

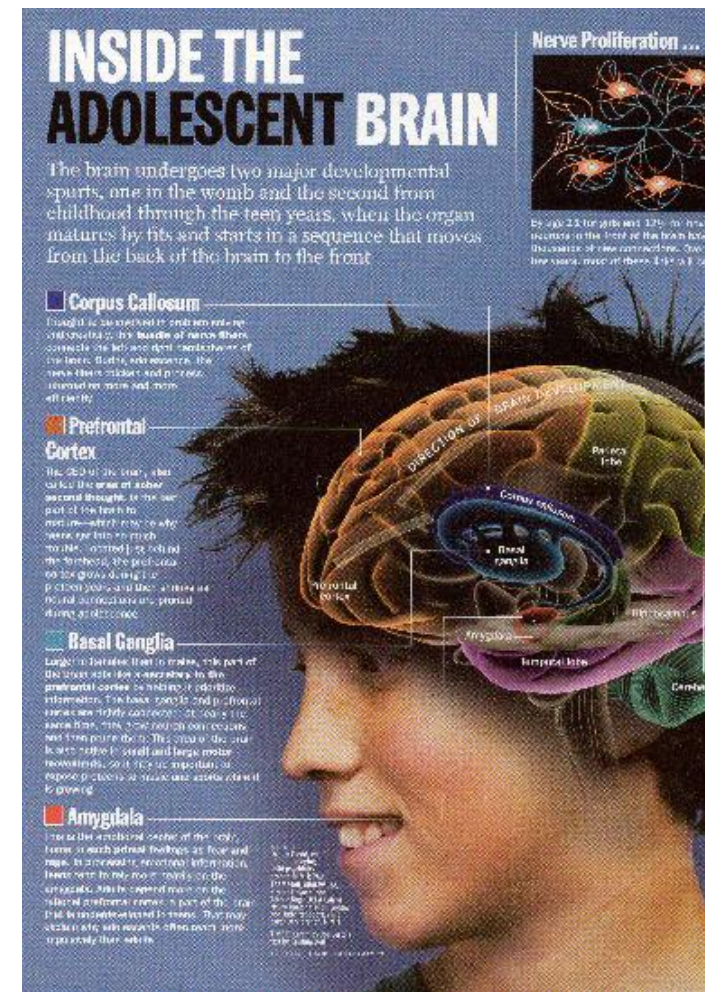
# The Adolescent Brain

## Traffic Safety and Risk Taking

Ken Winters, Ph.D.  
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University of Minnesota  
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Southeast Minnesota Toward  
Zero Deaths Workshop

May, 2009



# Get Out of My Life,

*but first could you drive me and Cheryl to the mall?*



A PARENT'S GUIDE TO THE NEW TEENAGER

Anthony E. Wolf, Ph.D.

NATIONAL BESTSELLER

*"There's still good old-fashioned information, advice, and wisdom, I highly recommend it!" —Edward Hallowell, author of Driven to Distraction and The Unofficial Guide to Adult ADHD*

# Why Do They Act That Way?

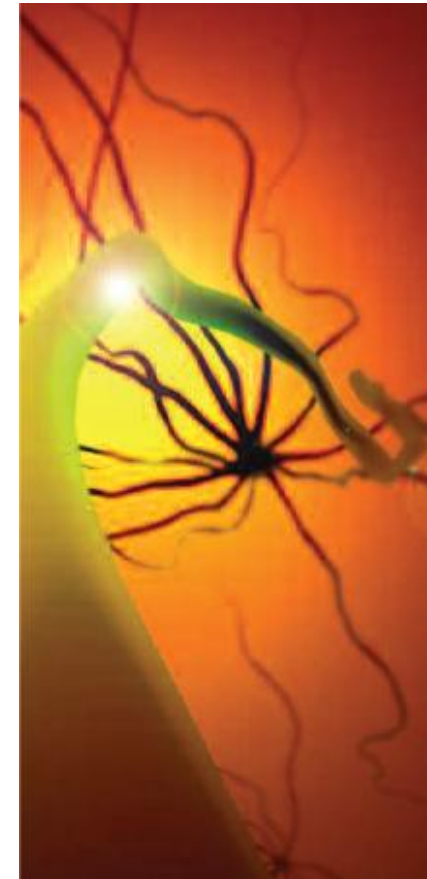
KEEP  
OUT

A Survival Guide  
to the Adolescent Brain  
for You and Your Teen

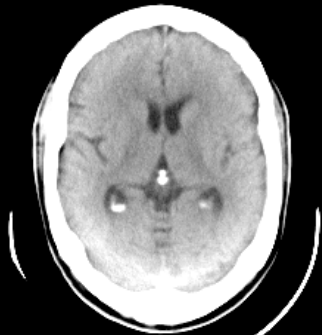
DAVID WALSH, Ph.D.

# Emerging Science: Brain Imaging

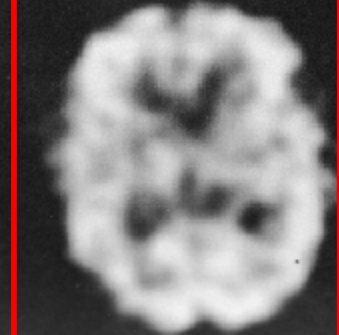
- **New insights because....**
  - 1990's information explosion due to brain imaging techniques (e.g., CT, PET and MRI).



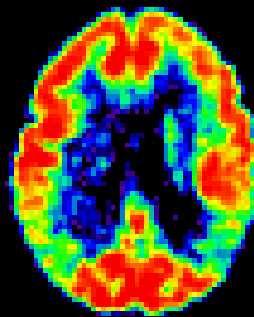
# Imaging Modalities



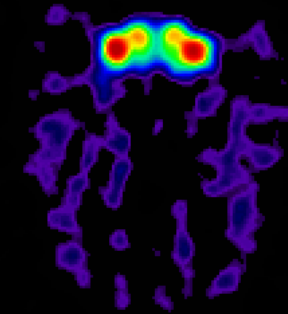
**CT**



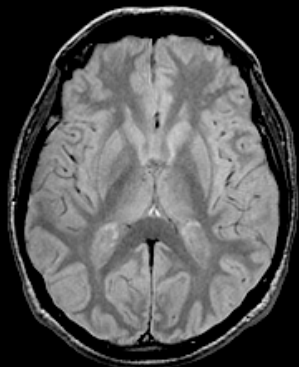
**SPECT**



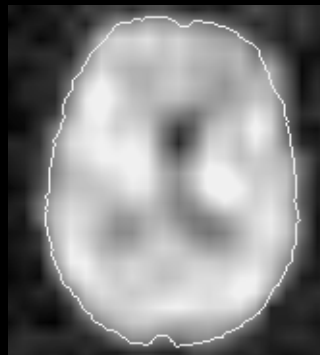
**FDG PET**



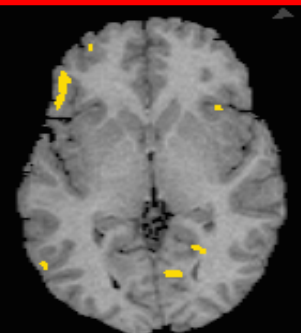
**Ligand PET**



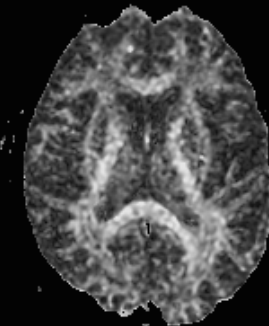
**Anatomic MRI**



**MR Spectroscopy**



**fMRI**



**Diffusion MRI**

§ Adolescence is a period of profound brain maturation.


§ We *thought* brain development was complete by adolescence

§ We now know... maturation is not complete until about age 25!!!

# INSIDE THE ADOLESCENT BRAIN

The brain undergoes two major developmental spurts, one in the womb and the second from childhood through the teen years, when the organ matures by fits and starts in a sequence that moves from the back of the brain to the front.

## Nerve Proliferation ...



By age 25, for girls and 25% for boys, the neurons in the front of the brain have lost the capacity of new connections. Over 70% of the neurons made at birth still exist by age 25.

### Corpus Callosum

Though it is as small as a centimeter wide, the corpus callosum is the bundle of nerves that connects the left and right hemispheres of the brain. During adolescence, the nerve fibers thicken and proliferate, resulting in more and more efficient connectivity.

