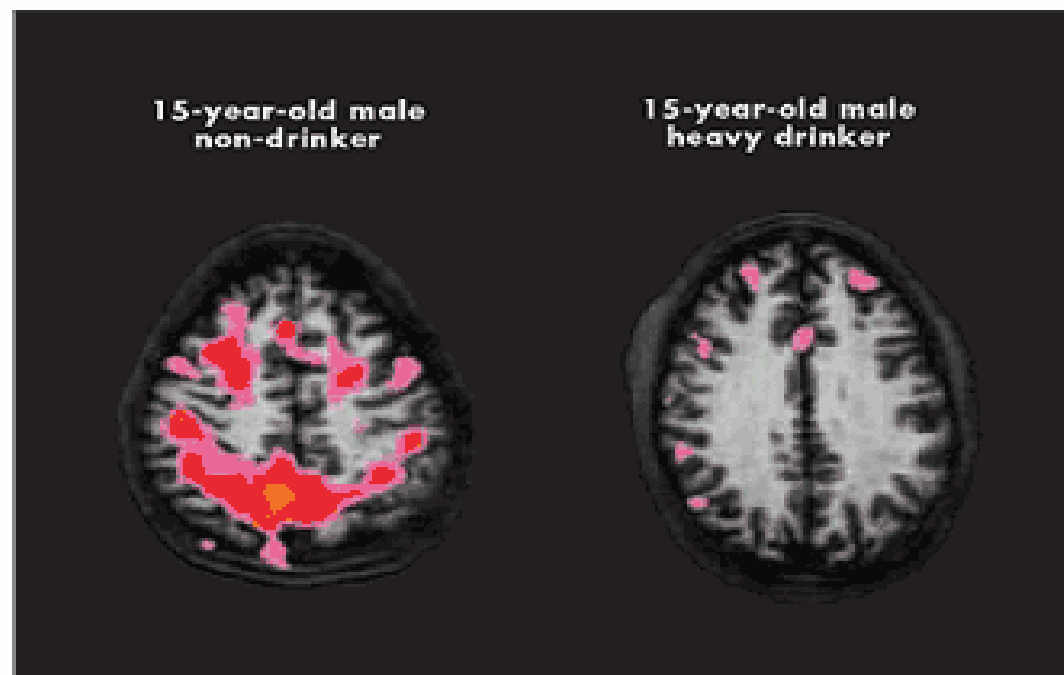


Image from Susan Tapert, PhD, University of California, San Diego.

# Marijuana's Unique Effects in Adolescence

- Greater damage in adolescents
  - Learning impairment and amotivation
  - Limits coping skills
  - Interferes with reproductive development
  - Suppresses immune system
  - Inhibits sperm production
- Higher rates of anger and depression
- Panic attacks in susceptible users
- RECENT RESEARCH: long term damage to hippocampus

# Gender: Girls' Disadvantages

- Greater *sensitivity* to stressors, particularly familial
  - Strongly related to early pubertal maturation
- Greater *incidence* of stressors in antisocial girls
  - Greater early pubertal maturation in antisocial girls
- Proneness to psychological and psychiatric illnesses: e.g., depression and anxiety (over  $\frac{3}{4}$  in JJ system)
- Differences in development of amygdala and hippocampus heighten stress sensitivity
- Adrenal gland sensitivity negatively alters mood
- Estrogen amplifies stress responses, increasing mood disturbances
- Perception of greater stress than males



# Gender: Girls' Advantages

- Larger Prefrontal Cortex → less acting out behaviors
- Advanced language and verbal skills
- More effective processing of social and emotional cues
- Female hormones protect against cognitive damage from stress
- “Tend and Befriend”, rather than “Fight and Flight” due to hormonal differences

