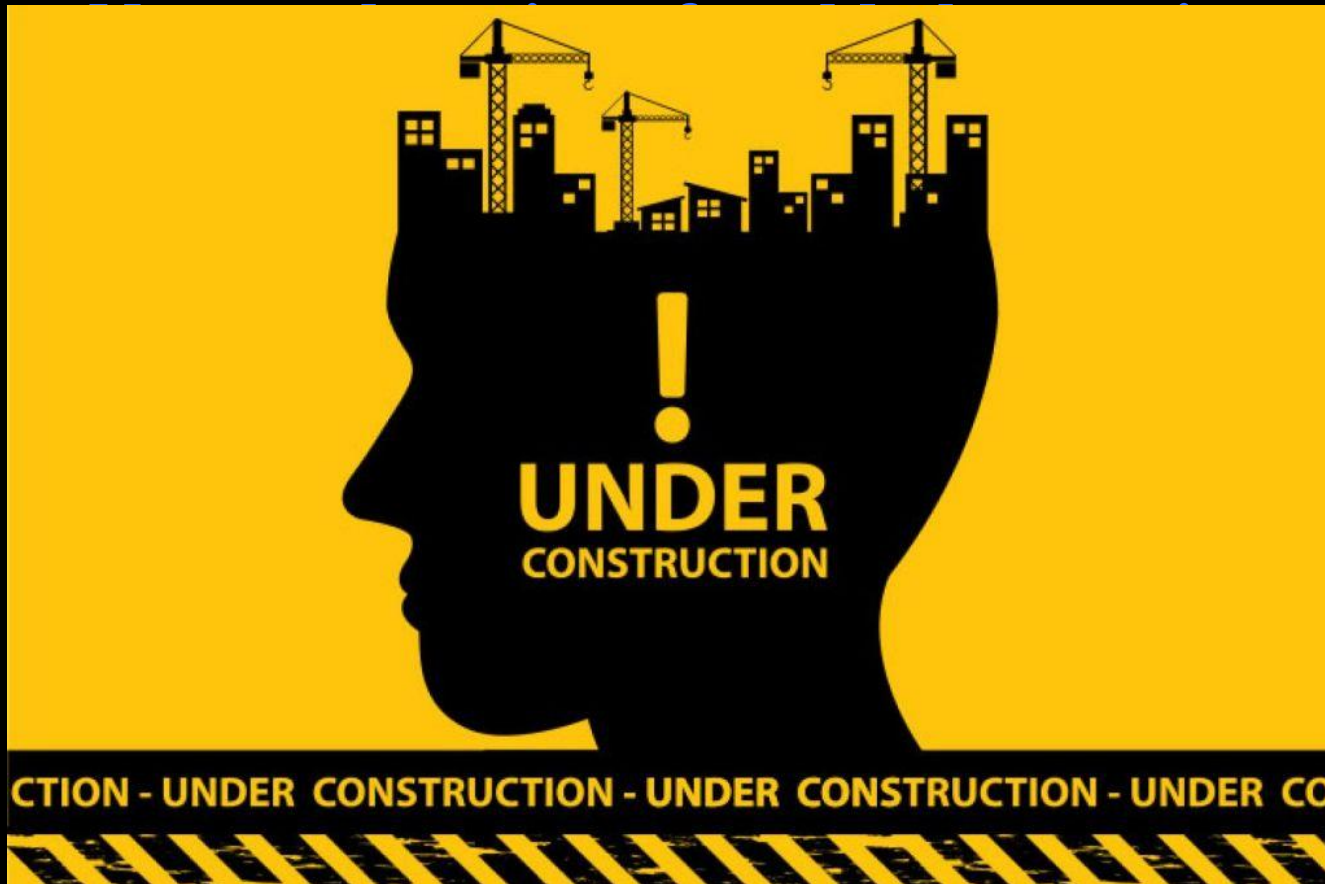


Adolescent Brain Development



Lesa K. Ellis, Ph.D, Westminster College

Road Map

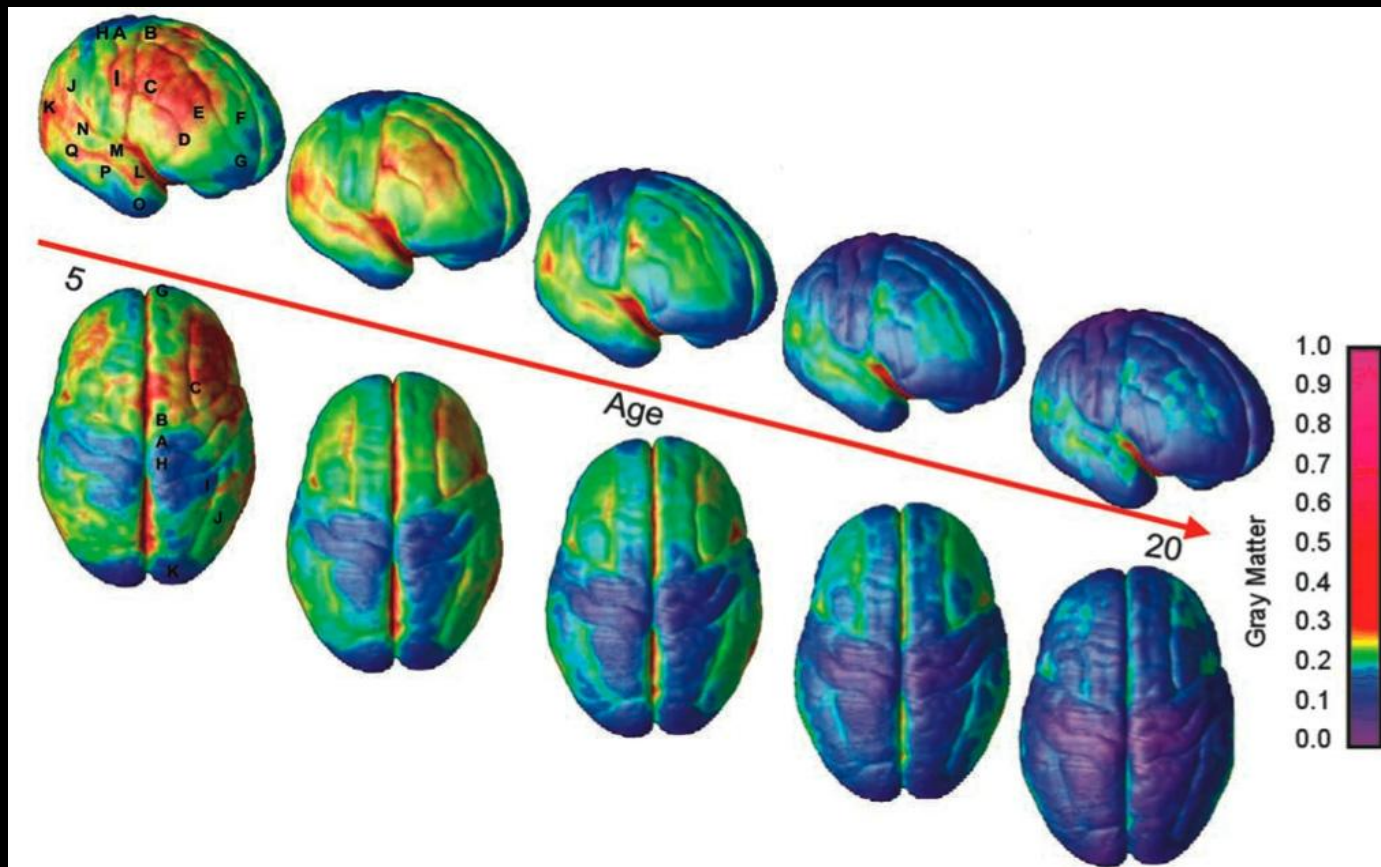
- Defining adolescence
- Brain development
- Puberty and pubertal timing
- Emotion
- Sleep
- Screens

**So what is an adolescent,
anyway?**

So what is an adolescent, anyway?

- Begins with the onset of puberty
- Ends with the end of major brain development
- Wait, aren't brains mostly developed by age 5?

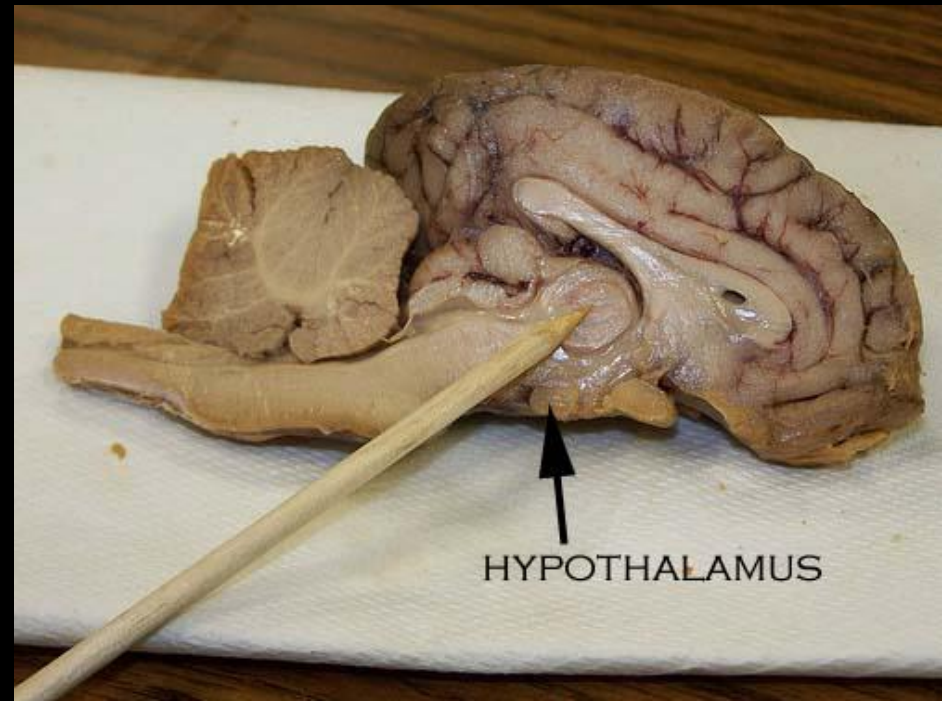
Longitudinal Neuroimaging of Brain Maturation



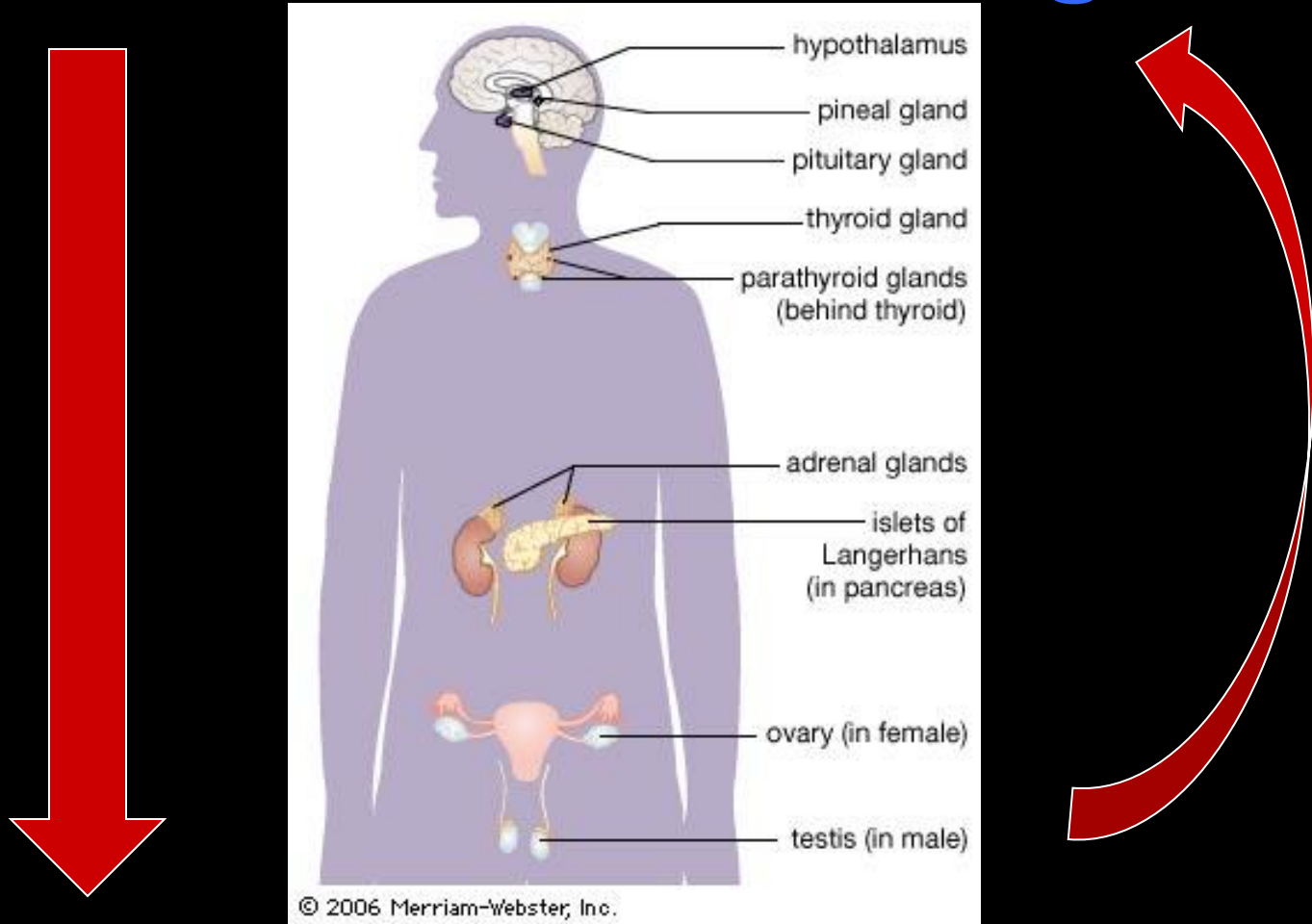
PUBERTY!!! WOOHOO!!!!!!