### Prefrontal Cortex

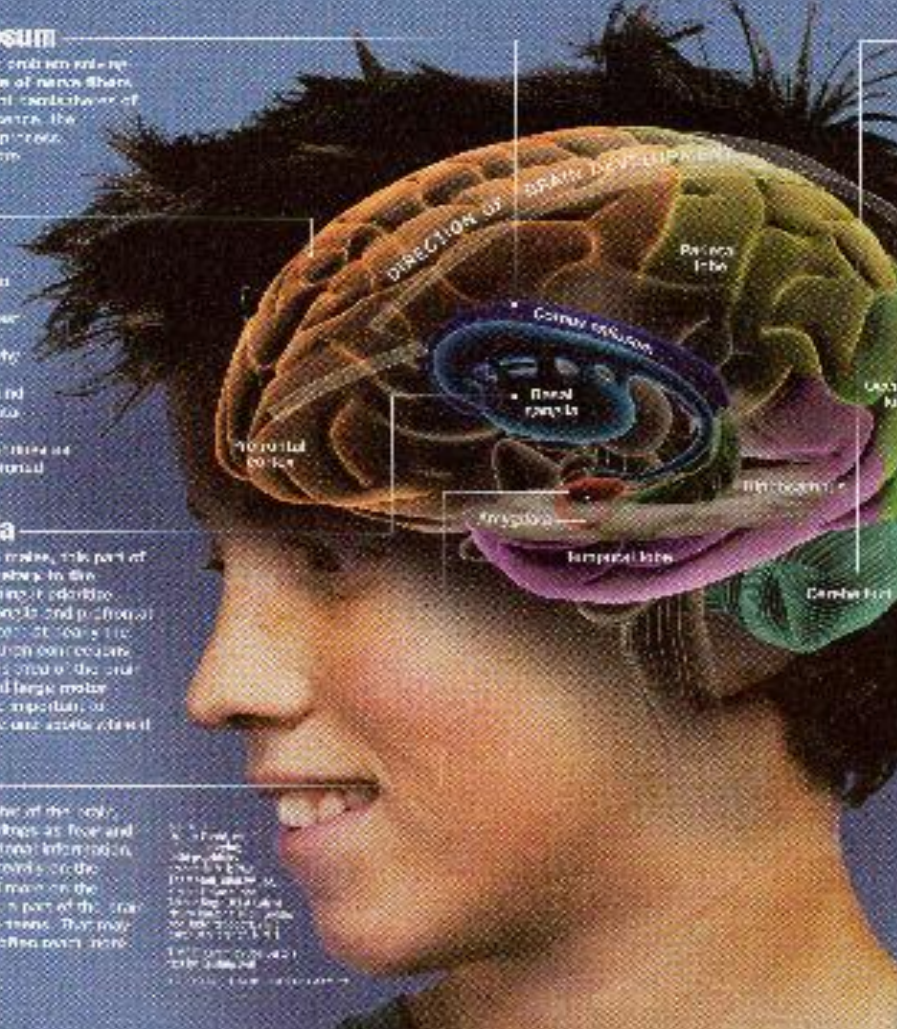
The CEO of the brain, also called the seat of higher-level thought, is the last part of the brain to mature. Not only how, but why we think is much more complicated just behind the forehead, the prefrontal cortex grows during the adolescent years and then continues to develop and mature until about age 25.

### Basal Ganglia

Larger in females than in males, this part of the brain acts like a switchboard to the prefrontal cortex by helping it sort through information. The basal ganglia and prefrontal cortex are tightly connected. It's like the switchboard, with a few neuron connections and then you're done. This part of the brain is still in small and large motor neurons, so it's an important, especially in the case of males, and it's still in process.

### Amygdala

One of the emotional centers of the brain, it's a small almond-shaped structure. It's involved in processing information, especially when it's about fear or the amygdala. It's a part of the limbic system, a part of the brain that's involved in emotion. That may explain why, when you're often overreacting to things, that's why.

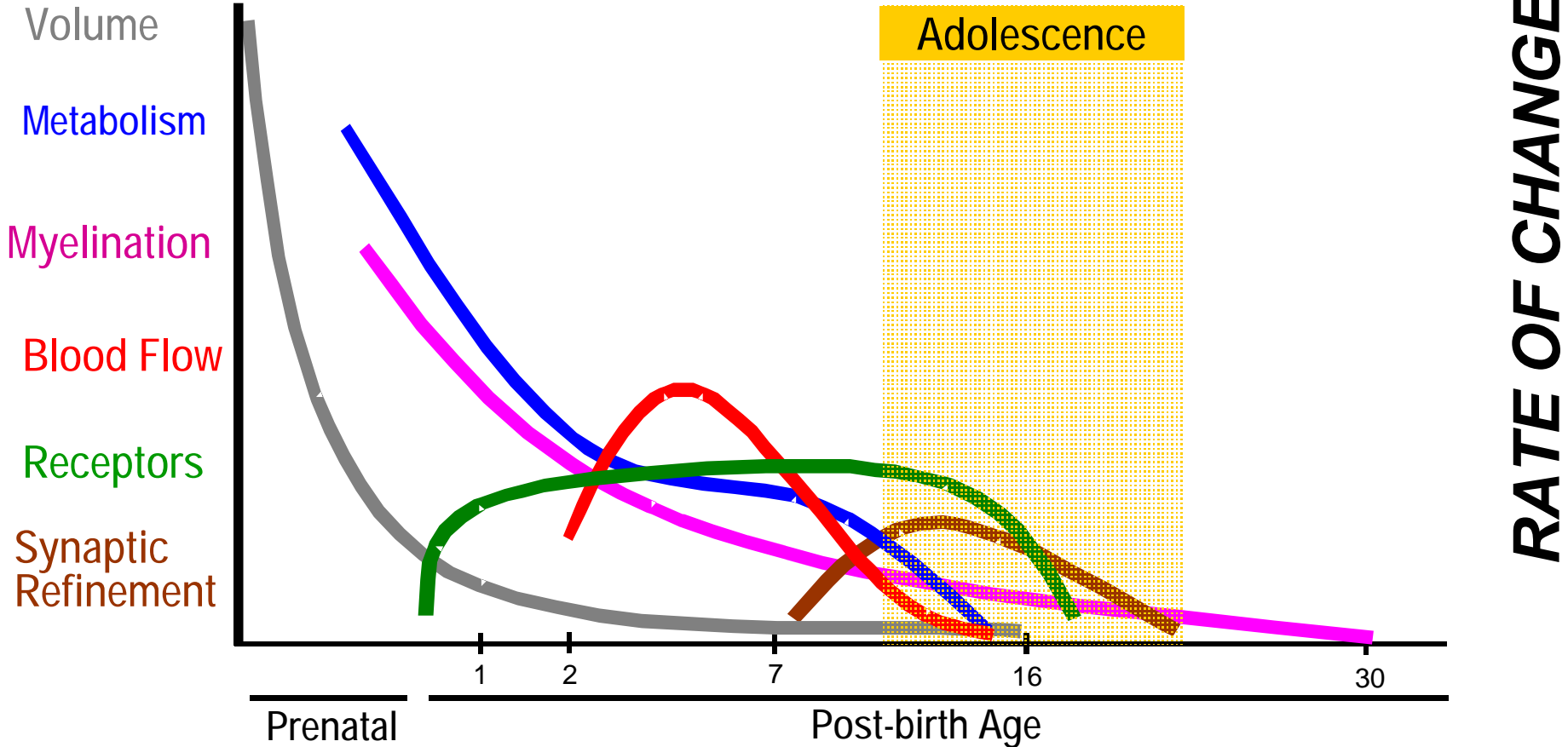


Labels in the diagram include: Prefrontal cortex, Direction of spatial development, Corpus callosum, Basal ganglia, Amygdala, Temporal lobe, and Cerebellum.

# An Immature Brain = Less Brakes on the "Go" System



# Brain Development



Tapert & Schweinsburg (2005)

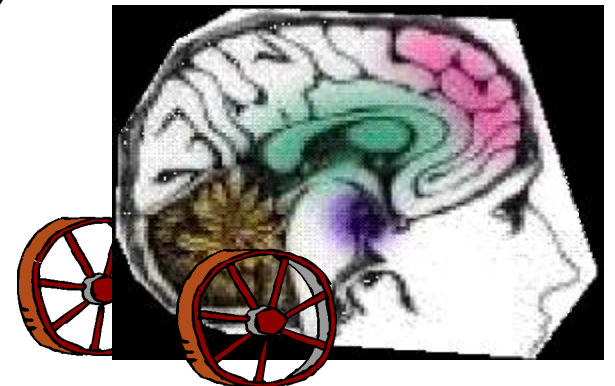
# Construction Ahead



- When the pruning is complete, the brain is faster and more efficient.