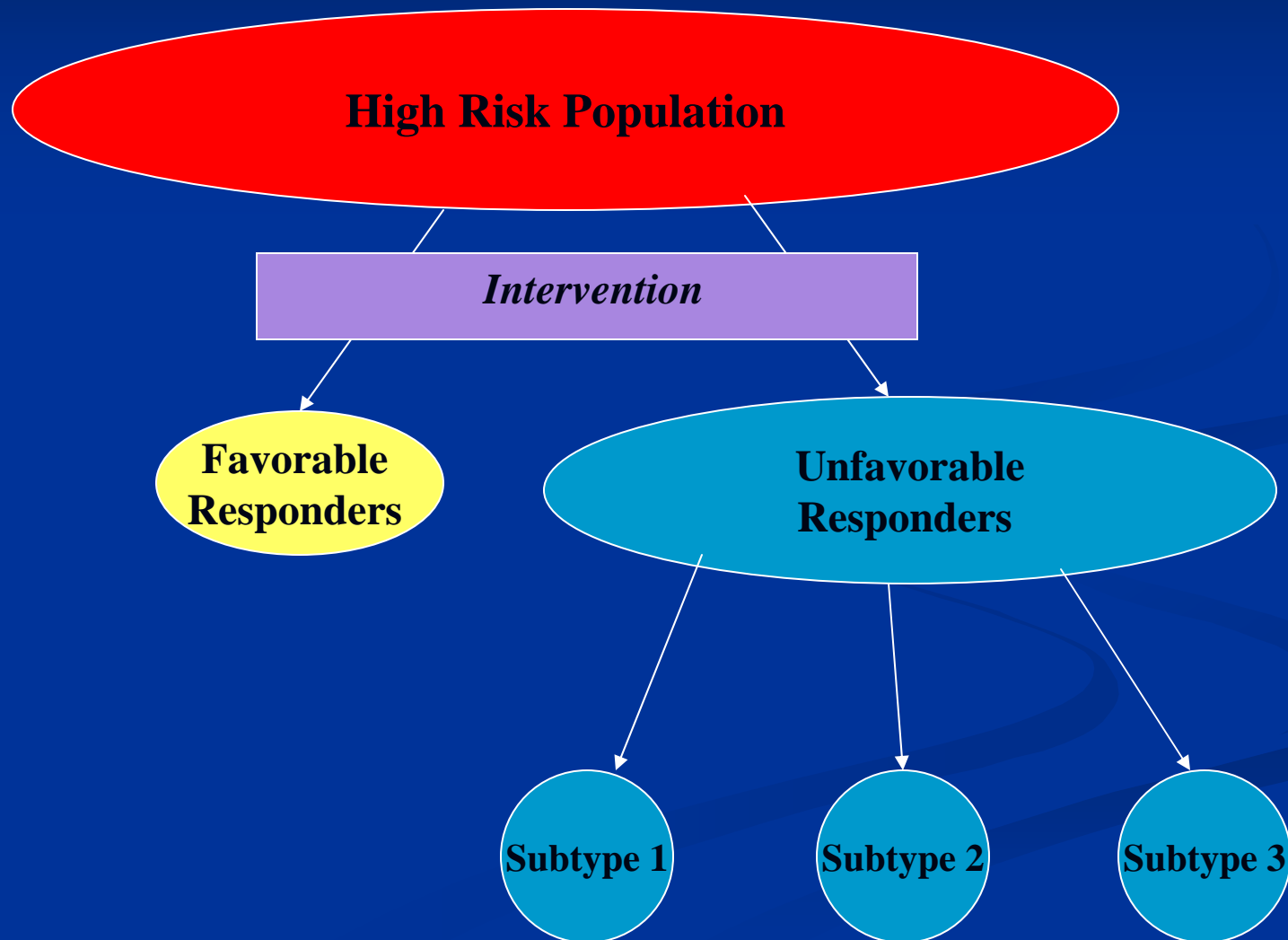
# Cognitive and Emotional Regulatory Differences

- Hot and Cool Cognition
  - Cool = cognitive processing without emotional context
  - Hot = emotional context for performing a task or solving a problem
- Girls develop PFC-limbic circuitry later than boys due to female hormones
- Girls have larger and more active PFC so can suppress externalizing behaviors but not internalizing

# Translational Research

- Basic understanding of the underlying pathophysiology of mental and behavioral disorders.
- Extends basic research findings to develop novel, efficacious prevention or treatment interventions:
  - Why do some respond well to conventional treatments?
  - Characterize heterogeneous subgroup that does not respond.
  - Does “effective” treatment actually change brain function?

# Differential Responses to Treatment Programming



# Prerequisites to Favorable Intervention Response

Processing materials requires participants to:

- ✓ Be cognizant of and responsive to potential negative consequences of behavior
- ✓ Inhibit inappropriate behavioral responses
- ✓ Understand and act on the benefits of deliberate and cautious decision-making



Deficits in *behavioral inhibition* and *dysregulated emotional responses* during cognitive processing may compromise ability to:

- Digest program materials
- Execute appropriate behaviors

# Recent Prevention Study

To assess the extent to which ECF and emotional perception moderate response to a model preventive intervention curriculum (PACT).