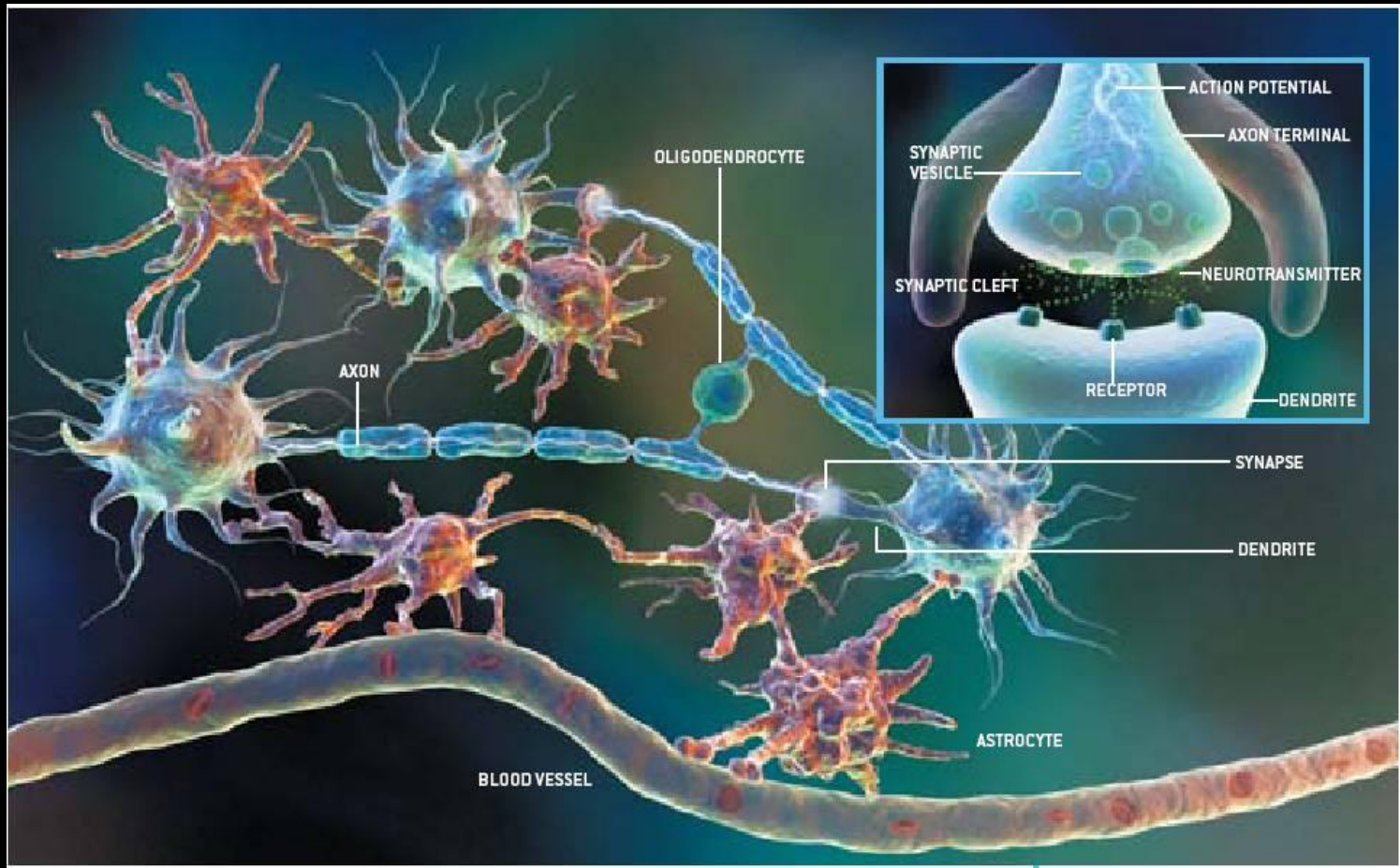
Puberty starts in your brain



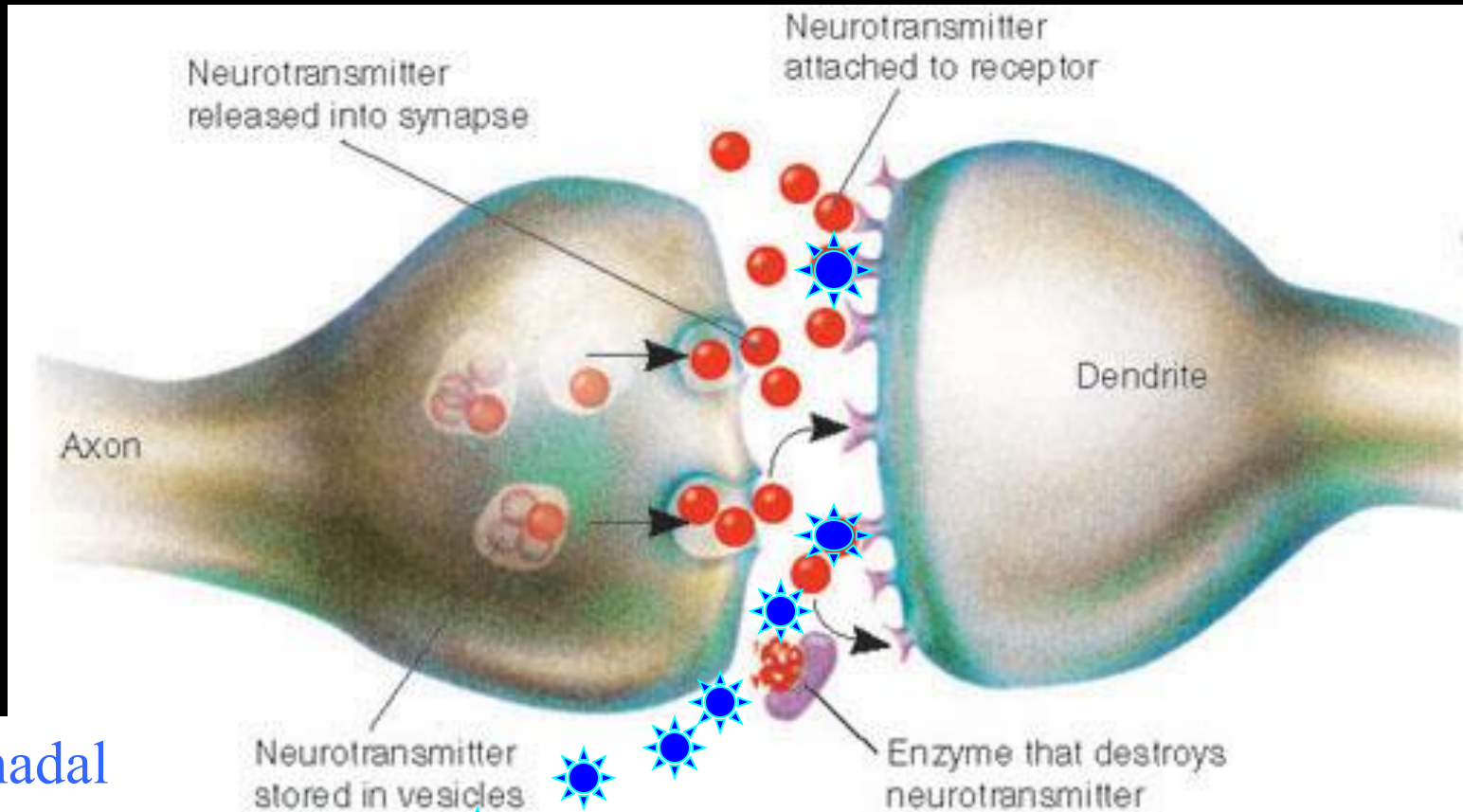
Hormone pathways – from the brain and back again



Neuronal communication



Neuronal communication



Gonadal
hormones from
body

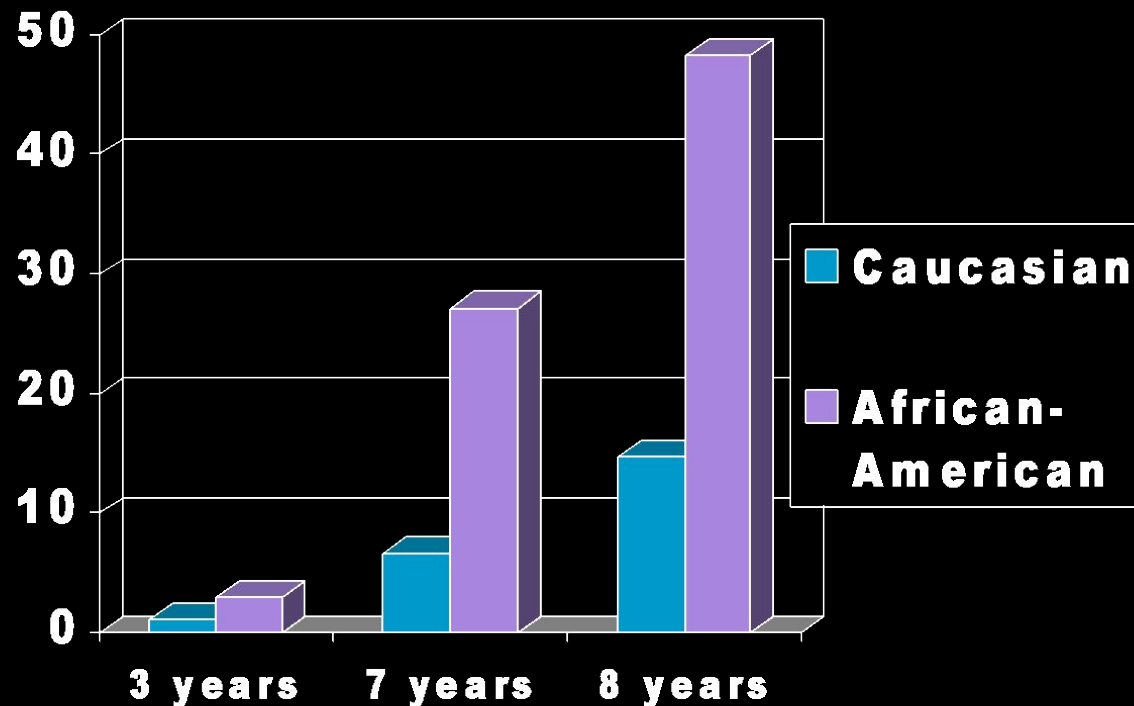
When does puberty start?

Thoughts?

When does puberty start?

- 1997 study of 17,077 girls (last large scale study done in the US!)
- Percent of girls showing pubic hair and/or breast development at doctor's exam

Percent of girls showing breast or pubic hair development by age



(Herman-Giddens, et al., 1997)

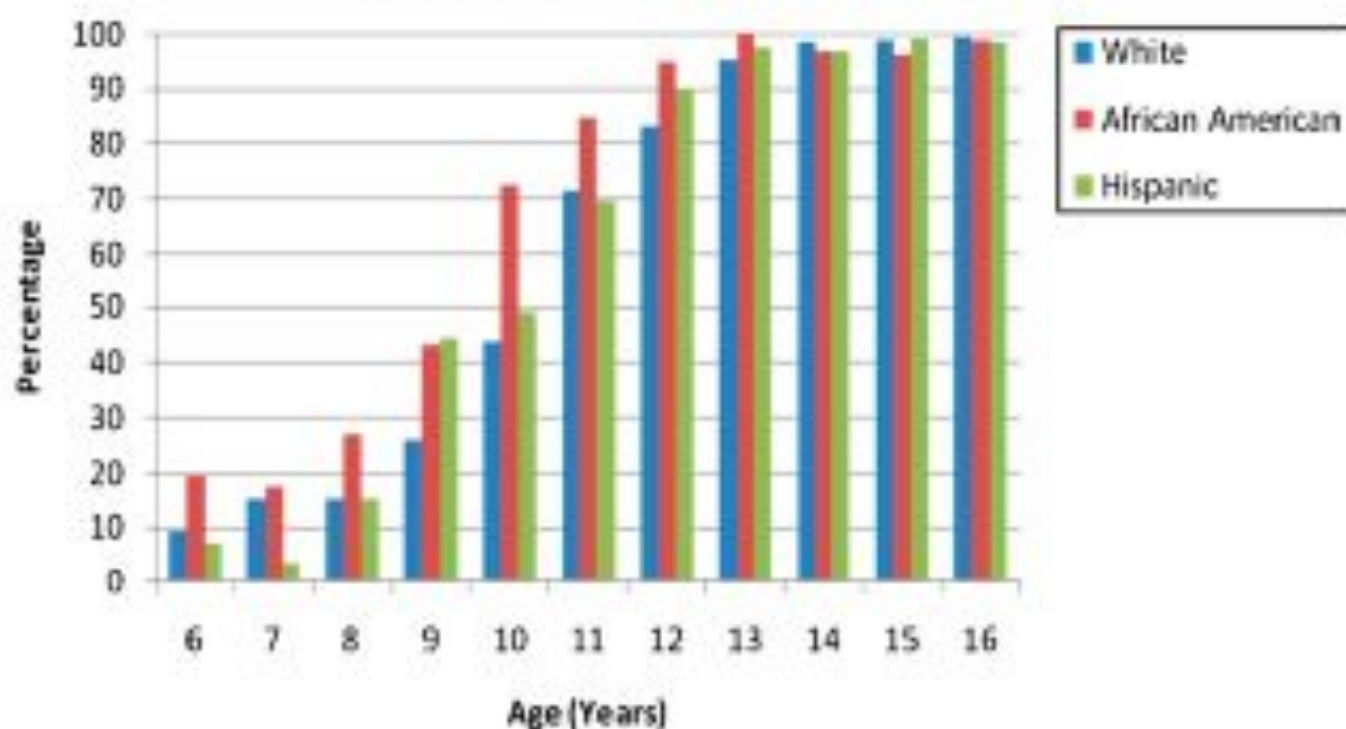
- Age 3: 3% African-American, 1% white
- Age 7: 27.2% African-American, 6.7% white
- Age 8: 48.3% African-American, 14.7% white

Study of males

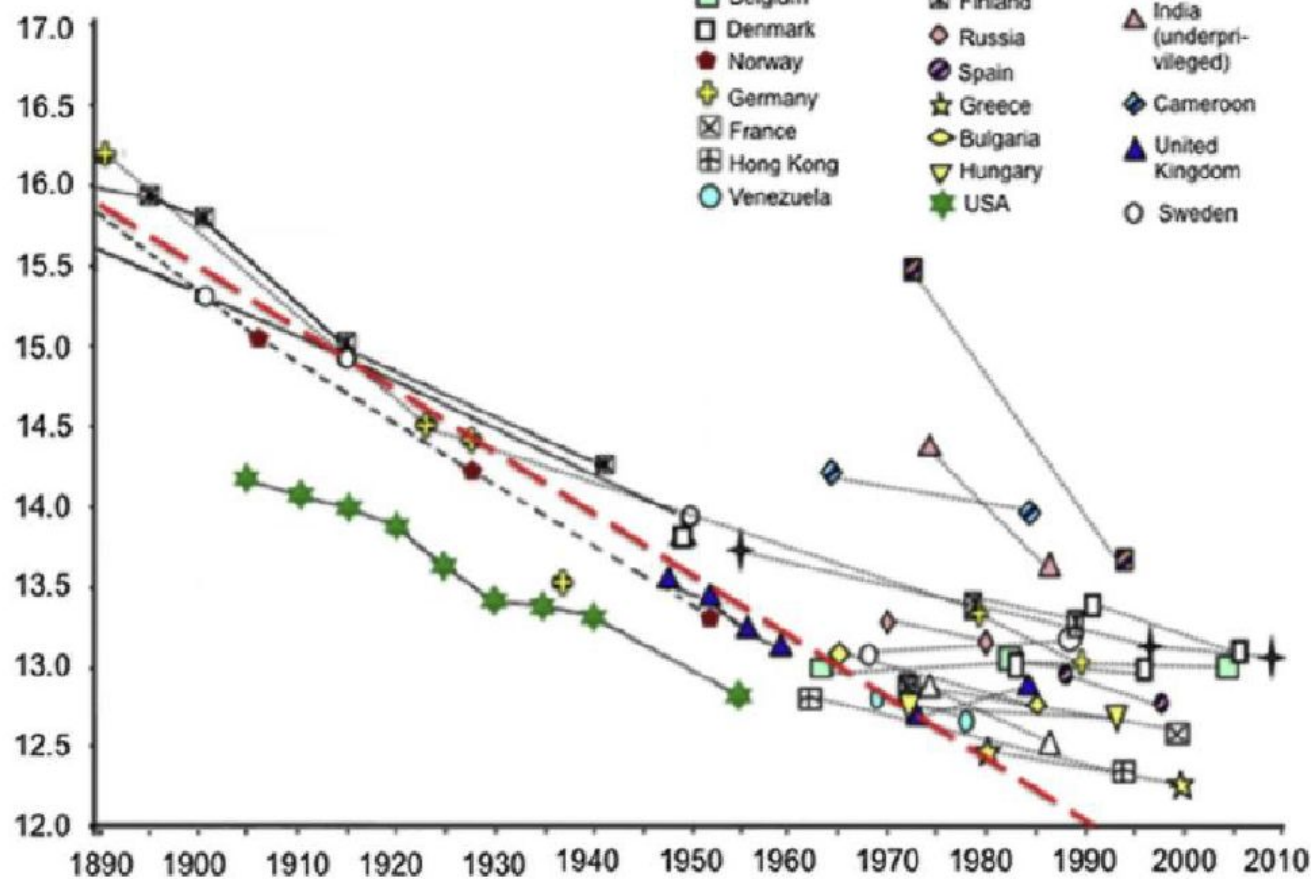
Herman-Giddens et al., 2012

- 212 pediatricians
- 4131 boys (White =2070, African American = 1062, Hispanic=999)
- Examined and classified by Tanner Stage

Prevalence of Tanner Stage 2 or Greater of Genital Development, by Race/Ethnicity



AVERAGE MENARCHEAL AGE (yr)



Parent, Franson, et al, 2015

Why is this happening?