- **But...** during the pruning process, the brain is not functioning at full capacity.

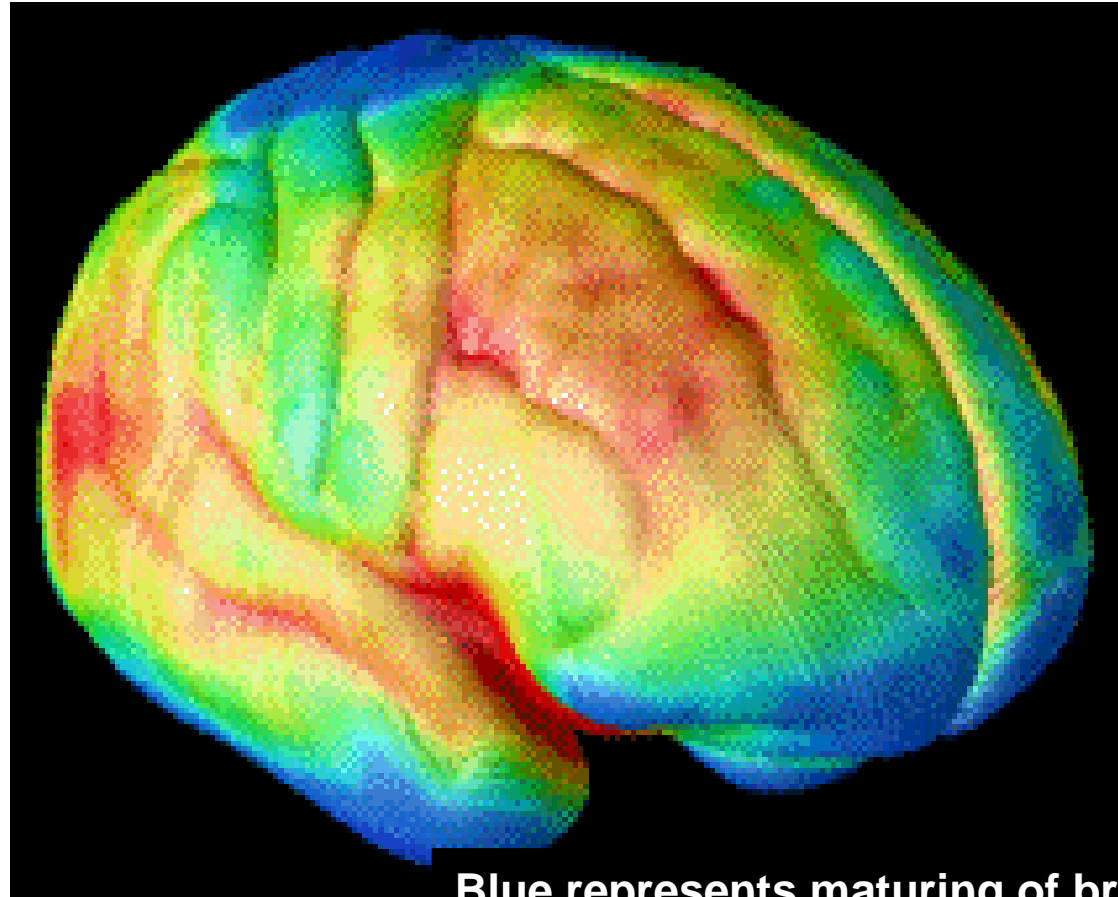


# Maturation Occurs from Back to Front of the Brain

## Images of Brain Development in Healthy Youth (Ages 5 - 20)

**Earlier:**  
Motor Coordination  
Emotion  
Motivation

**Later:**  
Judgment



Blue represents maturing of brain area

**Source: PHAS USA 2004 May 25; 101(21): 8174-8179. Epub 2004 May 17.**



Evidence accumulating that **being in a group** accentuates risk taking in youth more so than with adults

- Drug use with peers is the norm, not the exception
  - This one of the more reliable and long standing findings in the adolescent drug abuse literature (e.g., Clayton, 1992)



# Seven Implications of Arrested Development for Adolescent Behavior

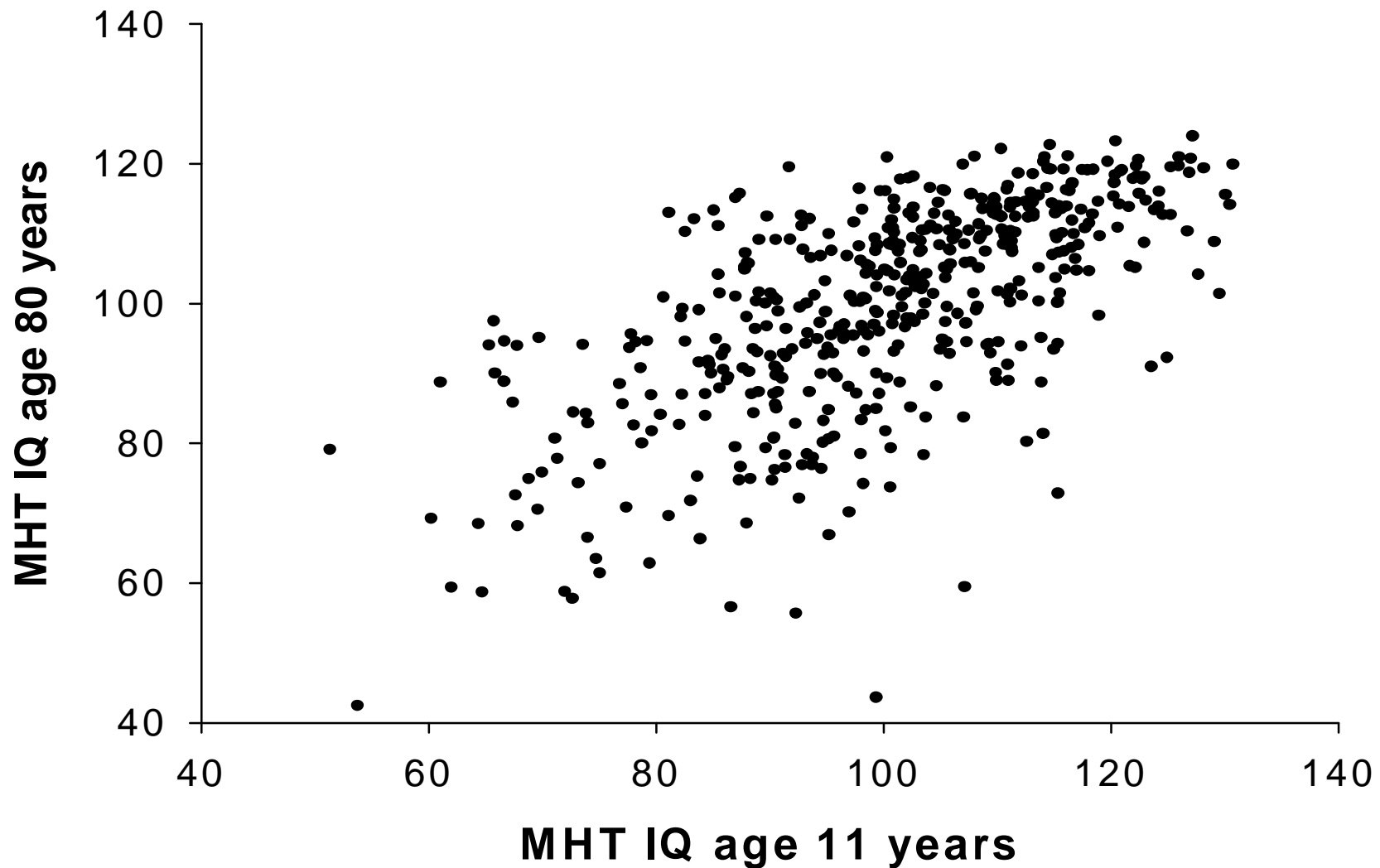
- Preference for ....
  1. physical activity
  2. high excitement and low effort activities
  3. activities with peers that trigger high intensity/arousal
  4. novelty
- Less than optimal..
  5. balance of emotion and logic when making decisions
  6. consideration of negative conseq.
- Greater tendency to...
  7. take risks and show impulsiveness



# An Immature Brain $\neq$ Low Brain Power



# Taking the Same Ability Test at Age 11 & Age 80: Scottish Mental Survey 1932



**Deary et al. (2004) *Journal of Personality and Social Psychology*, 86, 130-147.**

# An Immature Brain $\neq$ Absence of All Judgment



# Judgment Gets Better with Age



- By age 18, the adolescent's judgment for structured challenges is roughly equal to that of adults.
- But judgment that involves resisting impulses or delaying gratification is still under construction during late adolescence and early adulthood.

