Centre for Educational Neuroscience

Birkbeck UNIVERSITY OF LONDON

The Paradox of the Teenage Brain

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10 October 2017

Neuroscience!

The paradox

Charles Dickens

It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness,

A TALE OF TWO BRAINS.

IN THREE BOOKS.

BOOK THE FIRST. RECALLED TO LIFE.

CHAPTER I.

THE PERIOD.

It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to Heaven, we were all going direct the other way—in short, the period was so far like the present period, that some of its noisiest authorities insisted on its being received, for good or for evil, in the superlative degree of comparison only.

There were a king with a large jaw and a queen with a plain face,

"In adolescence and young adulthood, the cognitive skills assumed to underlie educational and economic success are at a lifetime peak … [yet] the application of these mental faculties to real life seems woefully inadequate. Instead of learning from experience, reasoning about risks, and making sound decisions, youth often make unhealthy and unsafe choices"

- Reyna and Dougherty (2012)

Introduction

Adolescence

Beginning

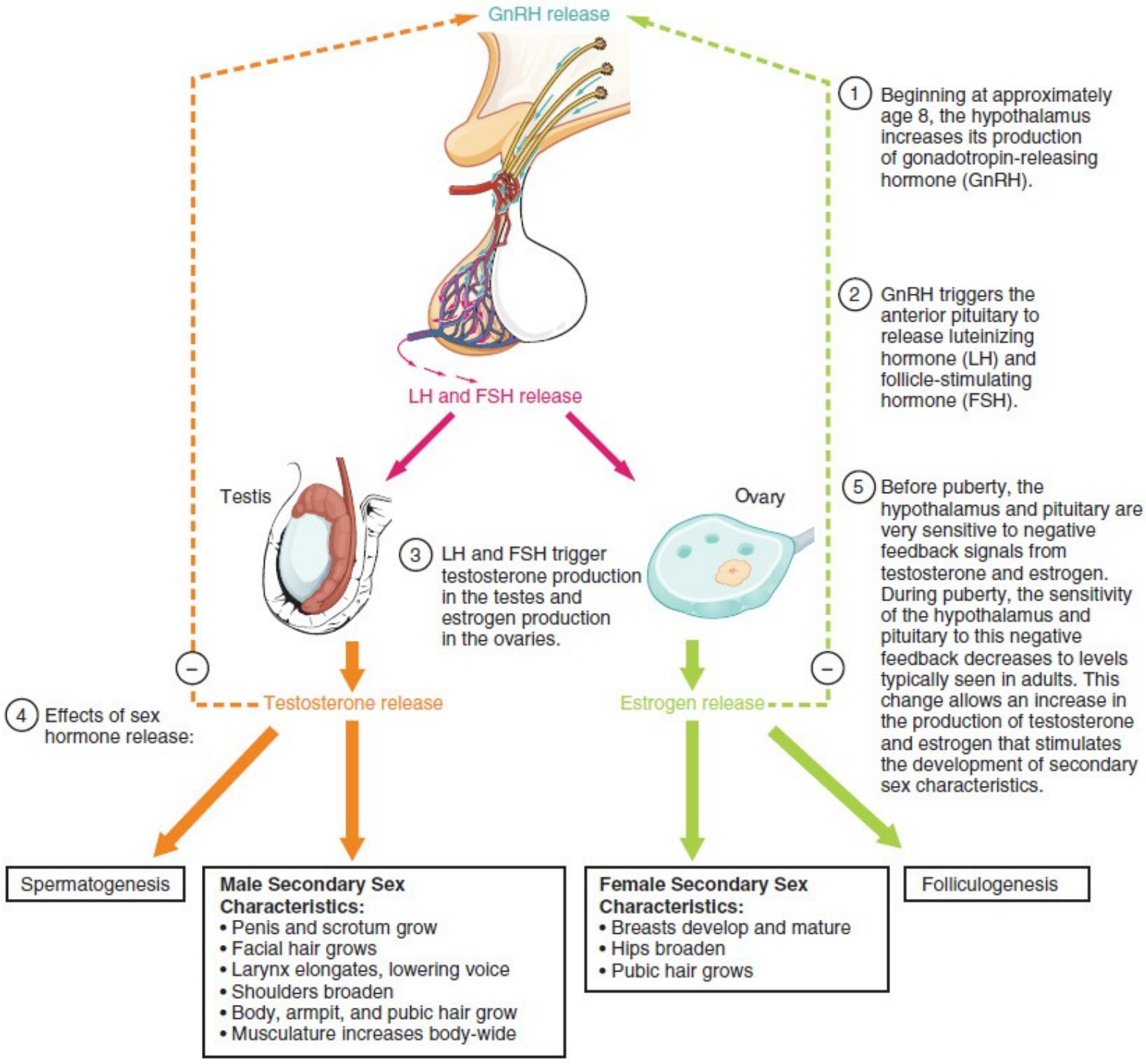
Biological – puberty

End

Responsible, independent member of society

Then: Puberty 15 years, Independence 18 years