Why is this happening?

- Individual factors
 - Body weight
 - Prenatal nutrition
 - Stress
- Exposure to endocrine disruptors
 - Naturally occurring
 - Chemical
- Mechanism – Epigenetics?

And why should we care?

And why should we care?

- Stage termination hypothesis
- Role of pubertal hormones in brain activity

Increased reactivity in emotional areas



Amygdala



Insula

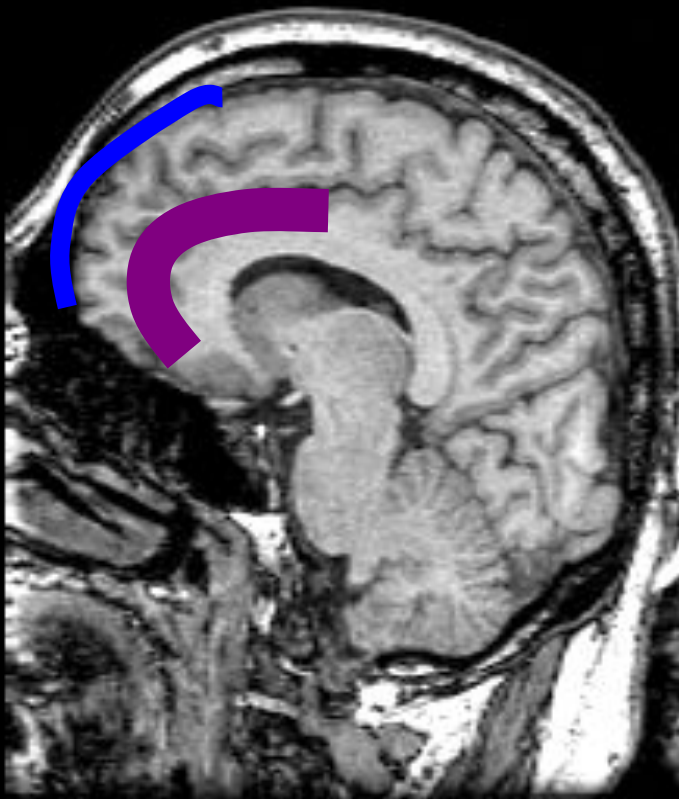
Increased reactivity in emotional areas



Nucleus Accumbens

- **Amygdala**
 - Fear processing, anxiety reactions
- **Insula**
 - Self awareness (bodily, social emotions??)
- **Nucleus Accumbens**
 - Reward processing

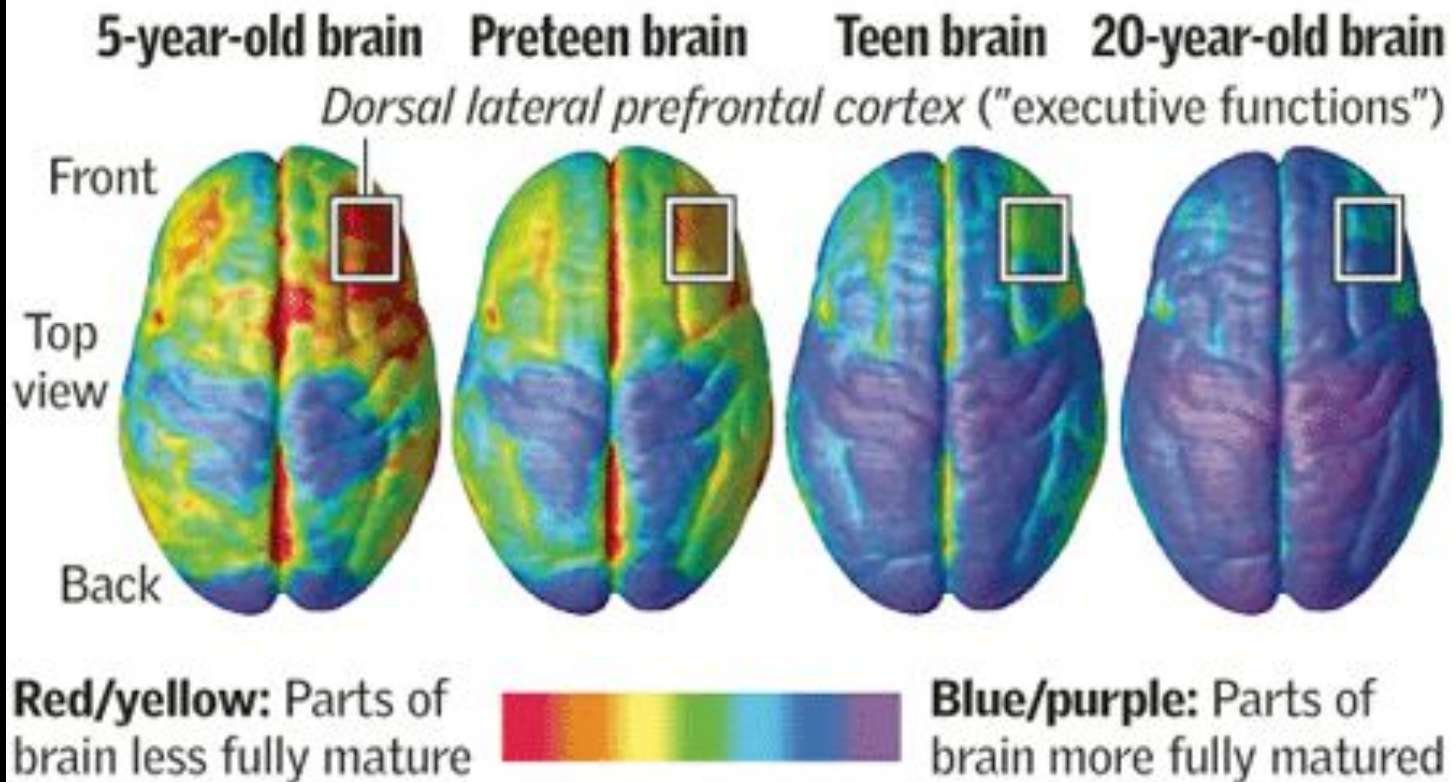
Delayed maturation of prefrontal structures



- **Anterior Cingulate**
 - Response inhibition (cognitive and emotional areas)
- **Prefrontal cortices**
 - Planning, working memory, executive functions

Judgment last to develop

The area of the brain that controls "executive functions" — including weighing long-term consequences and controlling impulses — is among the last to fully mature. Brain development from childhood to adulthood:

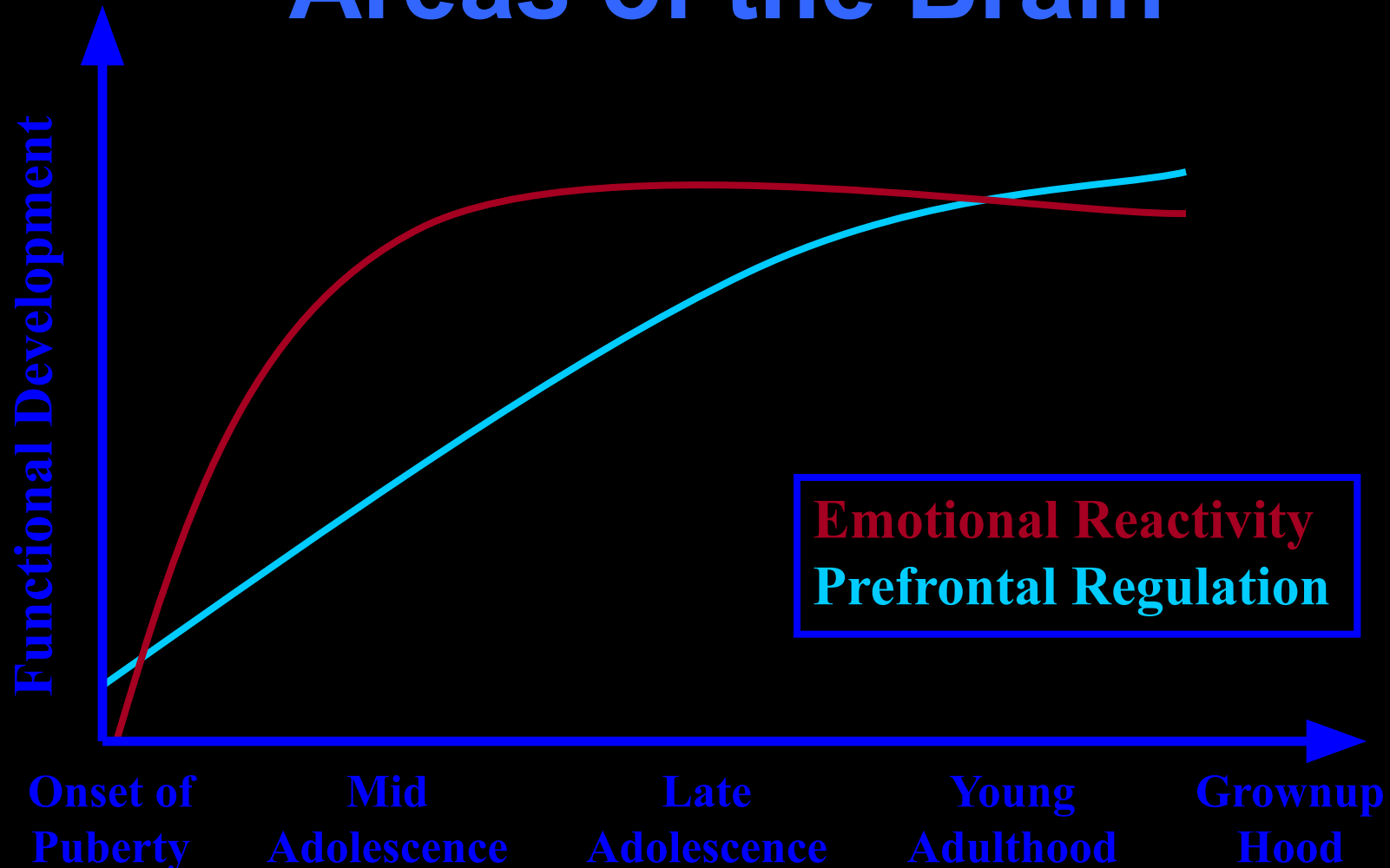


<https://www.addictionisreal.org/teenage-brain/>

Maturation of prefrontal structures

- May be tied to participation in “adult roles”.
- Is this happening sooner? Or later?

Asynchronous Development of Limbic and Prefrontal Areas of the Brain



Take home points

- Puberty plays a role in brain development (activation of emotional systems)
- Puberty is generally happening earlier and earlier
- Development of “regulatory systems” may be happening at later ages

Questions?

Behavioral manifestations of pubertal hormones

- Increased interest in sex
- Increased emotional reactivity and stress reactivity
 - (Dahl, 2006; Romeo, 2009)
- Increased risk taking and reward seeking
 - (Spear, 2000; Dahl, 2006; Casey, Jones & Hare, 2008)

Increased Stress Reactivity

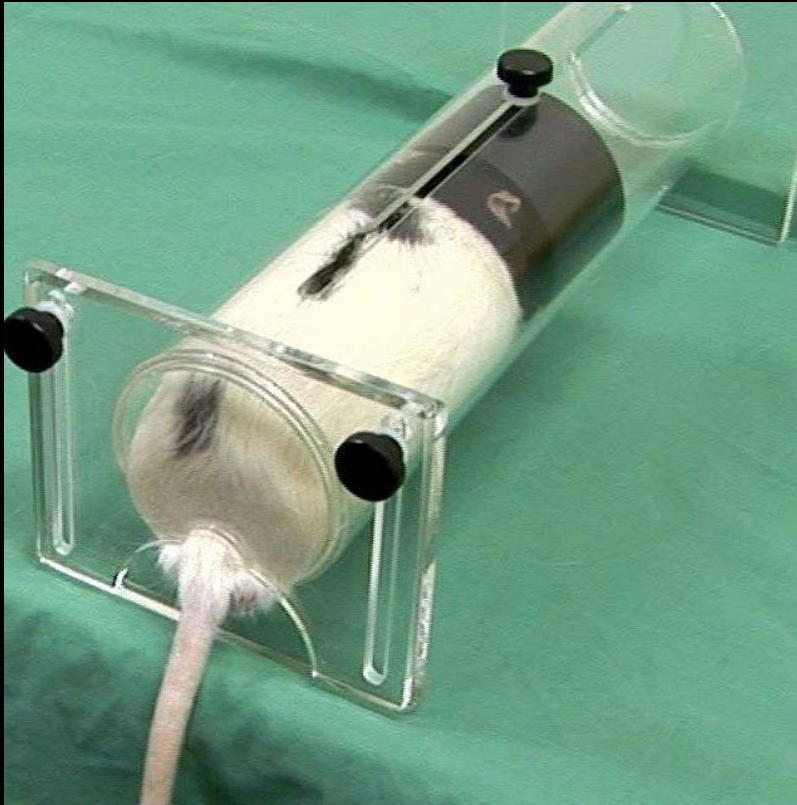
- Stressor

- A stimulus that challenges the body's homeostasis and triggers arousal

- Stress Response

- The physiological and behavioral arousal and any attempt to reduce the stress
- Release of hormones that activate “fight or flight”
- Excessive levels affect learning and memory, ability to handle future stress, development of depression