# Summary of Results

- Neurocognitive and Emotional Deficits Predicted Lack of Behavioral Change in Response to Acute Prevention:
- Adolescents with CD actually did worse with the intervention than nonCD kids
- Deficits in decision making and social competency skills explained the relationship b/t childhood stressors and adolescent drug use

# Psychopathy Exemplifies Need to Match Interventions to Generators

They are responsible for:

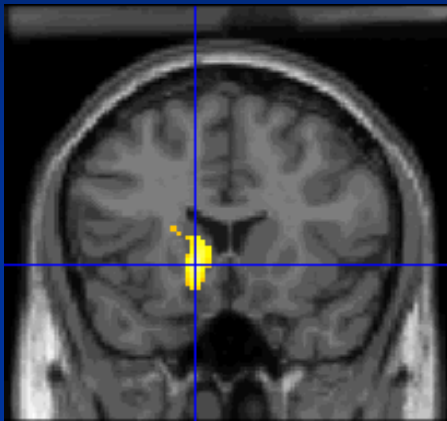
- A disproportionate amount of aggressive crimes against persons
- High recidivism rates
- High rates of substance abuse
- *Poor intervention outcomes*

# Domain Differences between Psychopaths and Nonpsychopaths

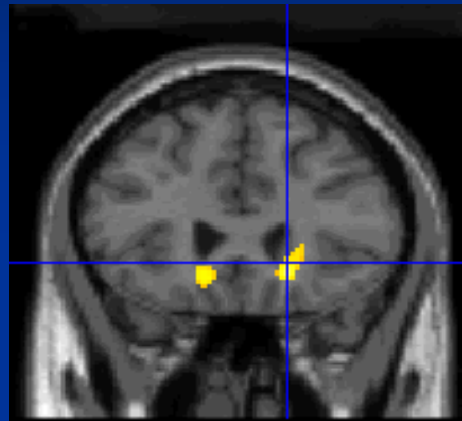
- ✓ Behavioral/Psychological
- ✓ Physiological
- ✓ Neuropsychological
- ✓ Chemical
- ✓ Neurological



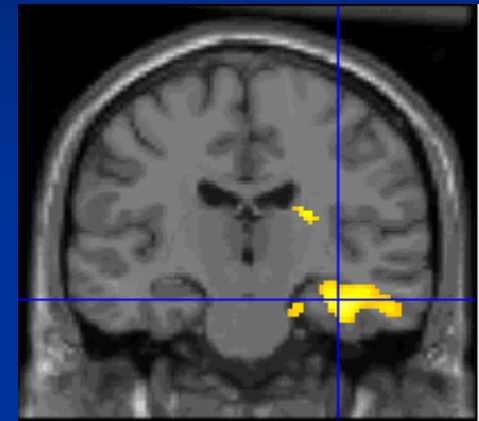
# Risky Decision Making: Neural Activation Patterns for Psychopaths > Non-Psychopaths