# Adolescence and driving.

## INSIDE THE ADOLESCENT BRAIN

The brain undergoes two major developmental spurts, one in the womb and the second from childhood through the teen years, when the organ matures by fits and starts in a sequence that moves from the back of the brain to the front.

### Nerve Proliferation ...



By age 13 for girls and 15 for boys, the neurons in the front of the brain have lost the capacity to fire continuously. Over the next years, most of these cells will be pruned.

### Corpus Callosum

Though it is as thick as a pencil and no wider than a hair, the bundle of nerves that connects the left and right hemispheres of the brain, fluffing into separate, thin nerve fibers, makes and processes information more and more efficiently.

### Prefrontal Cortex

The CEO of the brain, also called the area of higher-level thought, is the last part of the brain to mature—likely why teens are late to reach the adult world just behind the forehead, the prefrontal cortex grows during the adolescent years and then continues to develop and mature during adulthood.

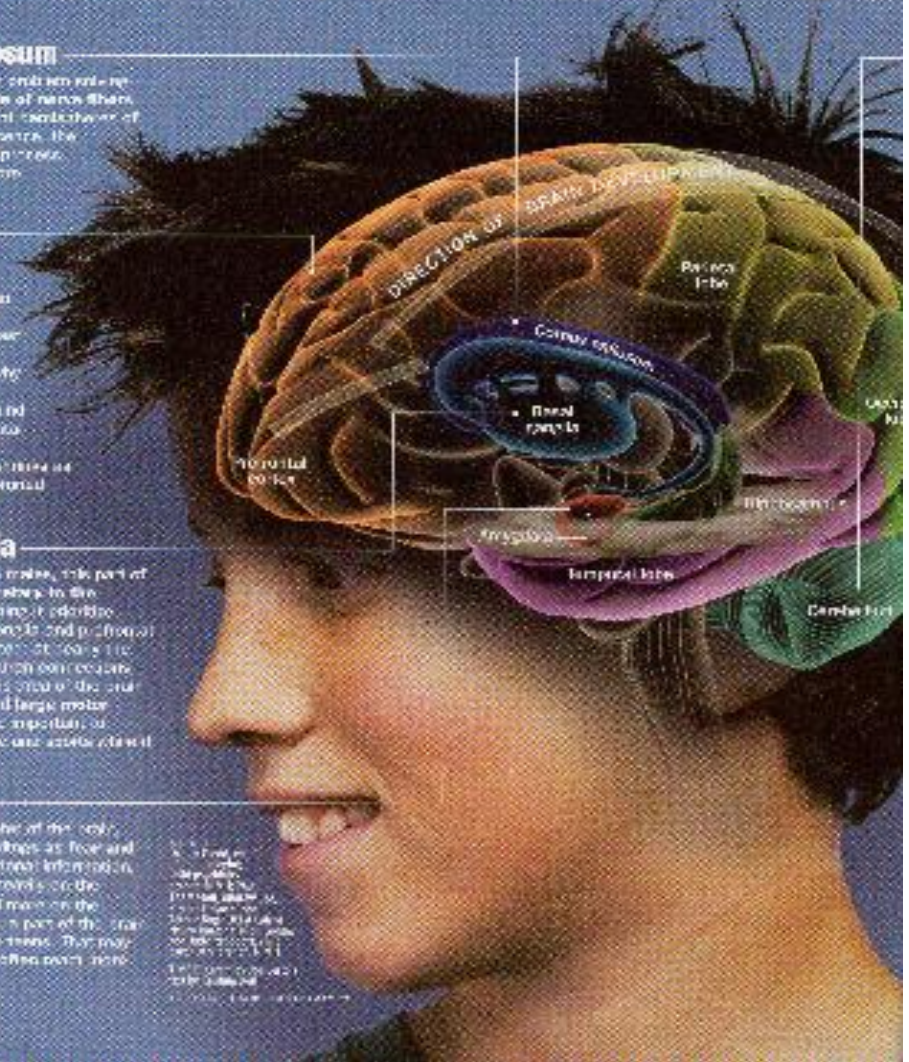
### Basal Ganglia

Larger in females than in males, this part of the brain acts like a secretary to the prefrontal cortex by helping it sort through information. The basal ganglia and prefrontal cortex are tightly connected. It sends the executive, high-level thought instructions and then pours the oil. The size of the basal ganglia helps in small and large motor movements, so it is an important, if especially in males, area associated to driving.

### Amygdala

One of the emotional centers of the brain, it reacts to feelings as love and rage. It processes emotional information, like when to be nice or to yell at the carpool. This is especially true for the adolescent brain, which is part of the limbic system and is more reactive. This may explain why adolescents often react more intensely than adults.

Source: *Brain Development in Adolescence*, by Daniel R. Anderson, Ph.D., and David Reardon, Ph.D., published by the American Psychological Association.



# Driving in the Kid Lane

---

- Motor vehicle crashes are the leading cause of death for 16- to 20-year-olds
  - about 5,500 teenage drivers or passengers die each year
  - about another 450,000 teenagers are injured, 27,000 of them requiring hospitalization
- Of those teenagers who are killed.....
  - 63 percent are drivers
  - boys account for about two-thirds of the fatalities

# Driving in the Kid Lane



- Although teenagers represent only 6 percent of drivers, they are involved in 14 percent of fatal crashes
- The crash rate among 16-year-olds is nearly nine times the rate of the general population

# Driving in the Kid Lane

- Inexperience

- Highest crash rate: the first month after teenagers got their license.
  - The crash rate drops dramatically with the next five months; in 12 months it drops by a factor of 3-fold

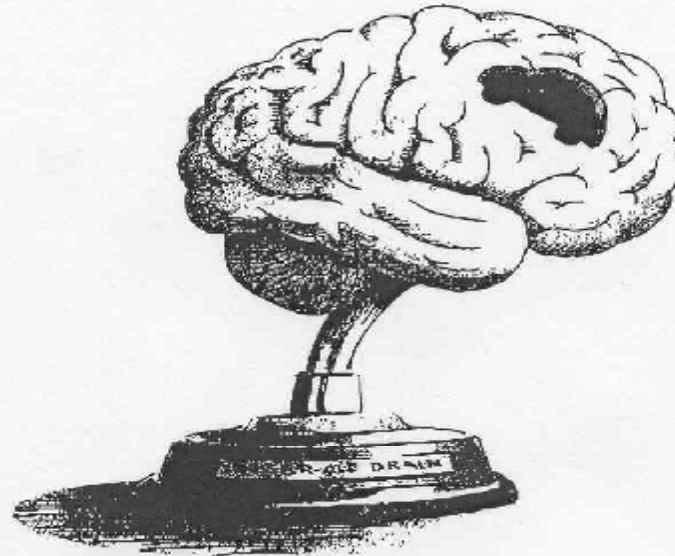
- Distractions

- cell phones, other passengers, adjusting radio

# Why do most 16-year-olds drive like they're *missing a part of their brain?*



BECAUSE THEY ARE.



Allstate ad, *NY Times*,  
May, 2007

EVEN BRIGHT, MATURE TEENAGERS SOMETIMES DO THINGS THAT ARE "STUPID."

But when that happens, it's not really their fault. It's because their brain hasn't finished developing. The underdeveloped area is called the dorsal lateral prefrontal cortex. It plays a critical role in decision making, problem solving and understanding future consequences of today's actions. Problem is, it won't be fully mature until they're into their 20s.

It's one reason 16-year-old drivers have crash rates three times higher than 17-year-olds and five times higher

crashes. These laws restrict the more dangerous kinds of driving teens do, such as nighttime driving and driving with teen passengers. Since North Carolina implemented one of the most comprehensive GDL laws in the country, it has seen a 25% decline in crashes involving 16-year-olds.

To find out what the GDL laws are in your state, visit [Allstate.com/teen](http://Allstate.com/teen). Help enforce them—and if they aren't strong enough, ask your legislator to strengthen them.