Stressed out rats



procedureswithcare.org.uk



Funny-bone.com

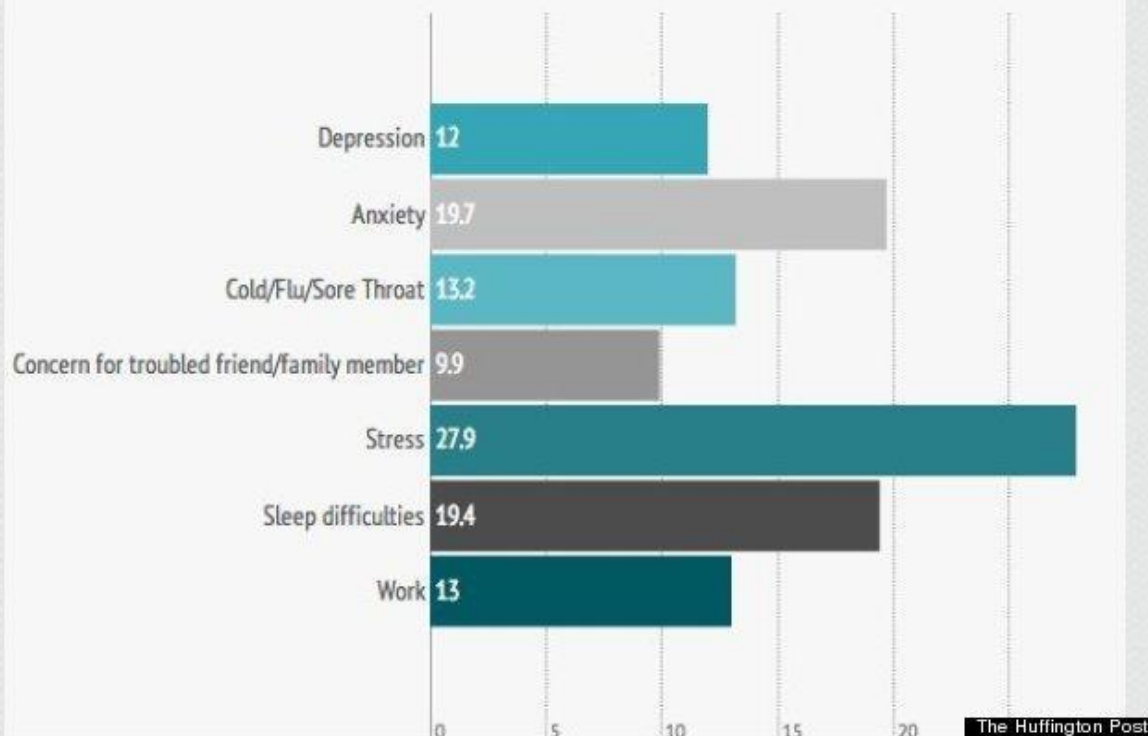
Romeo and his rats

- Adolescent rats secrete more stress hormone, and secrete it for a longer period of time than do adults.
- Adolescent rats take longer to habituate to stress.
- Social isolation for 30 days creates “depressed” rat, lasts into adulthood.

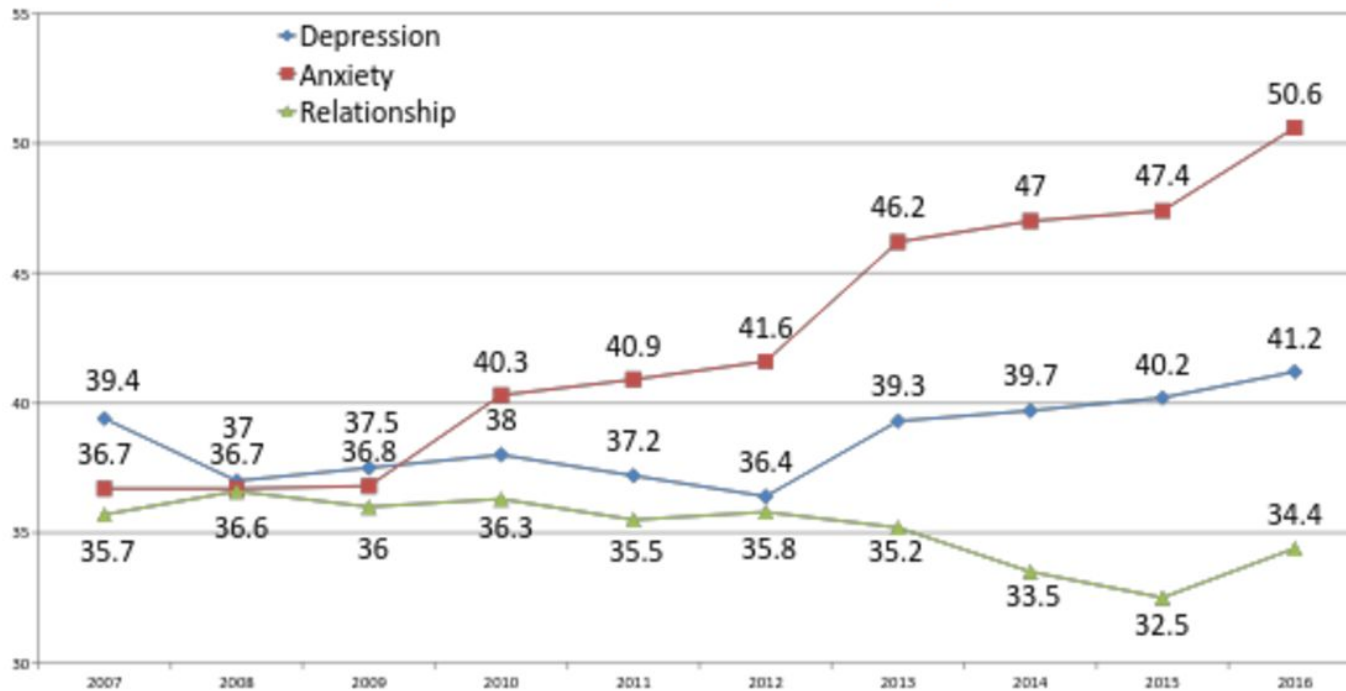
MENTAL HEALTH CONCERNS AMONG COLLEGE STUDENTS

ACCORDING TO THE FALL 2013 AMERICAN COLLEGE HEALTH ASSOCIATION NATIONAL
COLLEGE HEALTH ASSESSMENT SURVEY

The Percentage Of Students Reporting These Factors As Impacting Their Academic Success



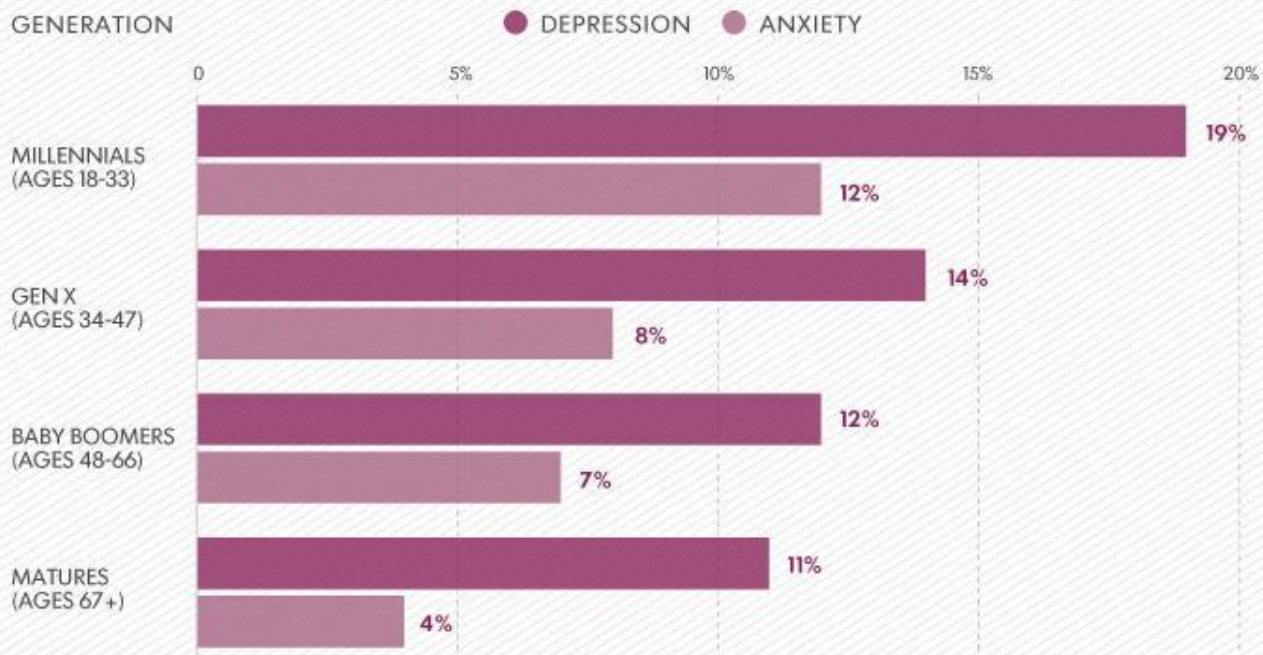
Most Frequent Presenting Concerns In Counseling Centers 2016 AUCCCD Survey

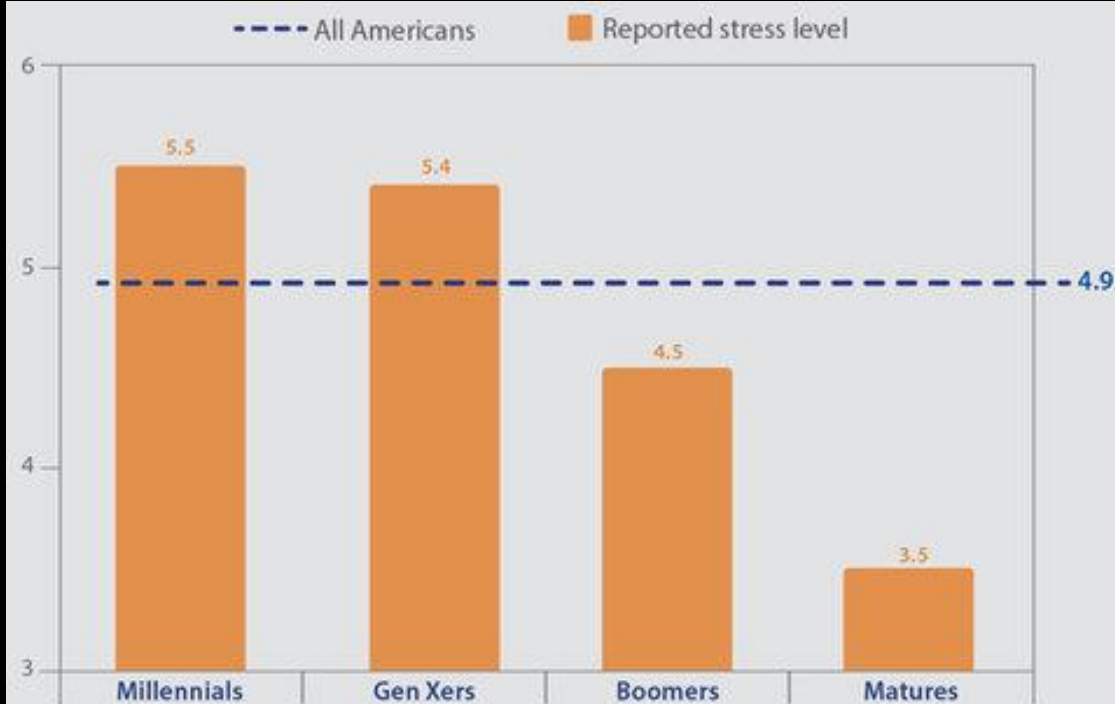


Reetz, D.R., Bershad, C., LeViness, P., & Whitlock, M. (2017). *The 2016 Association for University and College Counseling Center Directors Annual Survey*. CO: AUCCCD

YOUNG ADULT STRESS

Higher percentages of Millennials say they have been diagnosed with depression and anxiety disorders than other generations:





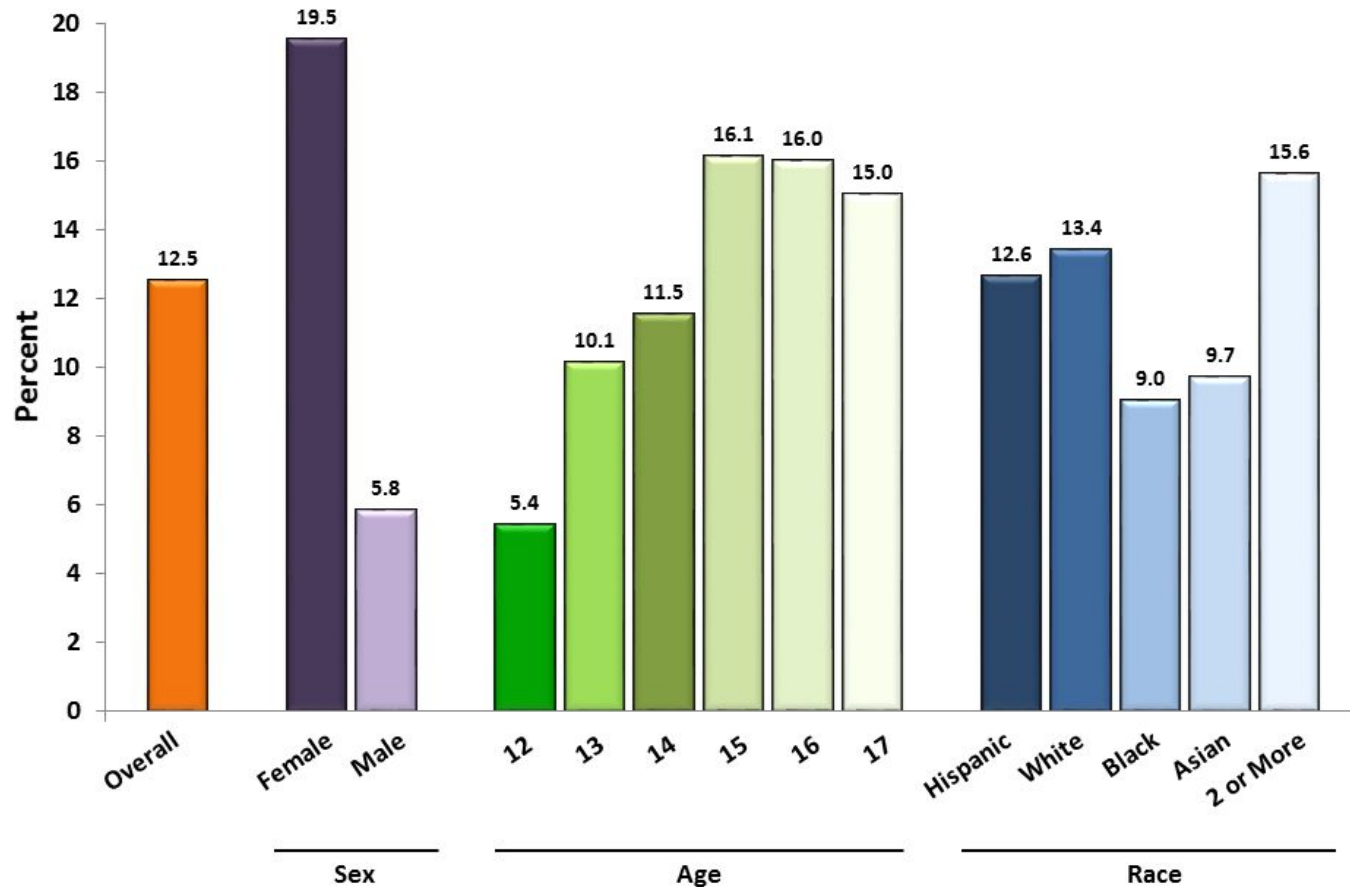
< STRESS LEVELS BY AGE

Stress levels for Millennials and Gen Xers is well above average stress level (4.9)

BASE: ALL QUALIFIED RESPONDENTS 2014 (Millennials n=720; Gen Xers n=548; Boomers n=1324; Matures n=476)

Q605 On a scale of 1 to 10, where 1 means you have "little or no stress" and 10 means you have "a great deal of stress," how would you rate your average level of stress during the past month?