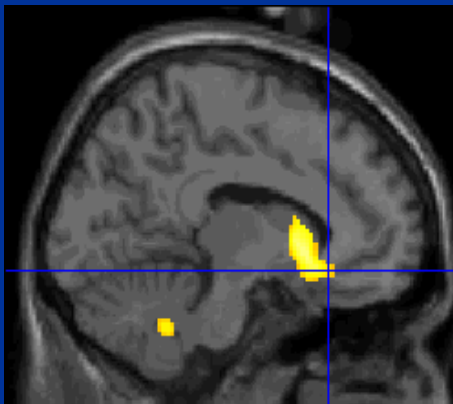
Left Caudate



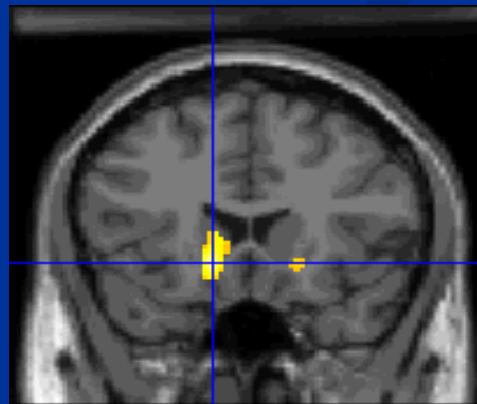
Right Caudate



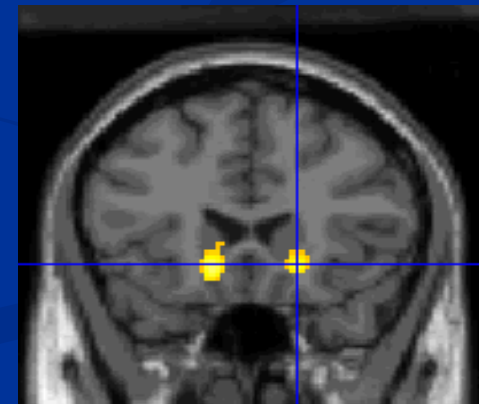
Right Hippocampus



Left Infragenual ACC

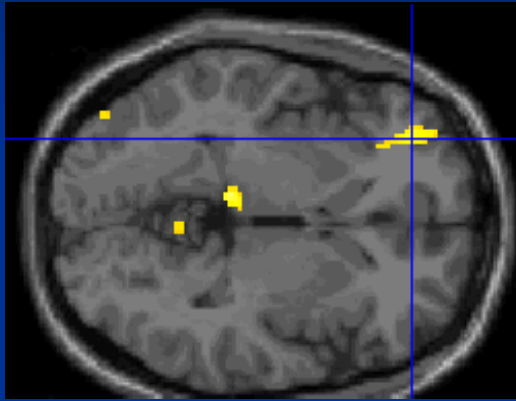


Left Ventral Striatum

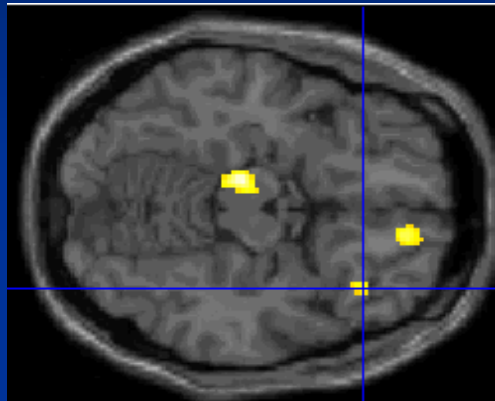


Right Ventral Striatum

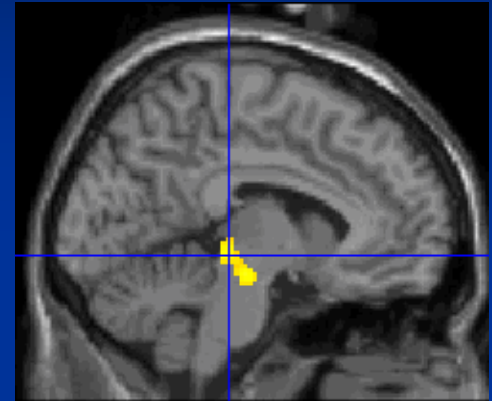
# Activation during Emotional Stroop: Psychopaths > Non-Psychopaths



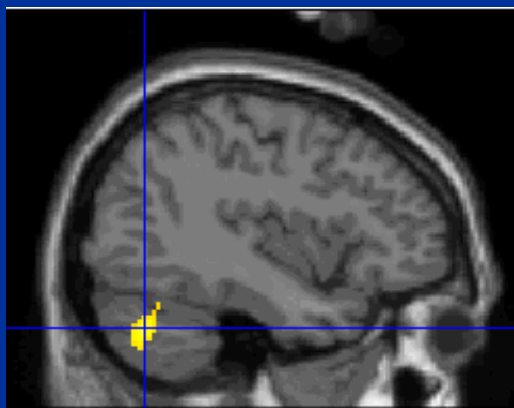
Left Lateral OFC



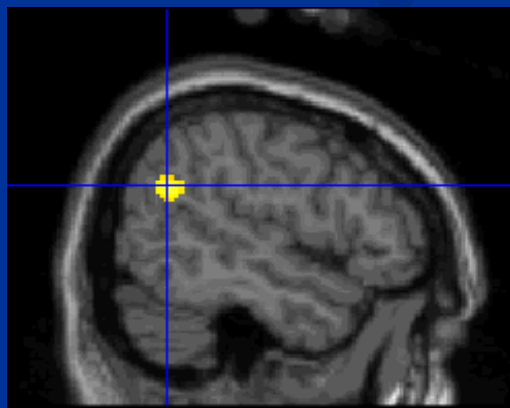
Right Lateral OFC



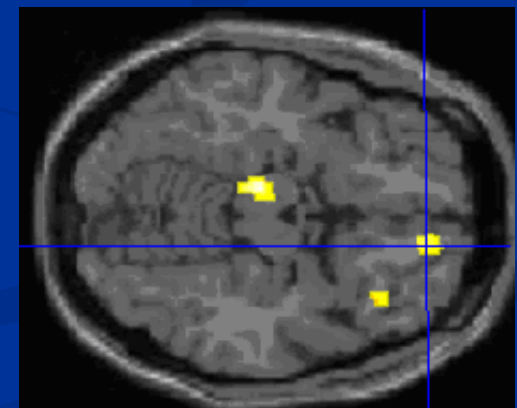
Periaqueductal Gray Matter



Left Cerebellum



Right Inferior Parietal Lobule



Right Medial OFC

# Processing Differences between Psychopaths and NonPsychopaths

Brain regions that regulate executive decision-making are reversed for processing cognitive vs emotional stimuli.