Let's help our teenagers not miss out on tomorrow just

# Adolescence, driving and alcohol.

## INSIDE THE ADOLESCENT BRAIN

The brain undergoes two major developmental spurts, one in the womb and the second from childhood through the teen years, when the organ matures by fits and starts in a sequence that moves from the back of the brain to the front.

### Corpus Callosum

Though it is as thick as a pencil and is only slightly larger than a bundle of nerves, the corpus callosum connects the left and right hemispheres of the brain, allowing information to travel between the two sides and process it more efficiently.

### Prefrontal Cortex

The CEO of the brain, also called the seat of higher-level thought, is the last part of the brain to mature—likely why teens are late to reach the legal drinking age. In the forehead, the prefrontal cortex grows during the adolescent years and then continues to develop and mature during adulthood.

### Basal Ganglia

Larger in females than in males, this part of the brain acts like a secretary to the prefrontal cortex by helping it organize information. The basal ganglia and prefrontal cortex are tightly connected, allowing the brain to make decisions and learn from its mistakes. The basal ganglia is also involved in small and large motor movements, so it plays an important role in sports and other activities that require fine motor control.

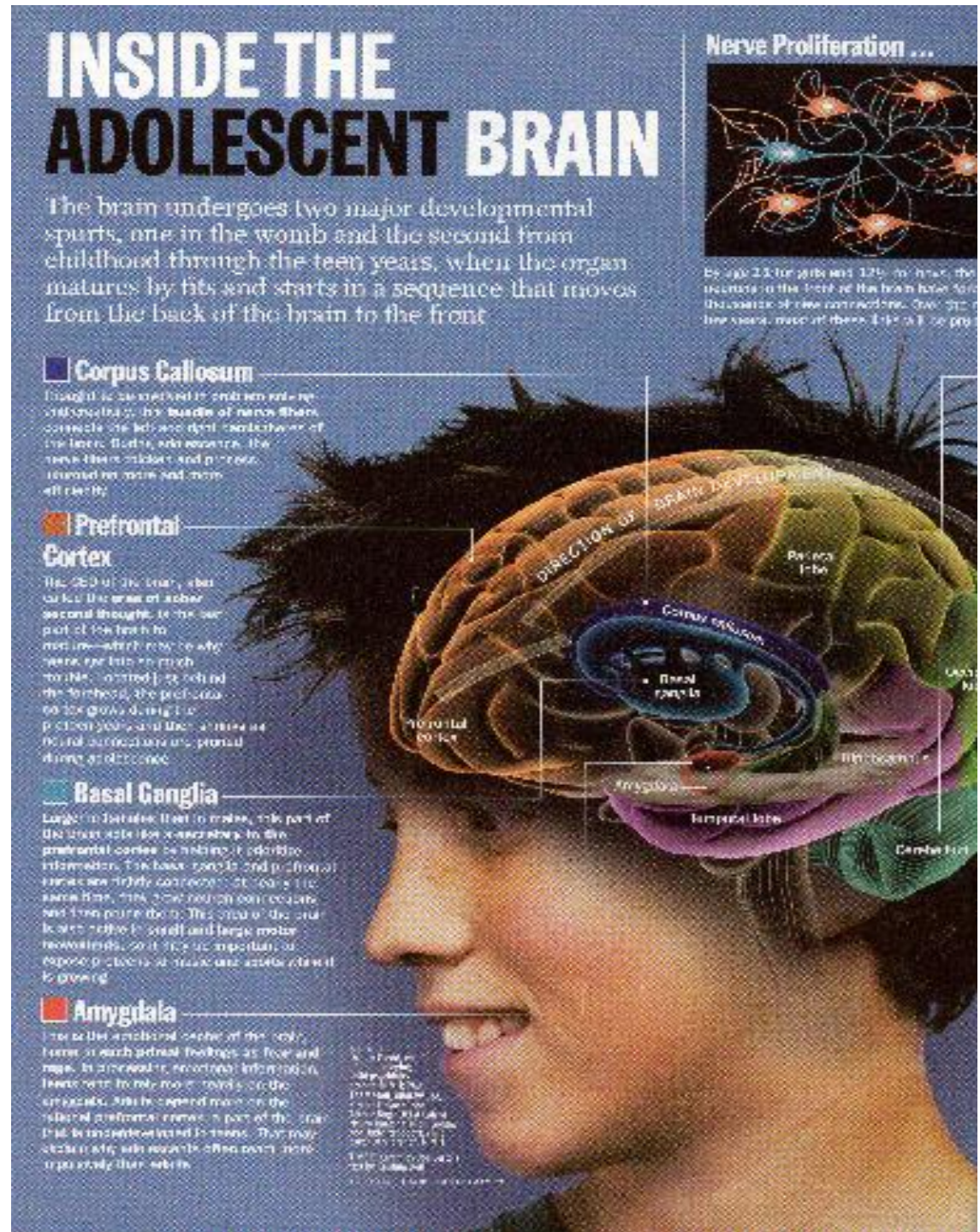
### Amygdala

One of the emotional centers of the brain, the amygdala processes feelings such as fear and rage. It is involved in processing information from the senses and is also involved in the amygdala. This is especially true for the adolescent brain, which is still developing. The amygdala is also involved in learning from its mistakes and is important for the development of the brain's ability to learn from its mistakes.

### Nerve Proliferation ...



By age 13 for girls and 15 for boys, the number of neurons in the brain has increased to the point of being nearly constant. Over the next years, most of these cells will be pruned.



# Motor Vehicle Crash and Age of Drinking Onset (N = 4,021; national sample)

Age of Drinking Onset	Odds Ratio: After Drinking	Odds Ratio: After Not Drinking	Significance
< 14	9.3	1.5	< .01
14 - 15	7.7	1.8	< .01
16 - 17	4.3	1.3	< .01
18 - 20	2.5	1.0	< .05
21+	1.0	1.0	

Hingson et al., 20

# Factors predicting DUI

## CA study



- **Predictors of increased likelihood of DUI**
  - drinking in unstructured situations
  - peers engage in or approve of drinking-driving
  - parental monitoring
  - perceived DUI law enforcement

# Riding with a teenage drunk driver

## Canada study



- **Significant predictors:**
  - Rural residence
  - Single parent
  - Lower SES
  - Lower school affiliation
  - Prior hx of drinking-driving

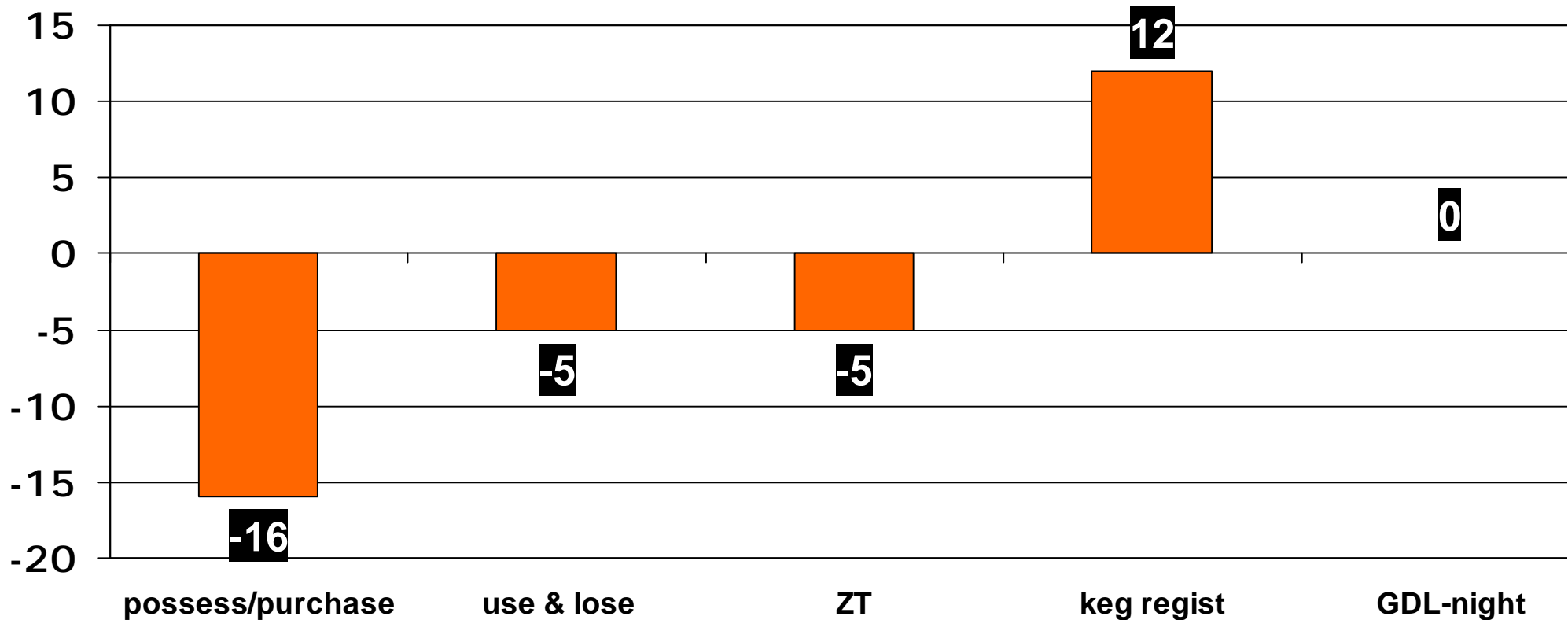
# The Impact of Underage Drinking Laws on Alcohol-Related Driving Fatalities