12-month Prevalence of Major Depressive Episode Among U.S. Adolescents (2015)

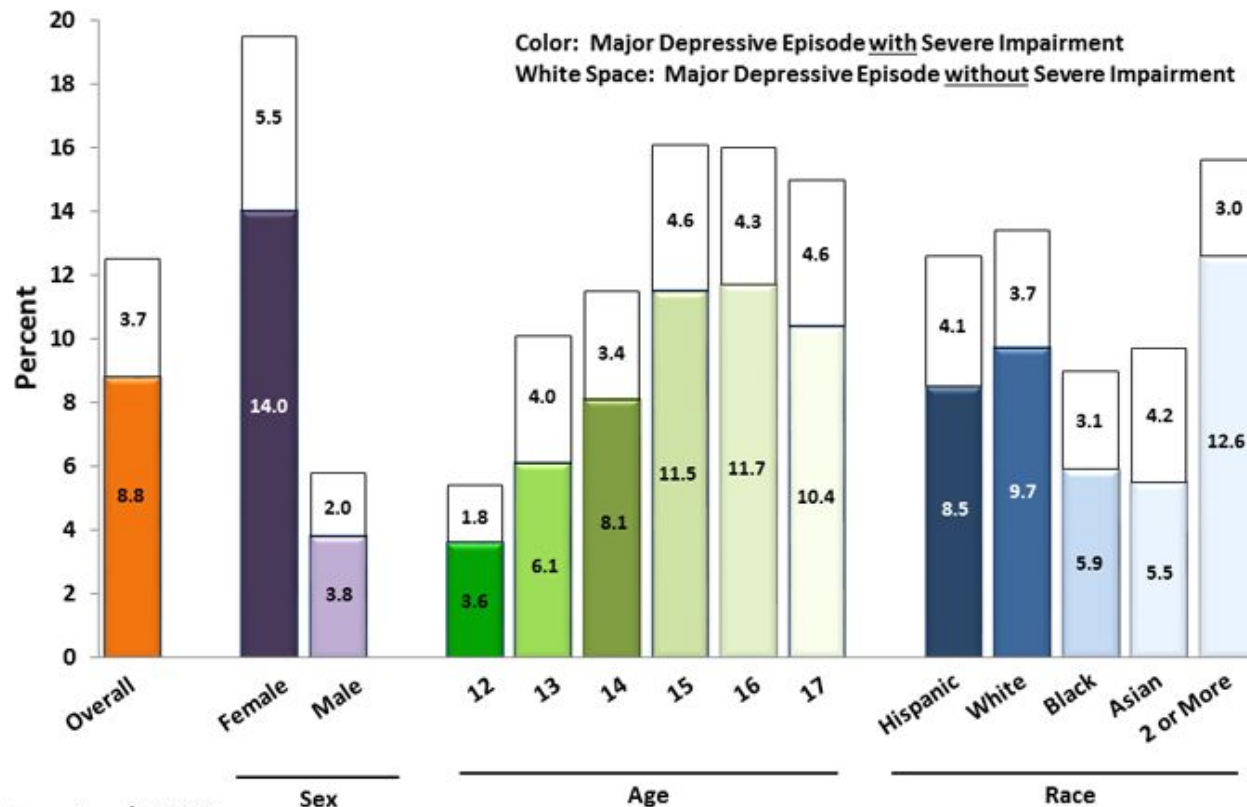


Data courtesy of SAMHSA

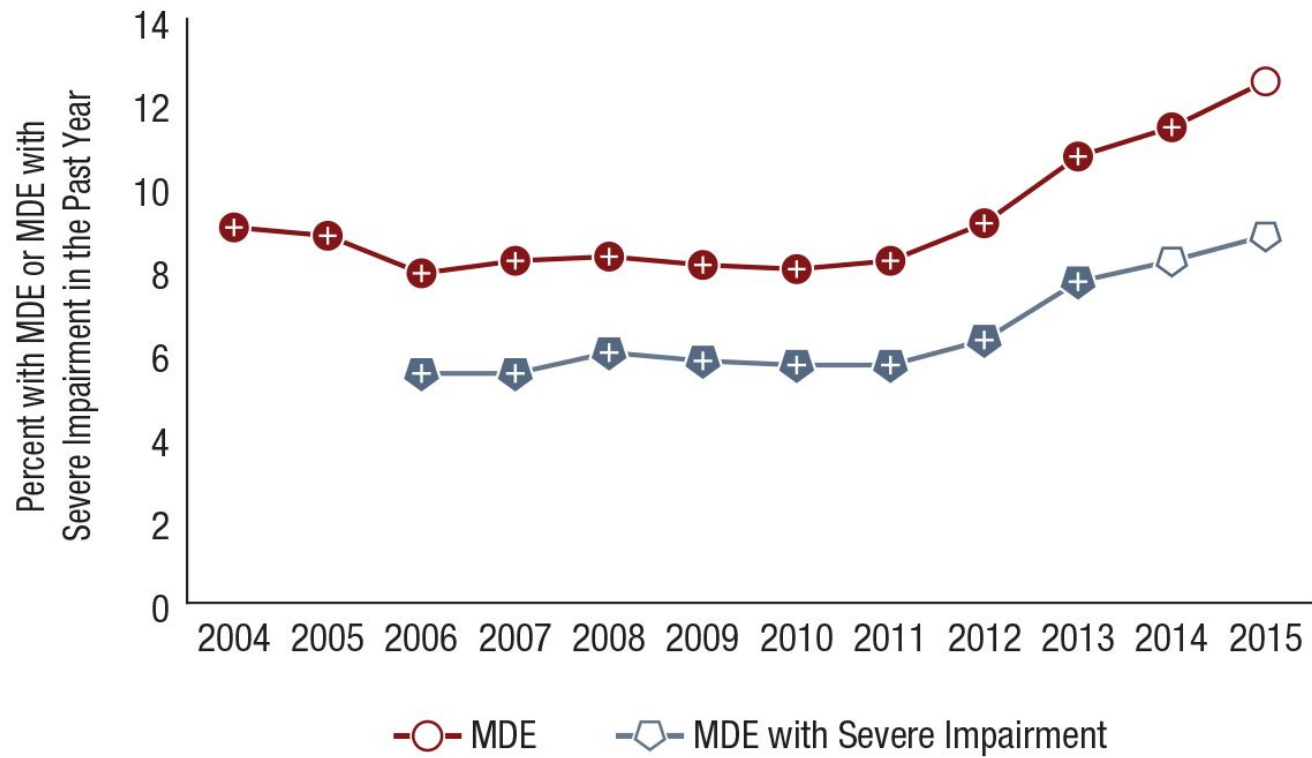
*NH/OPI = Native Hawaiian/Other Pacific Islander

**AI/AN = American Indian/Alaska Native

12-month Prevalence of Major Depressive Episode with Severe Impairment Among U.S. Adolescents (2015)



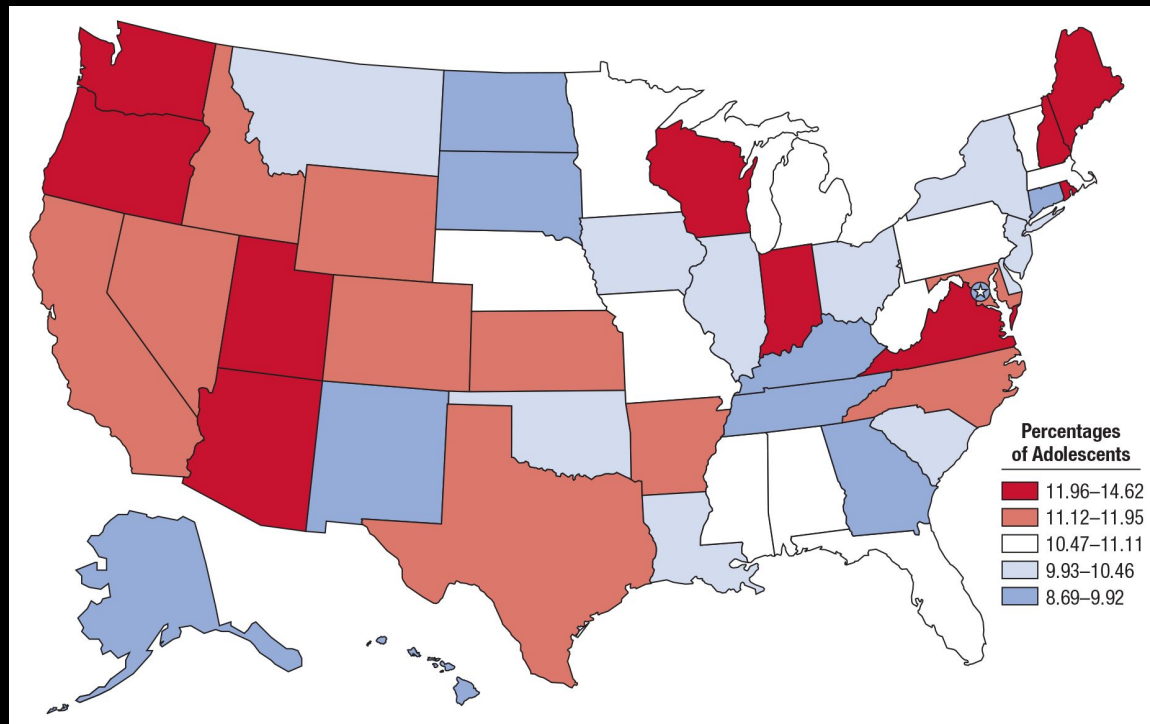
Data courtesy of SAMHSA



Why is it getting worse over
time?

Thoughts?

Figure 1. Major depressive episode in the past year among adolescents aged 12 to 17, by state: percentages, annual averages, 2013–2014 - SAMSHA



Suicide in Utah

- Leading cause of death for Utahns ages 10 to 17 and 18-24
- 2013 Youth Risk Behavior Survey (in 12 months prior to survey):
 - 25.7% felt sad or hopeless
 - 15.5% seriously considered attempting suicide
 - 12.8% made a suicide plan
 - 7.3% attempted suicide one or more times

Take home points

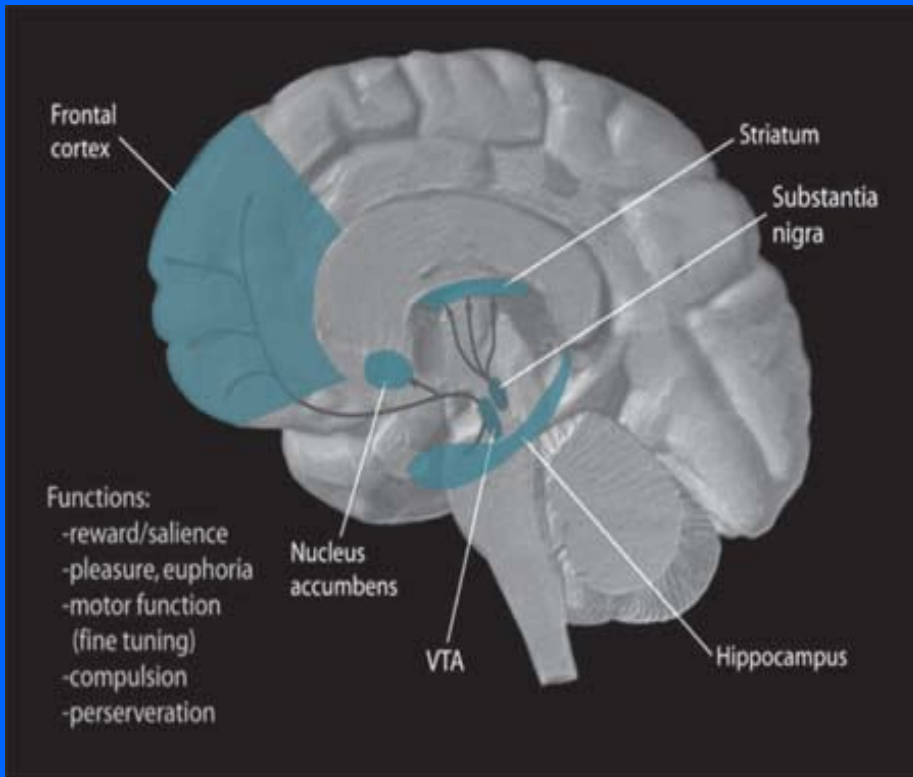
- Adolescent brain may be more susceptible to effects of stress than child, adult
- Can set up lifelong pattern of stress reactivity
- High levels of stress hormones associated with depression
- Increasing with each generation

Questions?

Increase in activity of “sensation seeking” systems

- Increased risk taking
- 200% increase in death and disability
- Accidents, suicide, homicide, substance abuse, violence, risky sexual behaviors, eating disorders, etc.
- Also occurs in rats, primates

-(Spear, 2000; Geidd, 2009)



- Remodeling of dopamine system in “reward” pathway
- Reward pathway responsible for pleasure

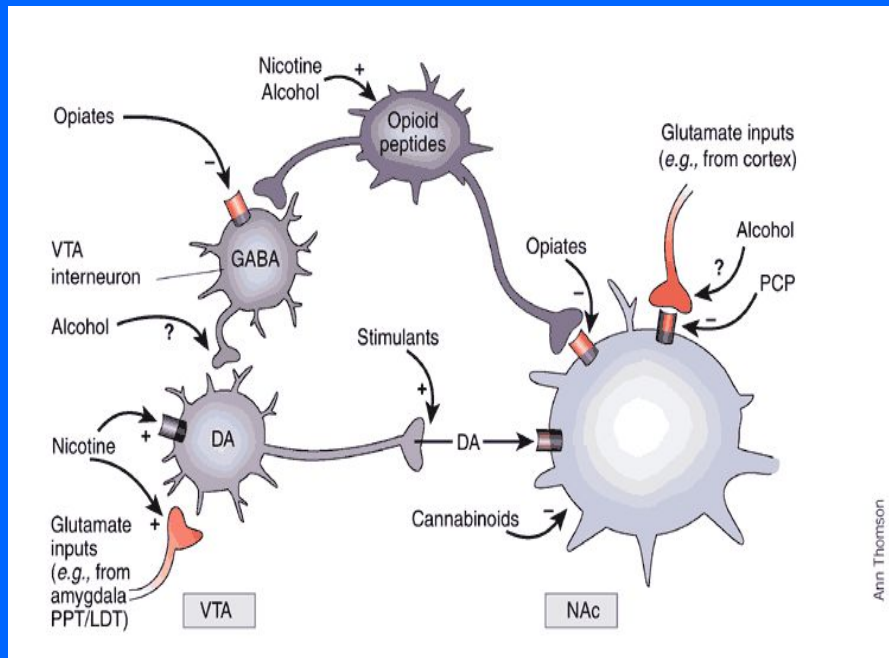
Casey, Jones, & Hare, 2008

Picture from Wikipedia

But why does this happen?