- Limbic and PFC disconnect causes more attention to rewards and less to penalty.
- Performance in psychopaths may be related to relative lack of activity in regions critical for error monitoring and affect.
- Result: cognitive deficits, lack of inhibitory control, absence of empathy, manipulativeness, and emotional detachment.

***Need for Interventions Targeted to Specific Deficits***

# **Underlying Mechanisms in Response to Prison Treatment**

The role of neurocognitive and emotional regulatory functions in prison treatment outcomes among inmates.

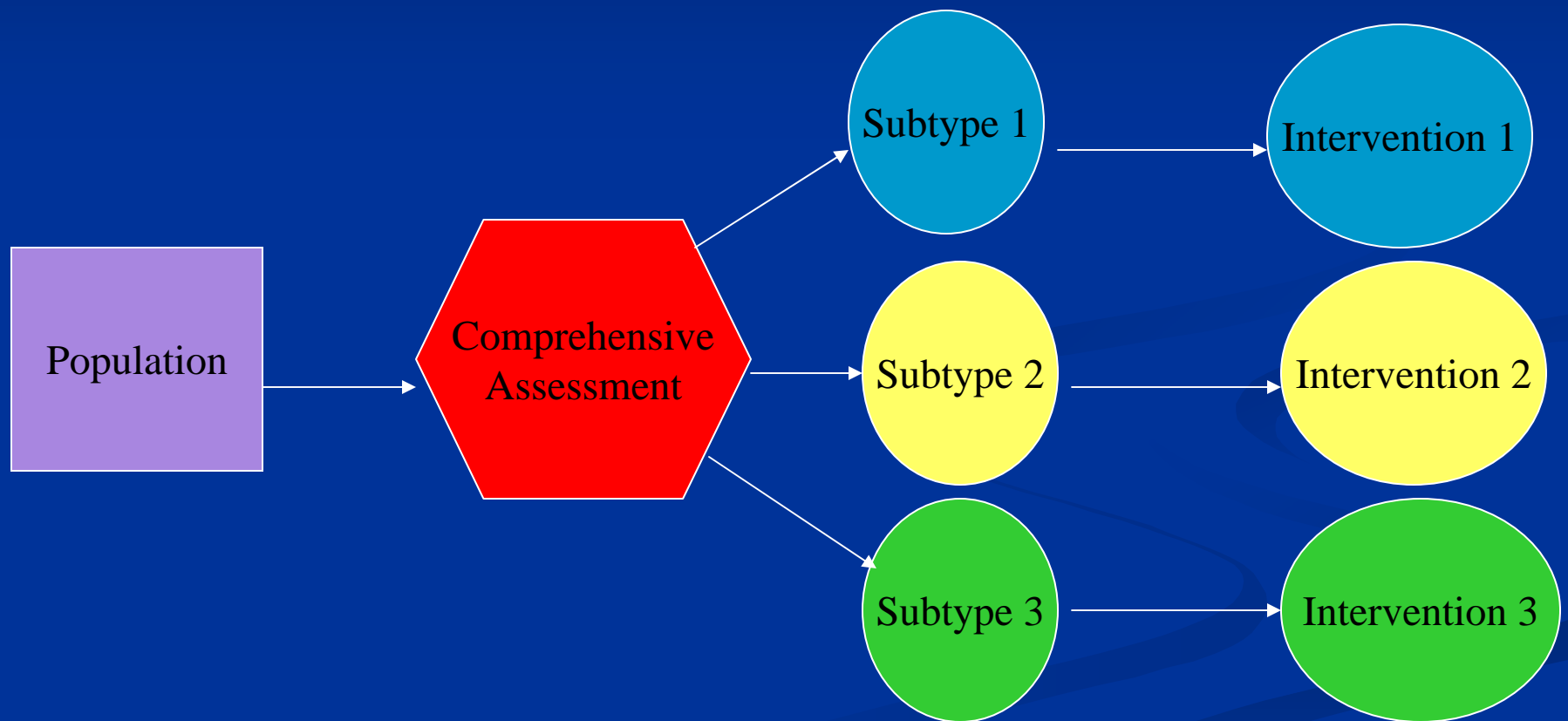
# Population

- Pseudo-random sample from 3 Maryland medium-maximum correctional institutions
- Approximately 225 inmates who volunteered for treatment
- Males between 21 and 45 years of age
- Literate and  $IQ > 70$
- At least 18 months left on their sentence
- No evidence of psychosis or severe mental disability