(Fell et al., 2009)



- Examined 5 laws pertaining to under age 21 drinking restrictions
- These 3 has the largest effects on reducing drinking-and-driving fatalities:
  - purchase/possession
  - zero tolerance
  - use and lose
- These 2 were not related
  - GDL - night restrictions
  - keg registration

# Underage drinking laws effects on ratio of age <21 drinking drivers to age <21 nondrinking drivers in fatal crashes (1982 to 2004)



Fell et al., 200

# Adolescence and alcohol.

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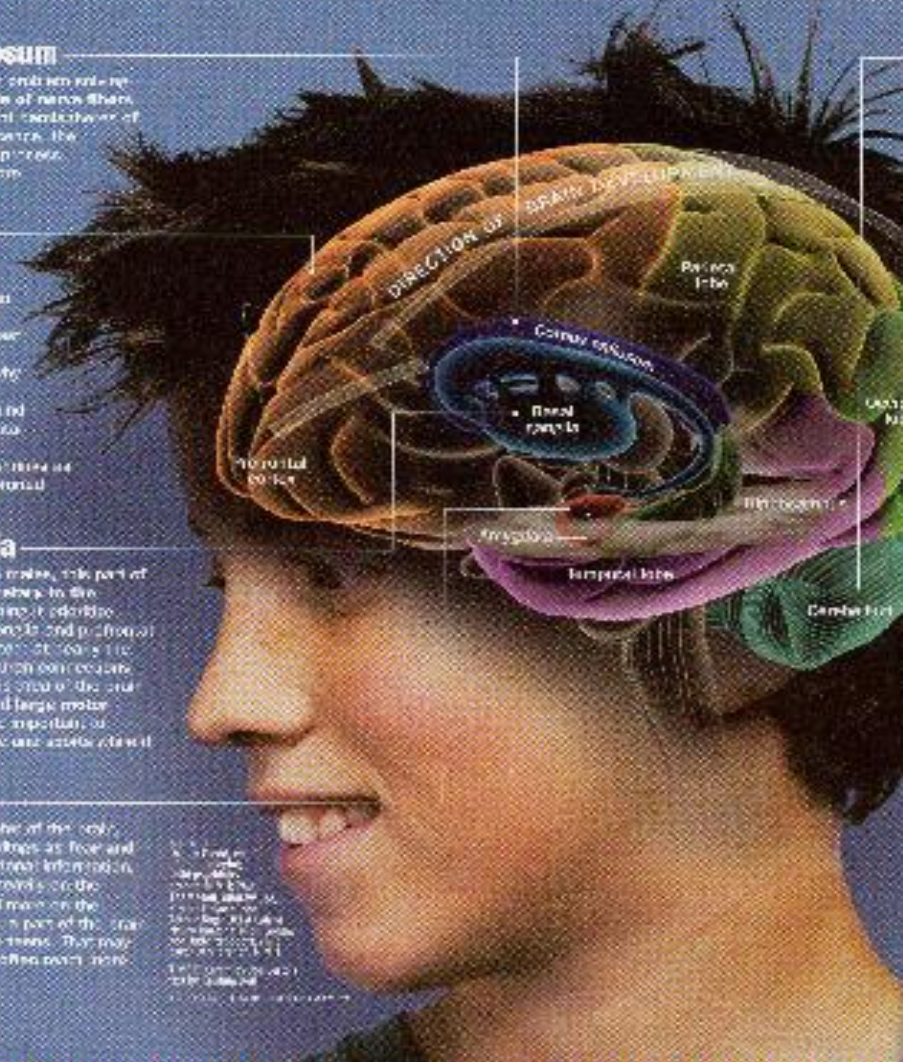
### Amygdala

One of the emotional centers of the brain, it is involved in processing information, especially when it comes to fear and stress. The amygdala is also involved in the brain's reward system, which is why it is so important in forming habits and preferences.


### Nerve Proliferation ...



By age 13 for girls and 15 for boys, the number of neurons in the brain has nearly doubled since birth. Over the next few years, most of these cells will be pruned.

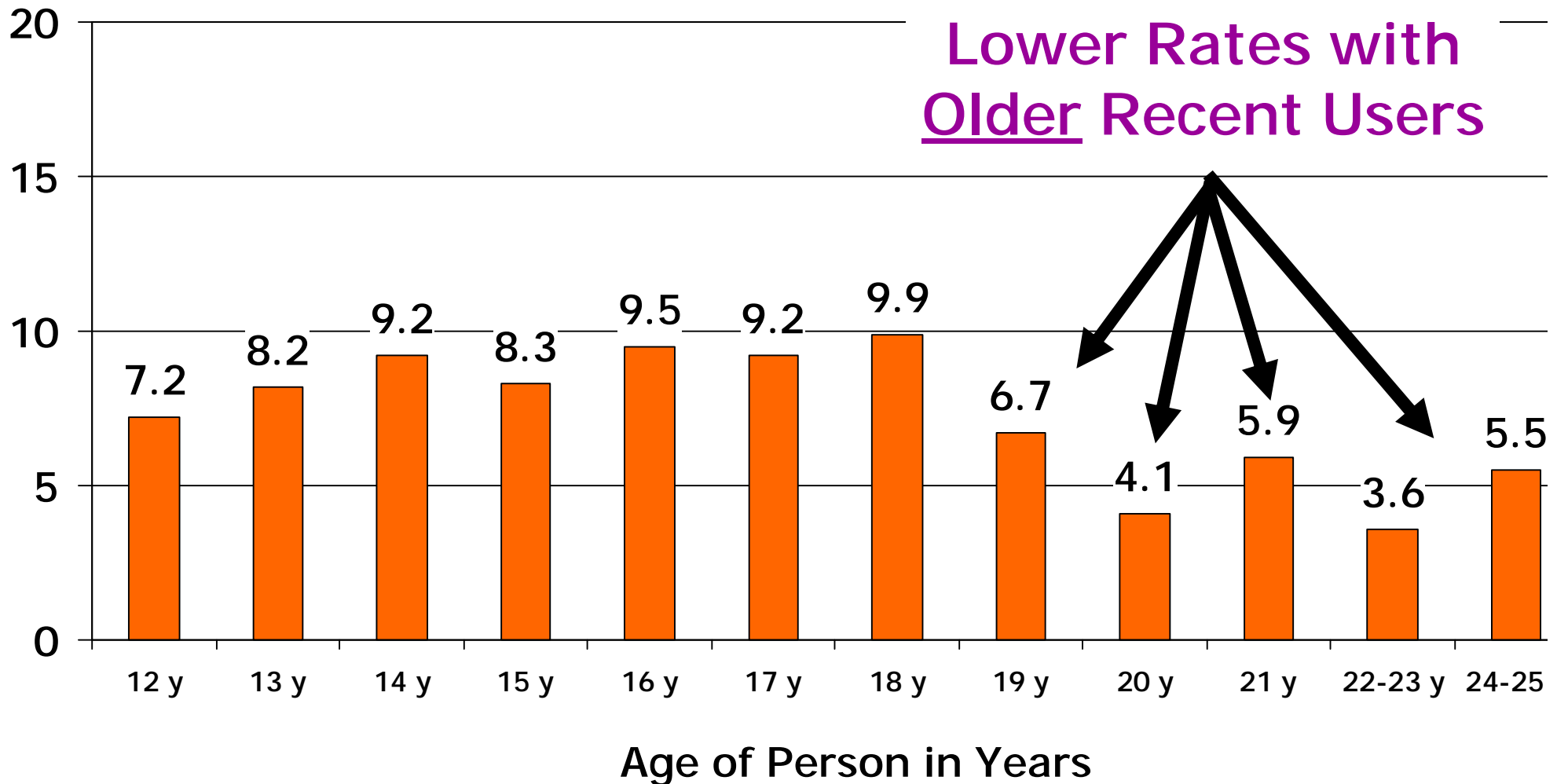


# Evidence in support that youth are highly vulnerable to the effects of alcohol




- 1. Greater rates of alcohol dependence**
2. Reduced sensitivity to intoxication
3. Increased social disinhibition
4. Increased cognitive disruption