- Why would humans (and other mammals) develop the tendency to take more risks during adolescence?

Reward pathway and addiction



- ALL addictive drugs activate this pathway, either directly or indirectly.
- Addictive drugs cause long term, genetic changes to this pathway
- Addictive drugs decrease brain's ability to experience "normal" pleasure Nestler, 2005
- The role of cues . . .

Adolescent brain and alcohol

– a dangerous concoction

- Increased dopamine activity
 - The activating effects of alcohol – socialize, laugh, dance all night!
- Decreased GABA activity
 - The sedative effects of alcohol – stumbly, slurred speech, pass out
(Spear, 2000)
- Binge drinking in adolescence
 - Never develop normal sedation effects



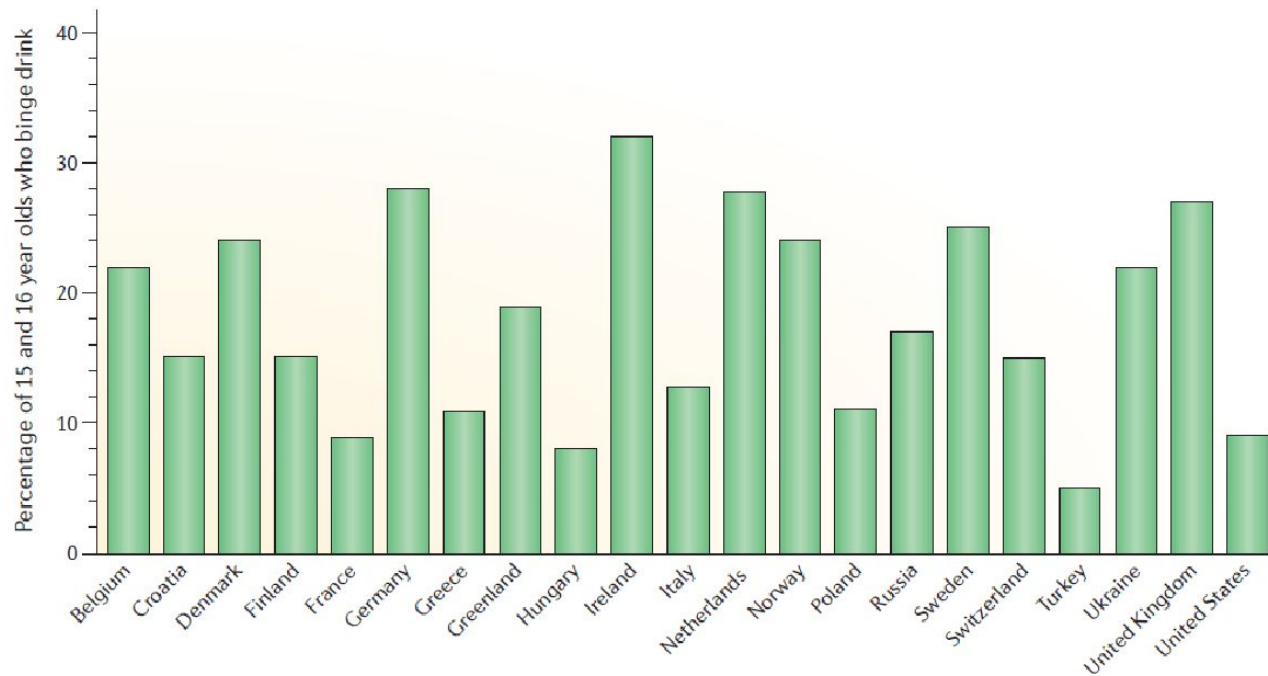


Figure 1 | **Binge drinking in individuals aged 15–16 years from various European countries and the United States.** In this data set, binge drinking was defined as the consumption of at least five drinks on a single occasion at least three times over the past month. Data from REF. 4.

Spear, Nature Reviews Neuroscience, Feb 2018

Factors that predict alcohol use before it starts

- Personality factors – sensation seeking, impulsivity, extraversion
- Cognitive factors – problems with executive functioning
- Genetic factors – doesn't predict initiation of alcohol use, but predicts severity of alcohol use later on

Consequences of adolescent alcohol use

- Deficits in cognitive functioning
- Permanent changes in how the brain responds to alcohol

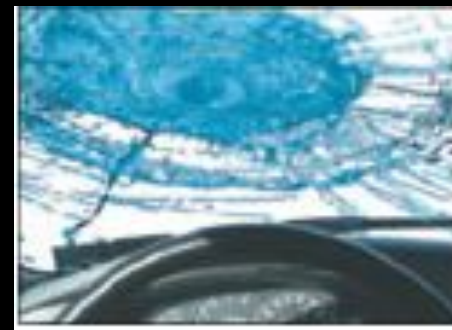
Is peer pressure real with
regard to risk taking?

Developmental Science



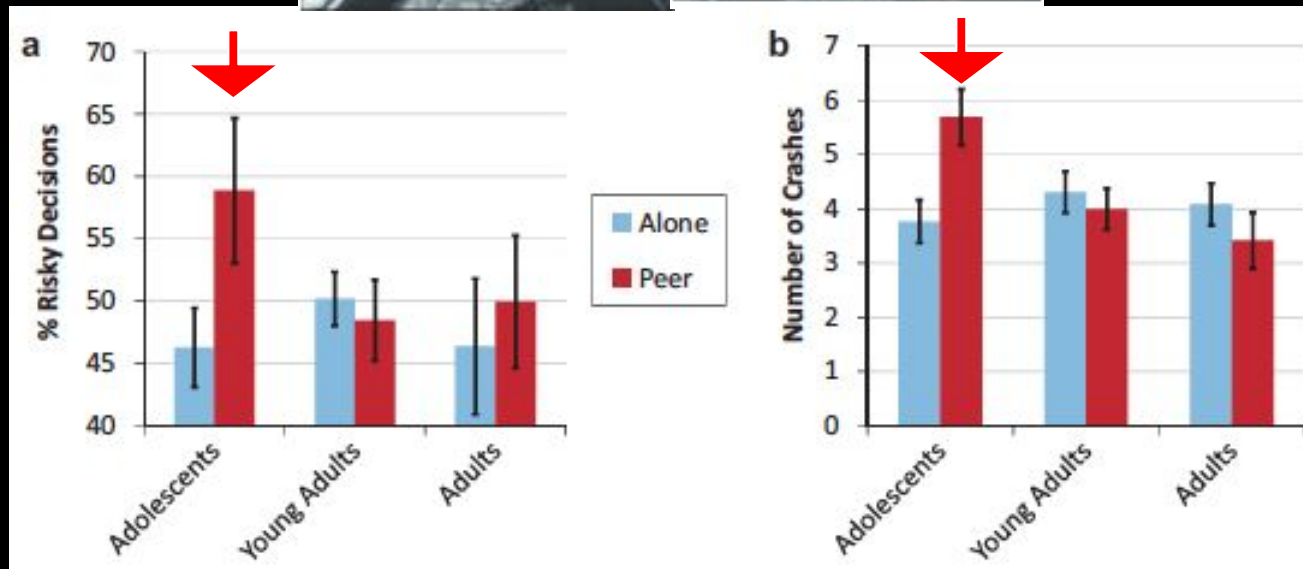
Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry

Jason Chein, Dustin Albert, Lia O'Brien, Kaitlyn Uckert and Laurence Steinberg



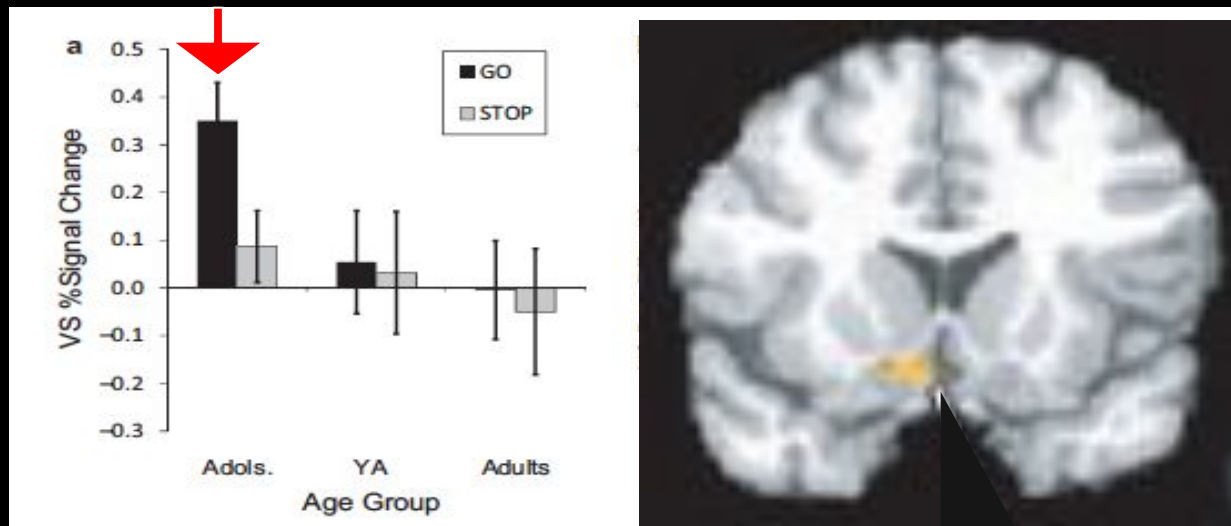
SOURCE: Chein et al *Dev Sci* 2010

More risky decisions and crashes in adolescents when with peer than alone



SOURCE: Chein et al *Dev Sci* 2010

Greater peer Influence in adolescents in reward processing areas



SOURCE: Chein et al *Dev Sci* 2010

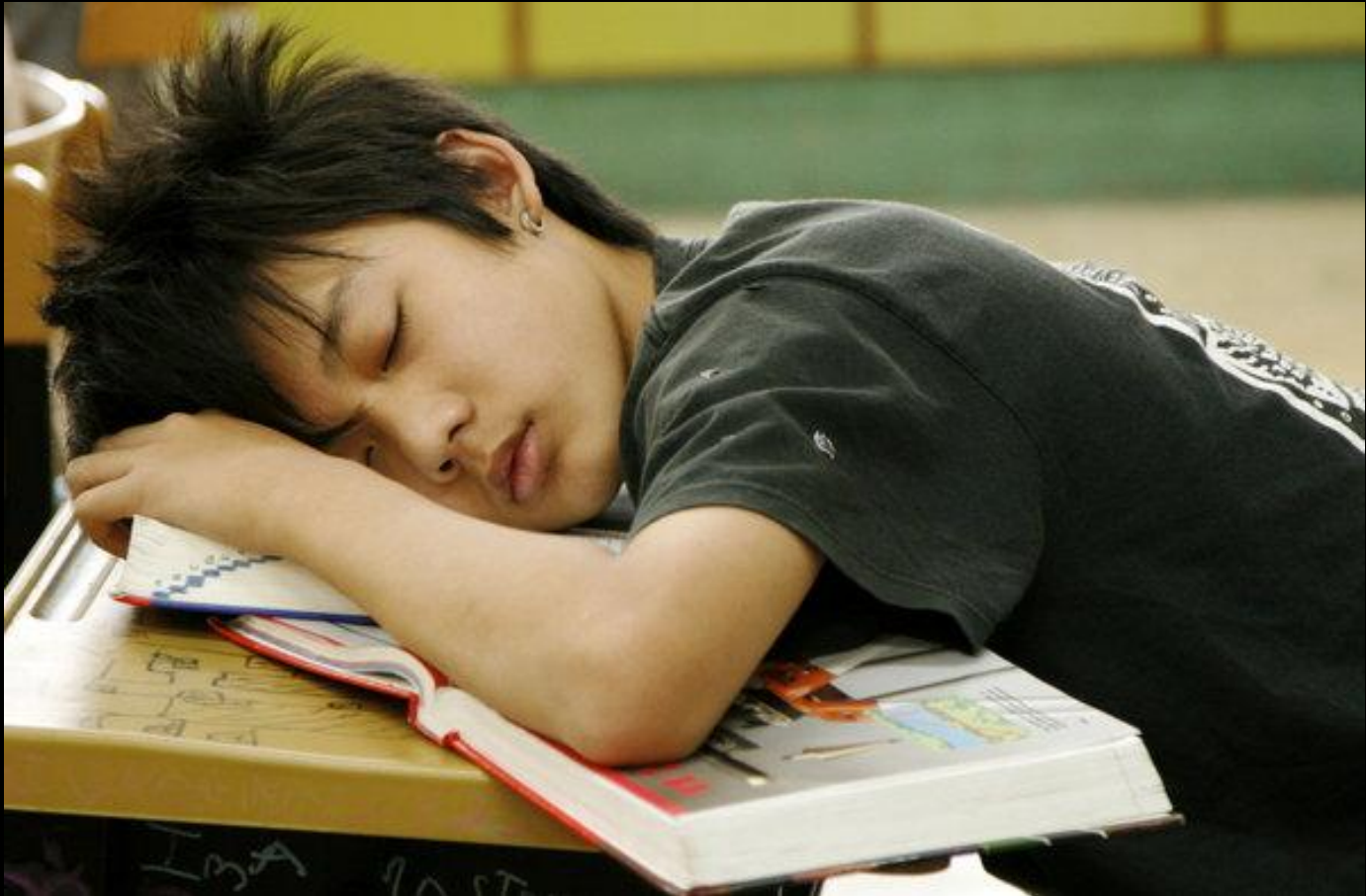
Take home points

- Adolescent reward pathways undergo substantial remodeling
- Increases in risky behaviors
- Addictive drugs “hijack” reward pathways
- Binge drinking is a big problem!
- The presence of peers increases risky behavior and activity of reward systems

Questions?

Sleep

Look familiar?



PUBERTY!!! WOOHOO!!!!