# Results

- Neuropsychological variables, esp impulse dyscontrol, predicted treatment response, gain and retention, as well as institutional infractions and segregations
- History of physical abuse significant predicted treatment outcomes
- Poor responders had lower cortisol response to stress
- Most background factors, months in prison, attitudes about treatment, history of drug use, aggression, and psychopathy were not related to treatment outcomes

# Interventions Matched to Special Needs of Individual or Subgroup





# Intervention Strategies Implicated by Brain Research

## Match intervention to individual's special needs:

- *Prenatal care* and mandatory *parenting classes*
- *Early identification* of children at risk
- *Provide children with:*
  - Stimulating, nurturing environment with strong social bonds
  - Complex cognitive and sensory environment to enhance plasticity and emotional regulation
- Well equipped *child welfare* system with uninterrupted *foster care*
- Incorporate child's *social support system* into programming
- *Stress reduction* and *remediation* for damaged systems
- *Targeted treatment*, e.g., cognitive neurorehabilitation, speech and language therapy, functional and integrative training, psychiatric evaluation and treatment, etc

# Leverage points for early intervention strategies?

Understanding underpinnings (gene x environment x **development** interactions) of affect regulation and cognitive control will inform:

- Type and timing of optimal intervention:
  - “universal prevention”
  - targeted interventions for high-risk youth
- Specific candidate areas of focus
  - Puberty-specific effects on cognition, motivation, emotion, & affect regulation
  - Affect and Sleep/Arousal Regulation
  - Gender differences

# A Developmental Perspective on Juvenile Justice

A fair and enlightened JJS takes into account the developmental and psychological facts of adolescence:

- Juvenile law does not account for differences between adolescents and adults
- Research should guide and inform law, policy and practice
- Need to improve quality of our practices for juvenile clients
- Need for interdisciplinary collaboration among lawyers, judges, clinicians and researchers

# Pertinent Questions

- Competence: Do juveniles have the same capacity as adults to participate in the trial process?
- Culpability: Should youths be held to the same level of accountability as adults when they commit crimes?



# Competency

- Ability to assist legal counsel and make decisions crucial to their defense
  - Less knowledgeable about legal process than adults
  - Basic cognitive & reasoning abilities are less mature
  - Socially inexperienced
  - Emotionally driven
  - Less likely to trust lawyers and communicate effectively

# Culpability

- Can they be held responsible for their actions in the same way as adults?
  - Emotionally and cognitively immature
  - Lack of future orientation
  - Susceptibility to peer pressure: group context
  - Inability to recognize risks inherent in their choices, much less consequences of their legal decisions
- Need for individualized JJS treatment
  - Maturity improves gradually and at different rates
  - High prevalence of mental disorders and developmental delays
  - High prevalence of economic disadvantage and adversity



“Juvenile offenders are criminals who happen to be young, not children who happen to be criminal.”

Get-tough advocate.





# Exemplars of Policy Changes Based on Developmental Information

- Adolescent driving
  - Duration of probationary license
  - Cell phone use
  - Other teenagers in the car
  - Curfew
- Fewer waivers to adult court in some states
  - Those waived more likely to commit new crimes
  - Except for psychopaths
- Alternatives to incarceration
- High schools opening later
- Increasing number of educational programs in schools focusing on risky decision making and behavior

# Enlightened Juvenile Justice

More questions than answers, but should consider:

- Diminished capacity
- Age-appropriate institutions, programs and protections
- One-kid-at-a-time approach (Zimring)
- Fully justified judicial decisions
- Special treatment (esp. given increasing numbers)
- IQ predicts competence to stand trial

# Conclusions

- Adolescents in the JJ or CJ system are not only subject to the normal perturbations in puberty, but may also present with numerous additional problems and special needs
- Adolescents may be less culpable but more capable of change and rehabilitation than adults.
- The science does not excuse adolescents from responsibilities for their crimes, but it offers some potential remedies.