# Percentages of Past Year Alcohol Use Disorder Among Those with a Recent Onset (Prior 2 Years) of Alcohol Use (SAMHSA, 2005)



# Evidence in support that youth are highly vulnerable to the effects of alcohol



1. Greater rates of alcohol dependence
- 2. Reduced sensitivity to intoxication**
- 3. Increased social disinhibition**
4. Increased cognitive disruption

# Are adolescents more susceptible to alcohol than adults?



## 1. Epidemiological data

Comparing adolescent and adult rats, both having no prior exposure to alcohol and matched on temperament....



**2. Adolescent rats are less sensitive to the sedative and motor impairment effects of intoxication.**

- more drinking before “signals to stop”

# Are adolescents more susceptible to alcohol than adults?

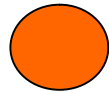


1. Epidemiological data
2. Adolescent rats are less sensitive to the sedative and motor impairment effects of intoxication.
3. Adolescent rats are more sensitive to the social disinhibition effects of alcohol.
  - greater social comfort from intoxication




Wanna look  
for some cheese  
with me?

Sure!

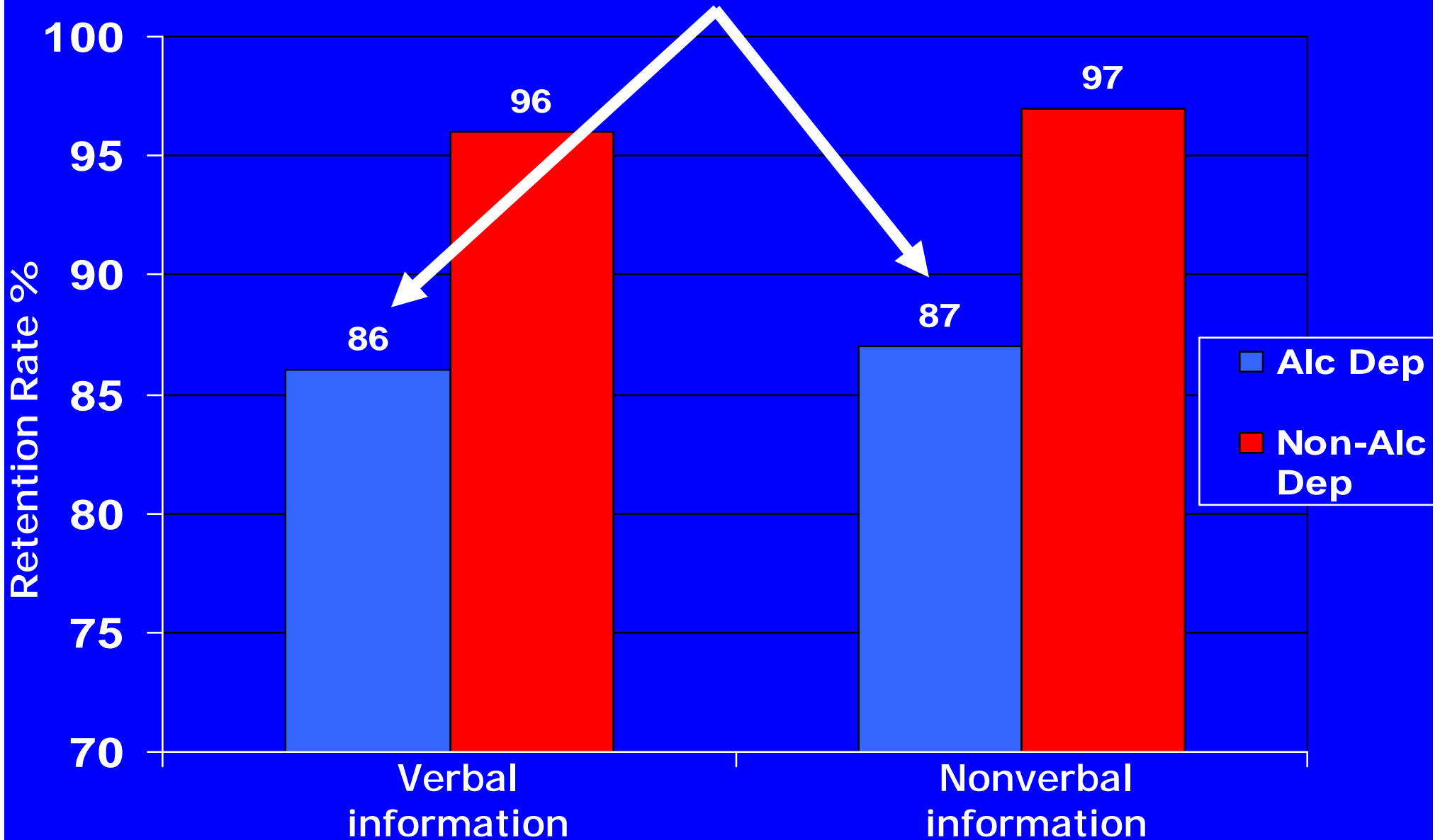


# Evidence in support that youth are highly vulnerable to the effects of alcohol



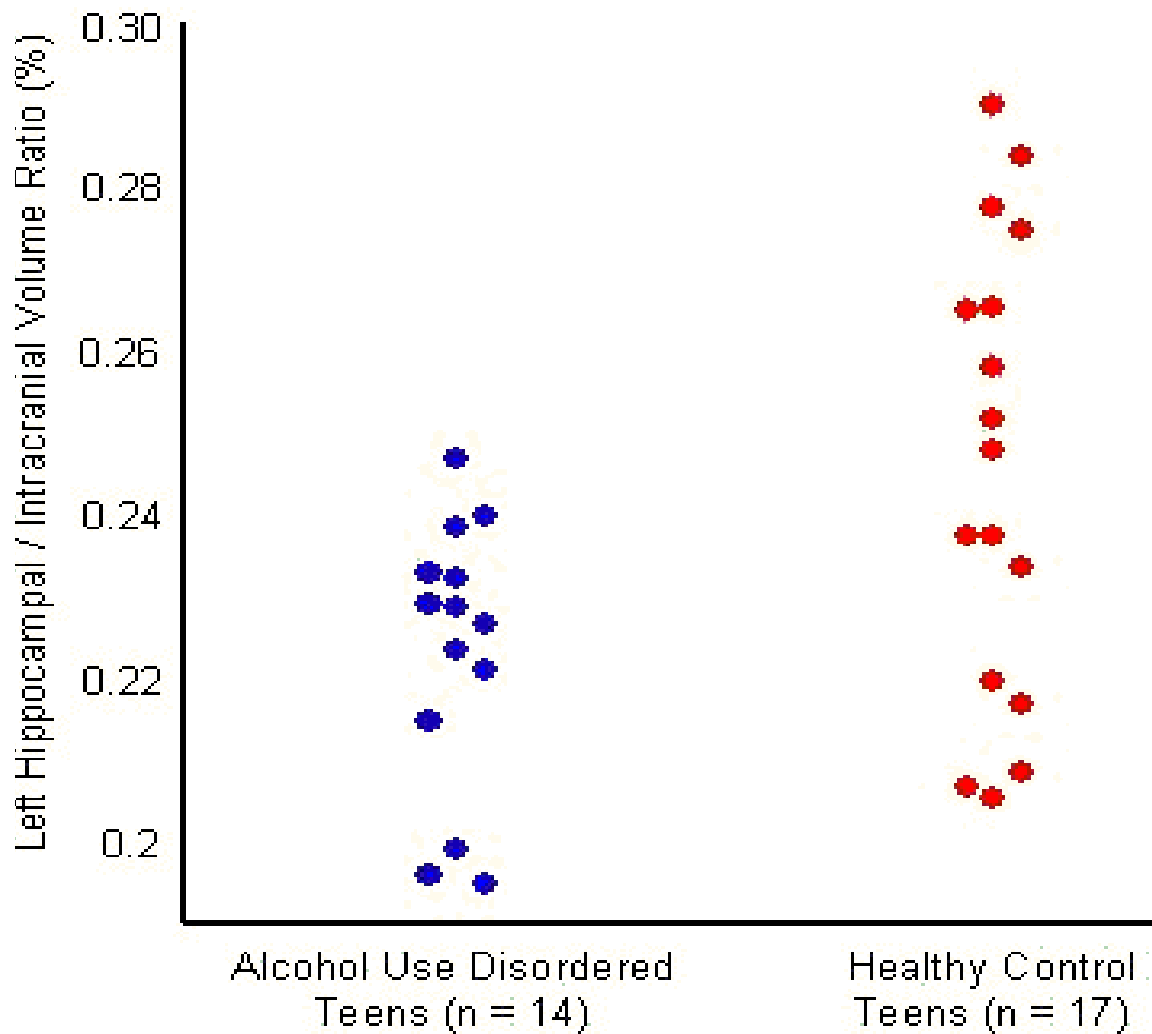
1. Greater rates of alcohol dependence
2. Reduced sensitivity to intoxication
3. Increased social disinhibition
4. **Increased cognitive disruption**