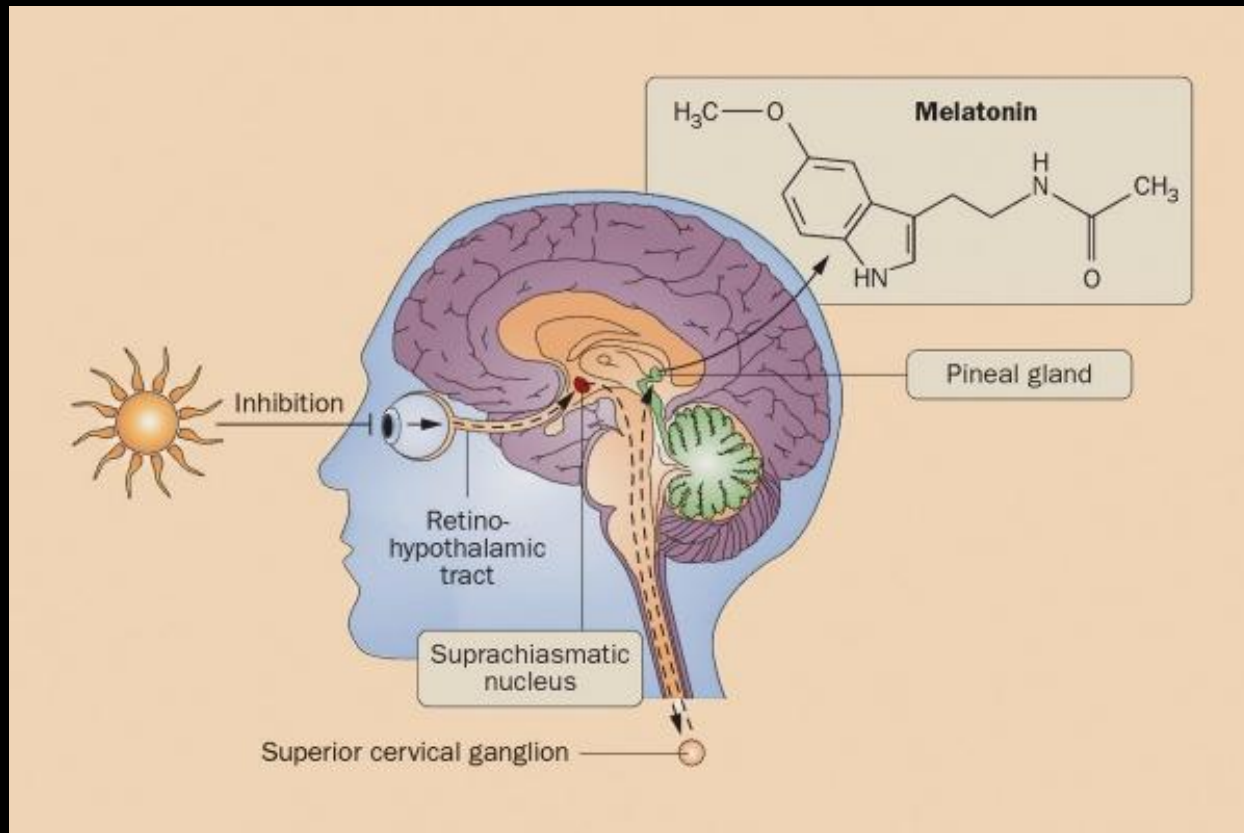


Sleep Needs Vary as We Age - Ideal Sleep Times

Newborns/Infants (0 - 12 months):	10.5 - 18 hours
Toddlers/Children (12 mo - 12 years):	10 - 13 hours
Adolescents	8.5 - 9.5 hours
Young Adults	7 - 9 hours
Older Adults	7 - 8 hours



What causes us to sleep?



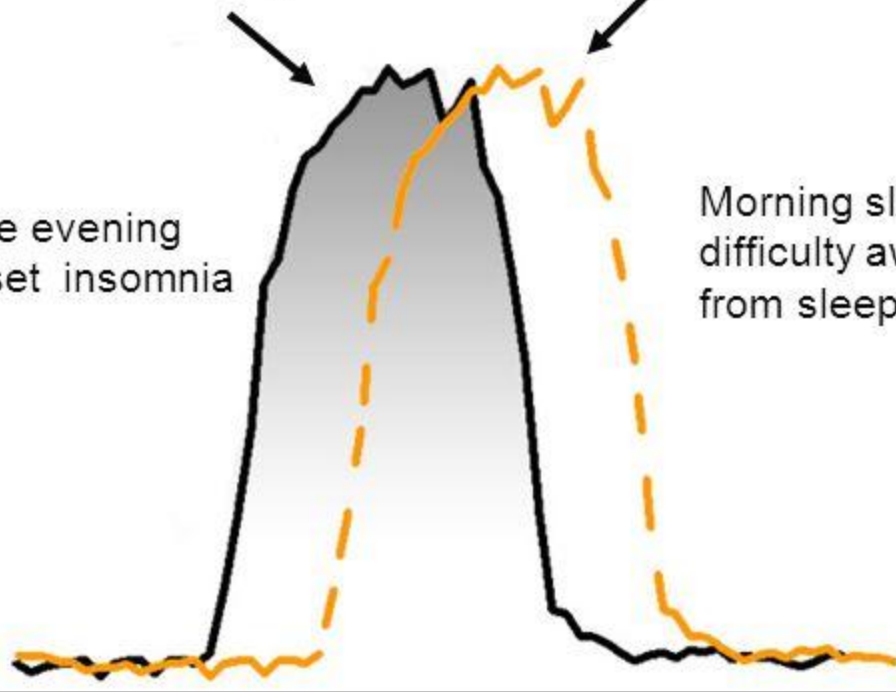
Adolescent Sleep-Wake Cycle

Normal circadian melatonin phase

Later circadian melatonin phase

Alert in the evening
Sleep onset insomnia

Morning sleepiness
difficulty awakening
from sleep



Delayed sleep time and
reduced sleep duration
during the school week



← Normal sleep time



← Restricted sleep time with delayed phase

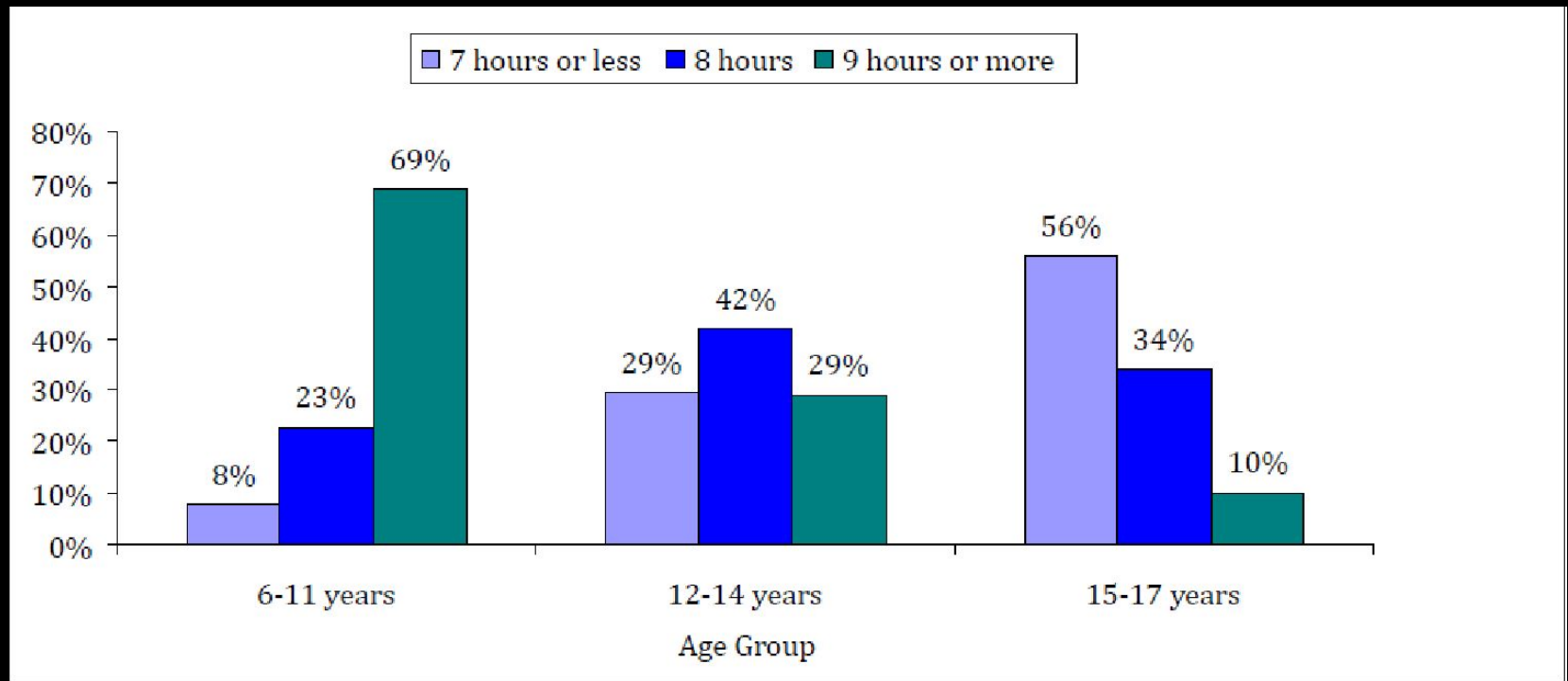


← NL sleep time with delayed phase⁹

Phase shift in sleep patterns after onset of puberty

- *Increased* need for sleep (9.25 hours)
- More active at night, less active in morning
- Delay in release of melatonin
- Best sleep times: 1am - 9am

Hours of sleep by age group



Building a sleep deficit

School
start times

Social
life

Stress



Excitement

Access
to light

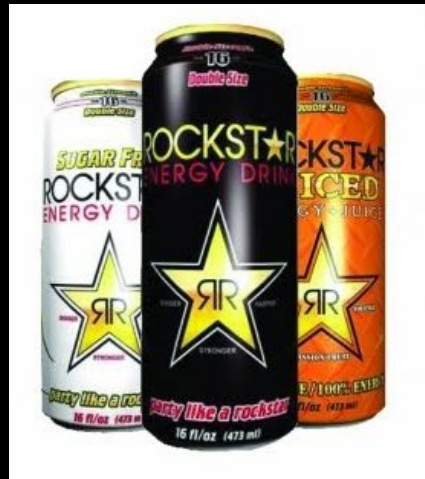
Screens

The problem with weekends



Vicious cycle

Monday Morning



And why should you care?



School start time studies

- School start times are out-of-sync with sleep times
- Lots of concern; not much action

Emotion



- Higher levels of anger, irritability, frustration
 - Greater amygdala activity
 - Catastrophizing
- Baseline insomnia predicts later problems with self-esteem and depression
- BUT sleep problems, anxiety and depression are all related; which comes first?

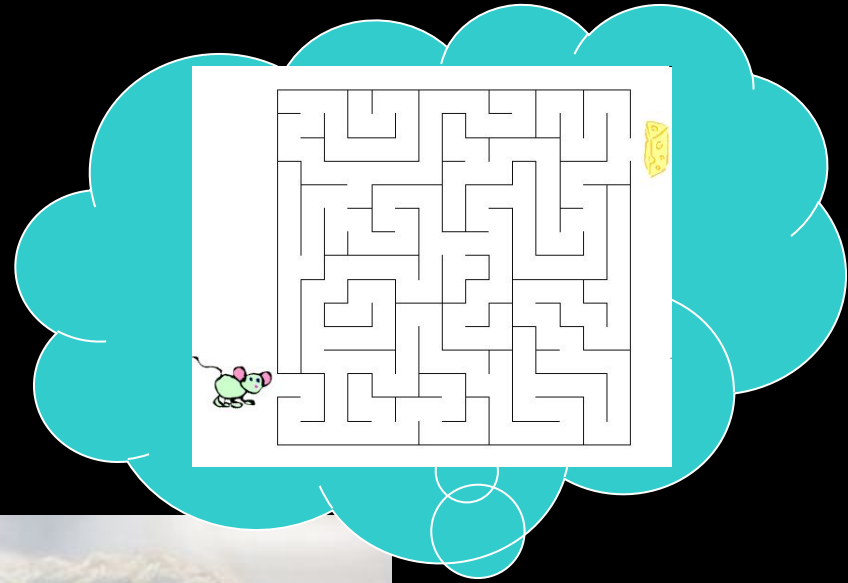
Food and weight



<http://www.medpagetoday.com/primarycare/dietnutrition/24919>

- Increased cravings for sweets/carbs
- Increased insulin resistance
- Poor sleep in early adolescence predicts later obesity
- Very difficult to lose weight

Learning and memory



Screens

How much time are
adolescents spending on
screens?

Is this an addiction?

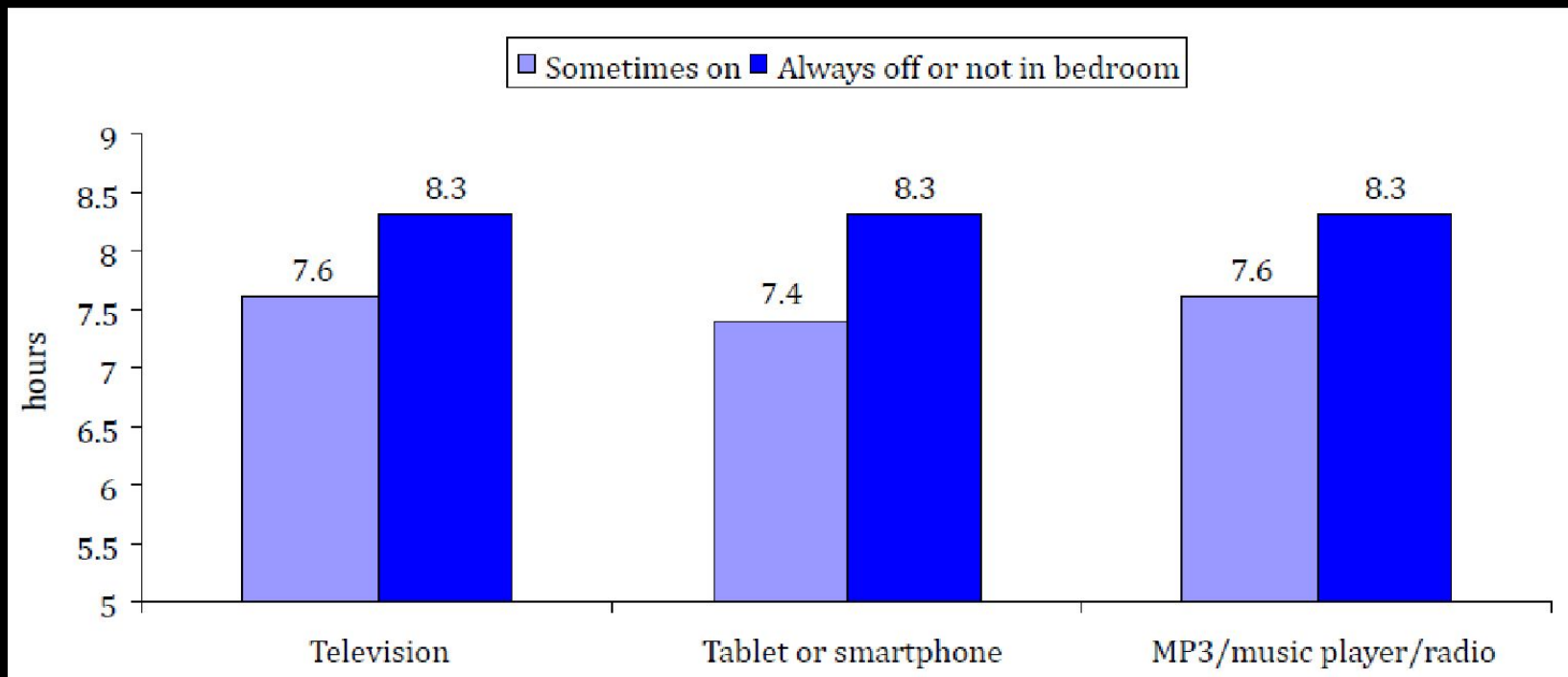
Smartphone Addiction Scale for Adolescents

Items

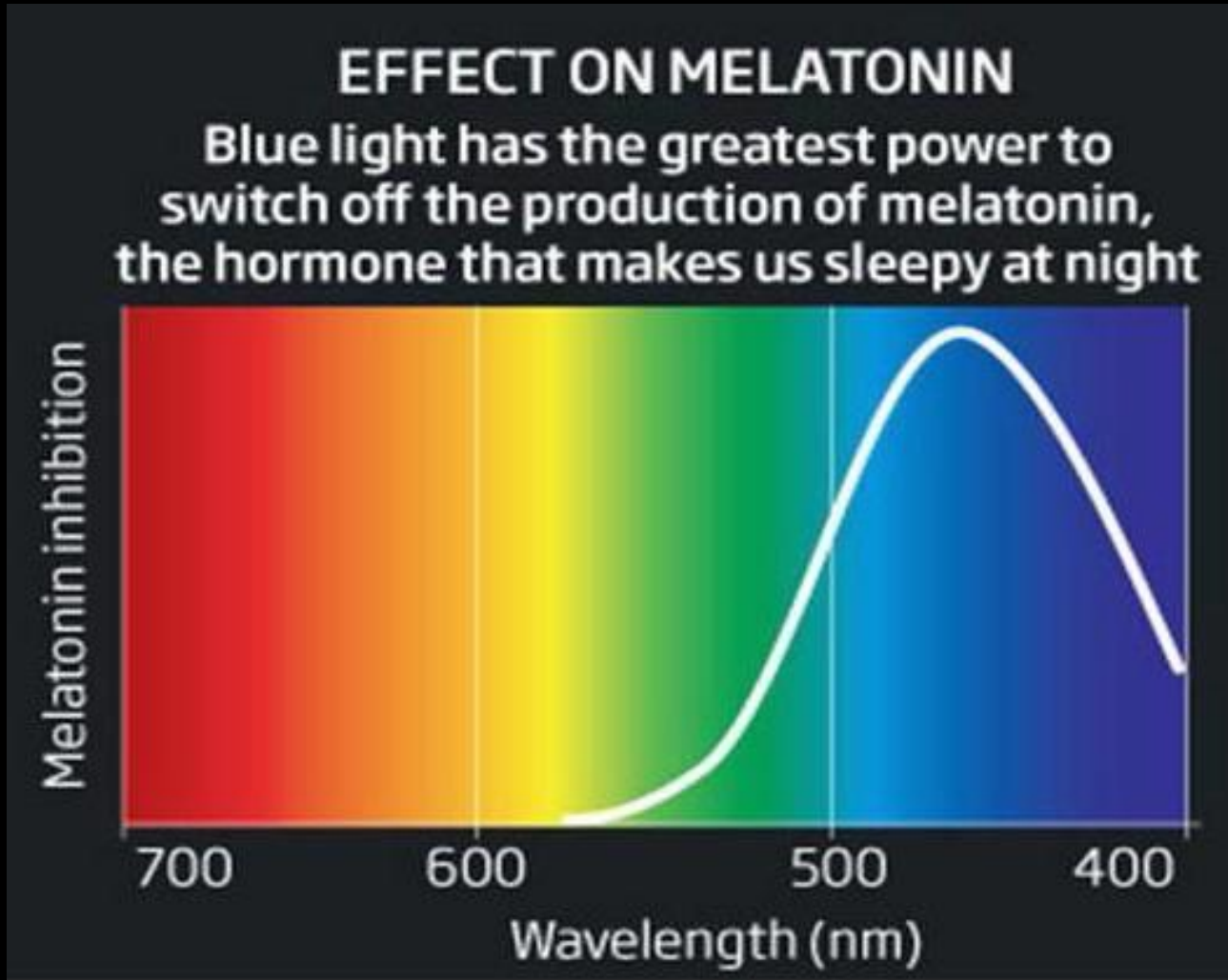
- | | |
|----|---|
| 1 | Missing planned work due to smartphone use |
| 2 | Having a hard time concentrating in class, while doing assignments, or while working due to smartphone use |
| 3 | Feeling pain in the wrists or at the back of the neck while using a smartphone |
| 4 | Won't be able to stand not having a smartphone |
| 5 | Feeling impatient and fretful when I am not holding my smartphone |
| 6 | Having my smartphone in my mind even when I am not using it |
| 7 | I will never give up using my smartphone even when my daily life is already greatly affected by it. |
| 8 | Constantly checking my smartphone so as not to miss conversations between other people on Twitter or Facebook |
| 9 | Using my smartphone longer than I had intended |
| 10 | The people around me tell me that I use my smartphone too much. |

Correlations between screen use and outcomes

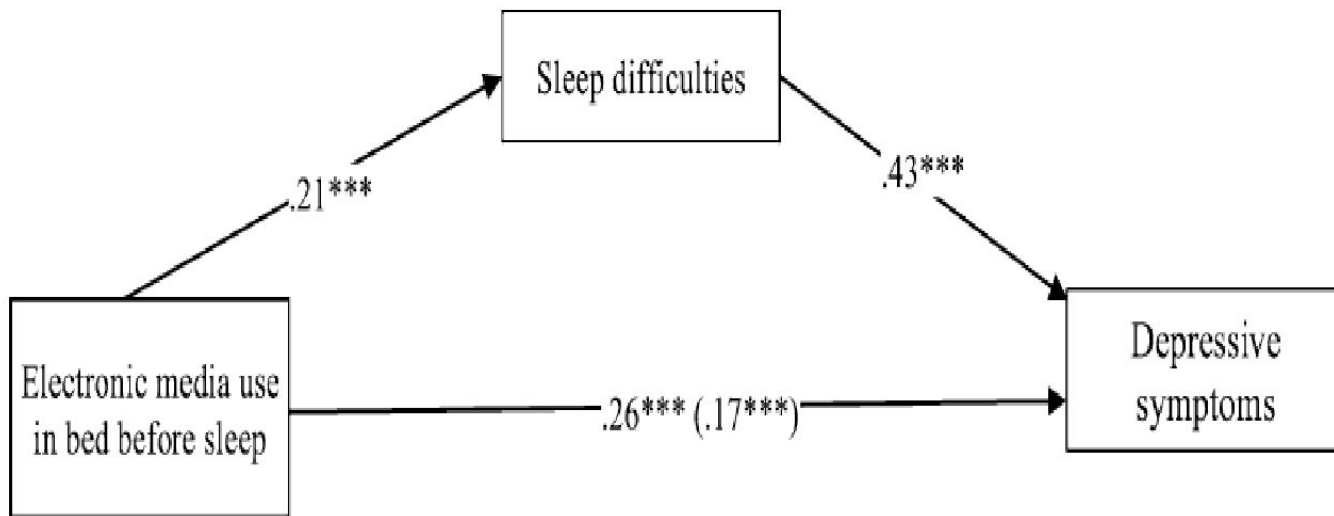
Hours of sleep with and without devices



Screens and melatonin



Interesting relationship . . .



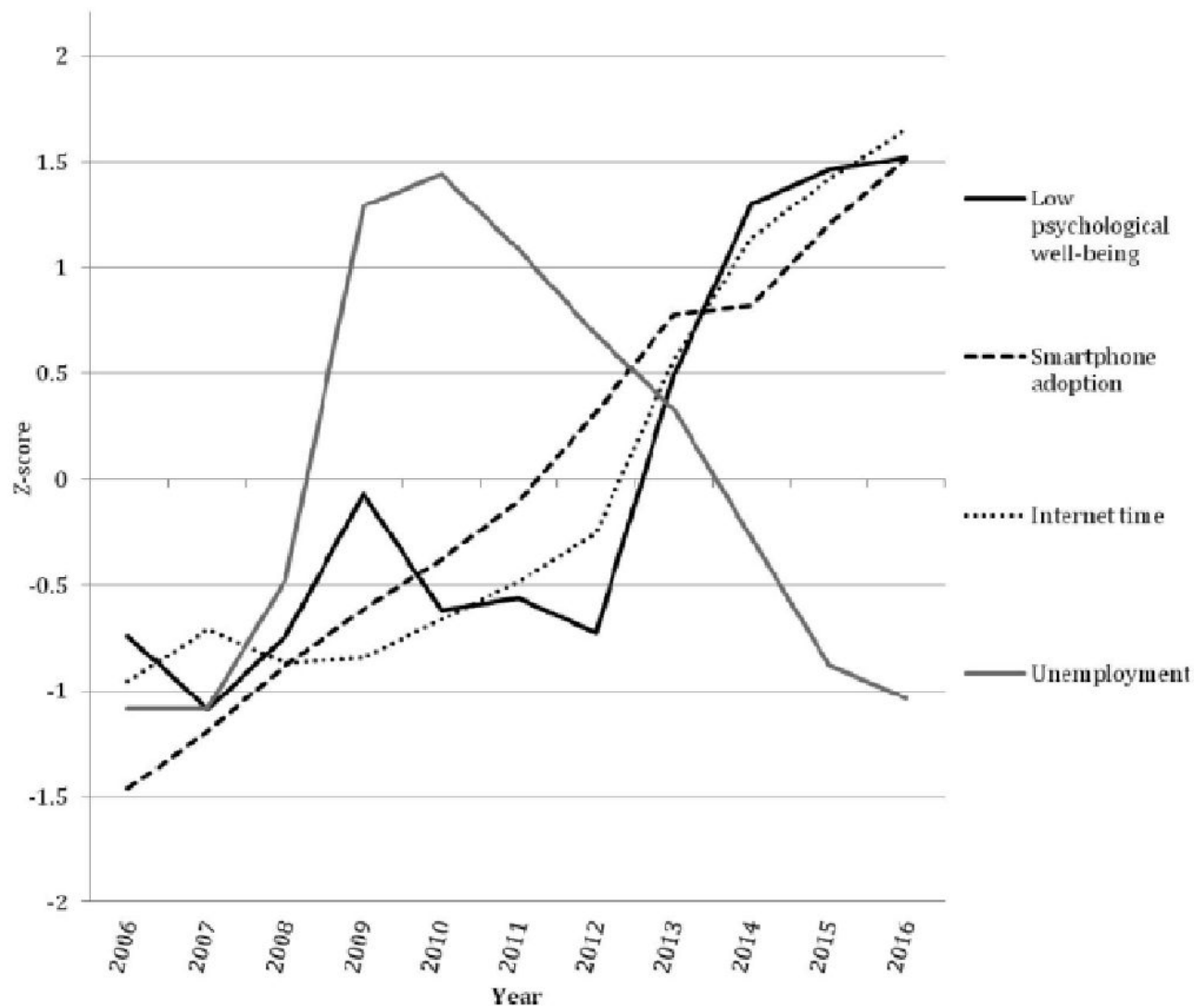
Screens and well-being

- 2018 study (Twenge, et al.)
- Questionnaire data from 500,000+ adolescents (Monitoring the Future)

DECLINES IN ADOLESCENTS' WELL-BEING AFTER 2012



Figure 1. Total self-esteem, 8th, 10th, and 12th graders, 1991–2016. Error bars represent ± 1 SE. The y-axis is truncated to illustrate the changes. The potential range of self-esteem was 1–5, with an SD of approximately .97. More detail given in Table 1.



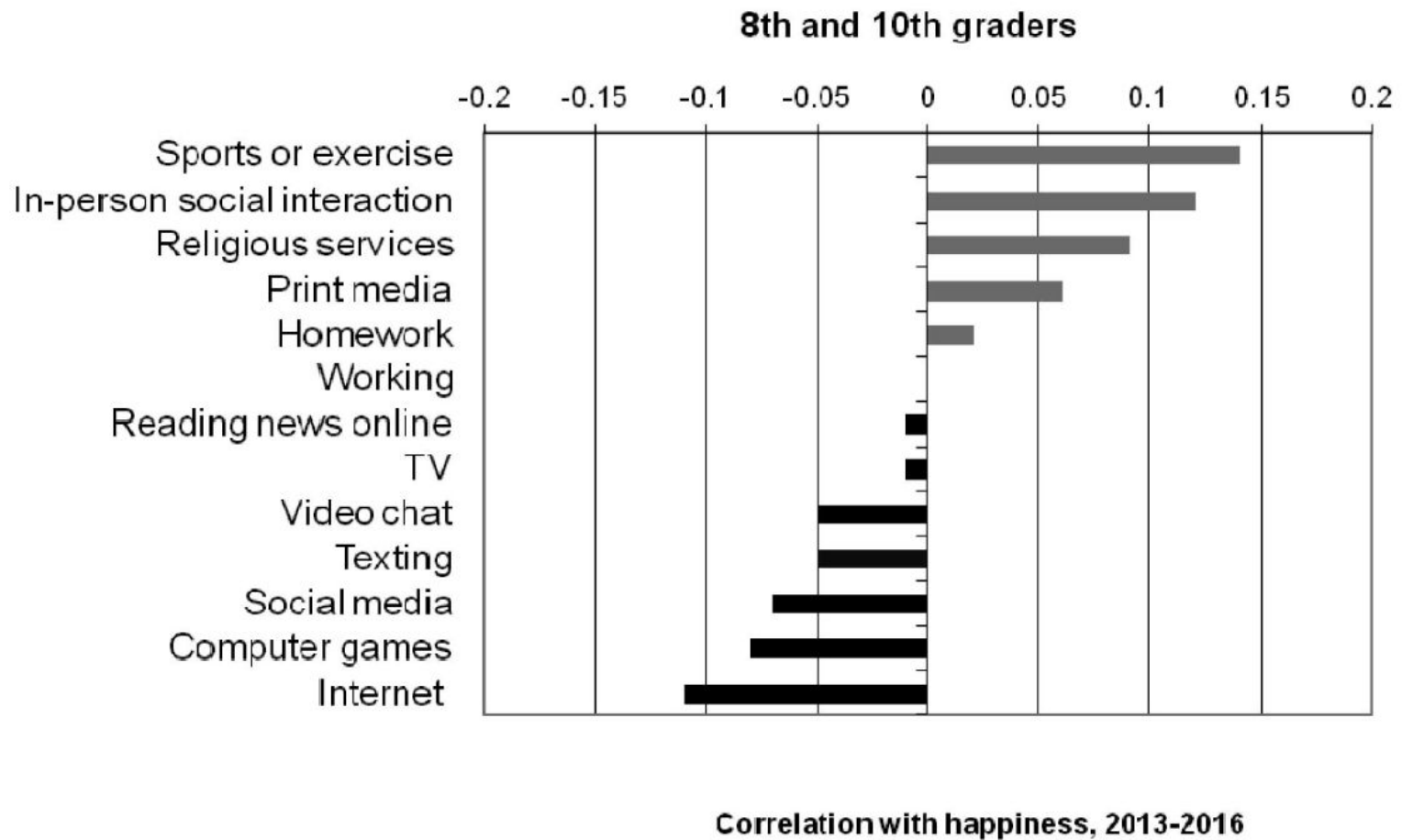


Figure 4. Partial correlations between happiness and screen activities (black bars) and nonscreen activities (gray bars), including demographic controls, 8th and 10th graders, 2013–2016.

ABCD study

- 10 year study of 10,000 adolescents, starting at age 9
- Neuroimaging
- Screens, family relationships, drugs, etc.
- Examine how brains change over time