# 10% less retention



Brown et al., , 20

# MRI: Hippocampal Size



- Hippocampus

- Encodes new info
- Left smaller in AUD teens ( $p < .01$ )
- **But no relationship with cognitive functioning (due to less severe alcohol group than Brown et al. sample?)**

Nagel, Schweinsburg, Pham, & Tapert, 20

# Summary

## INSIDE THE ADOLESCENT BRAIN

The brain undergoes two major developmental spurts, one in the womb and the second from childhood through the teen years, when the organ matures by fits and starts in a sequence that moves from the back of the brain to the front.

### Corpus Callosum

Though it is as small as a pin, the corpus callosum is a bundle of nerves that connects the left and right hemispheres of the brain. During adolescence, the nerve fibers thicken and proliferate, resulting in more and more efficient wiring.

### Prefrontal Cortex

The CEO of the brain, also called the seat of higher-level thought, is the last part of the brain to mature—likely why teens are late to reach the adult world just behind the forehead, the prefrontal cortex grows during the adolescent years and then continues to develop and mature during adulthood.

### Basal Ganglia

Larger in females than in males, this part of the brain acts like a secretary to the prefrontal cortex by helping it identify information, take basic signals and push them forward. It's like a secretary who takes notes, files them, and then reports back. The basal ganglia is made up of small and large motor neurons, so it's an important part of the brain's motor and cognitive circuitry.

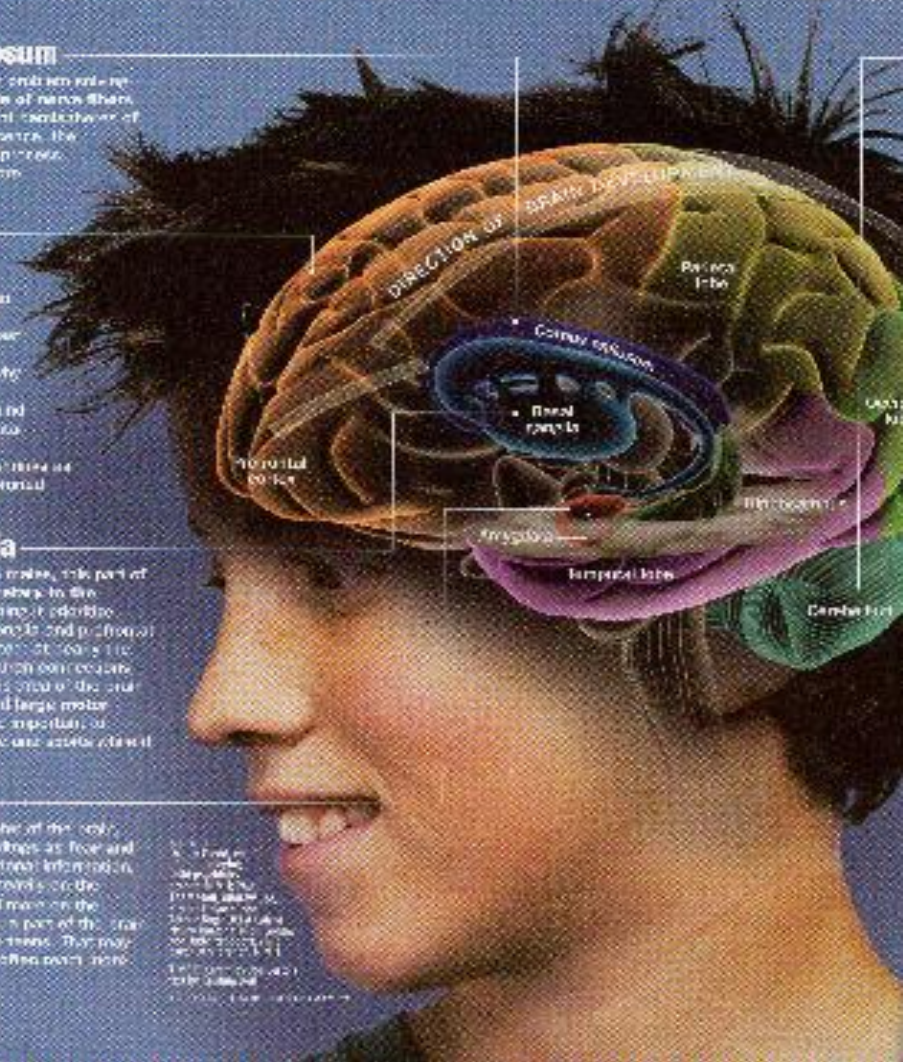
### Amygdala

One of the emotional centers of the brain, it's involved in feelings such as fear and rage. It's involved in processing information, especially when it's related to the amygdala. This is especially true for the adolescent brain, which is still developing. The amygdala is involved in many of the brain's emotional and cognitive functions. It's a key part of the brain's emotional and cognitive circuitry.

### Nerve Proliferation ...



By age 13, for girls and 15% for boys, the number of the type of the brain cells that produce new connections, called GABAergic neurons, more than doubles in the brain.



# Summary



- Adolescence is a 10-20 year period of transition from dependence to independence
- Normal adolescence is characterized by....
  - increase in conflicts with family members
  - desire to be with one's friends
  - resistance to messages from authority
  - irritability
  - **risk taking (unsafe and unhealthy behaviors)**

# Summary



- The brain undergoes a considerable amount of development during the teen years
- The last area to develop is the prefrontal cortex, which is involved in planning, decision making and impulse control
- Alcohol - and likely other drugs - affects the young person more profoundly than its effects on adults

# Brain Development: Implications for **Safety**

- The developing brain does not give rise to optimal....
  - planning
  - equal consideration of both negative and positive consequences
  - impulse control and forestalling gratification

# Brain Development: Implications for **Safety**

---

- Maximize the effects of safety messages and campaigns by engaging the developing brain with.....
  - novelty
  - peer influences
  - physical and sensory activities

# Take Home for Parents

**P** = Promote activities that capitalize on the strengths of the developing brain

**A** = Assist your child with challenges that require planning


**R** = Reinforce their seeking advice from you and other adults

**E** = Educate about risk taking and negative consequences

**N** = Never underestimate the effects of alcohol on the developing brain

**T** = Tolerate the “oops” behaviors due to an immature brain





**THANK YOU!**

**winte001@umn.edu**

# Suggested Readings

Dahl, R.E. & Spear, L.P. (Eds.) (2004). *Adolescent brain development: vulnerabilities and opportunities*. NY, NY: *Annals of the New York Academy of Sciences*, Volume 1021.

Dubuc, B. (n.d.). *The brain from top to bottom*. Retrieved September 1, 2004, from McGill University Web site: [http://www.thebrain.mcgill.ca/flash/index\\_d.html#](http://www.thebrain.mcgill.ca/flash/index_d.html#)

Nestler, E. J., & Malenka, R. C. (2004, March). The addicted brain. *Scientific American*, 290 (3), 78-85.

Wallis, C. (2004, May 10). What makes teens tick? *Time*, 163, 57-65.

*U.S. News & World Report*. (Special Issue, 2005). *Mysteries of the teen years*. Author.