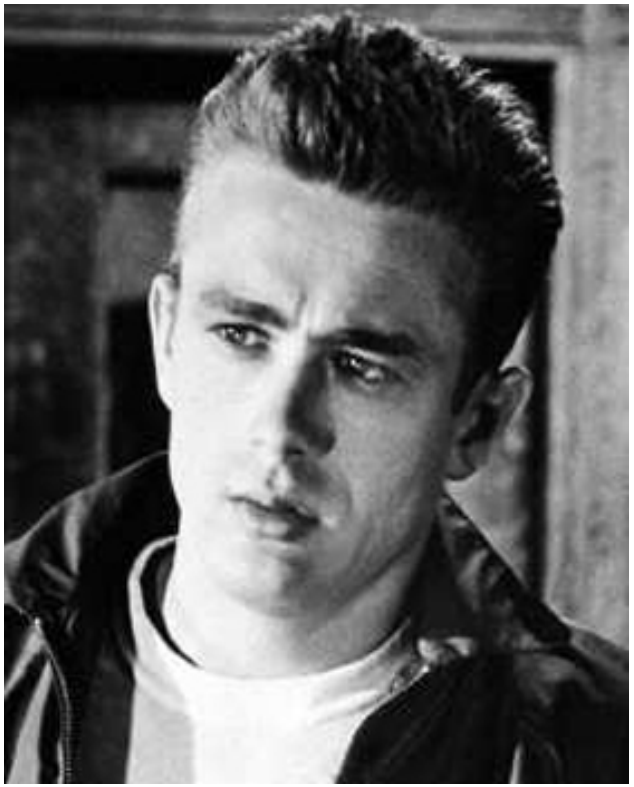
Now: Puberty 12 years, Independence 25 years


GnRH release
1 Beginning at approximately age 8, the hypothalamus increases its production of gonadotropin-releasing hormone (GnRH).
2 GnRH triggers the anterior pituitary to release luteinizing hormone (LH) and follicle-stimulating hormone (FSH).
LH and FSH release
Testis
Ovary
3 LH and FSH trigger testosterone production in the testes and estrogen production in the ovaries.
5 Before puberty, the hypothalamus and pituitary are very sensitive to negative feedback signals from testosterone and estrogen. During puberty, the sensitivity of the hypothalamus and pituitary to this negative feedback decreases to levels typically seen in adults. This change allows an increase in the production of testosterone and estrogen that stimulates the development of secondary sex characteristics.
Testosterone release
Estrogen release
4 Effects of sex hormone release:
Spermatogenesis
Male Secondary Sex Characteristics:
• Penis and scrotum grow
• Facial hair grows
• Larynx elongates, lowering voice
• Shoulders broaden
• Body, armpit, and pubic hair grow
• Musculature increases body-wide
Female Secondary Sex Characteristics:
• Breasts develop and mature
• Hips broaden
• Pubic hair grows
Folliculogenesis

Hormones and the brain

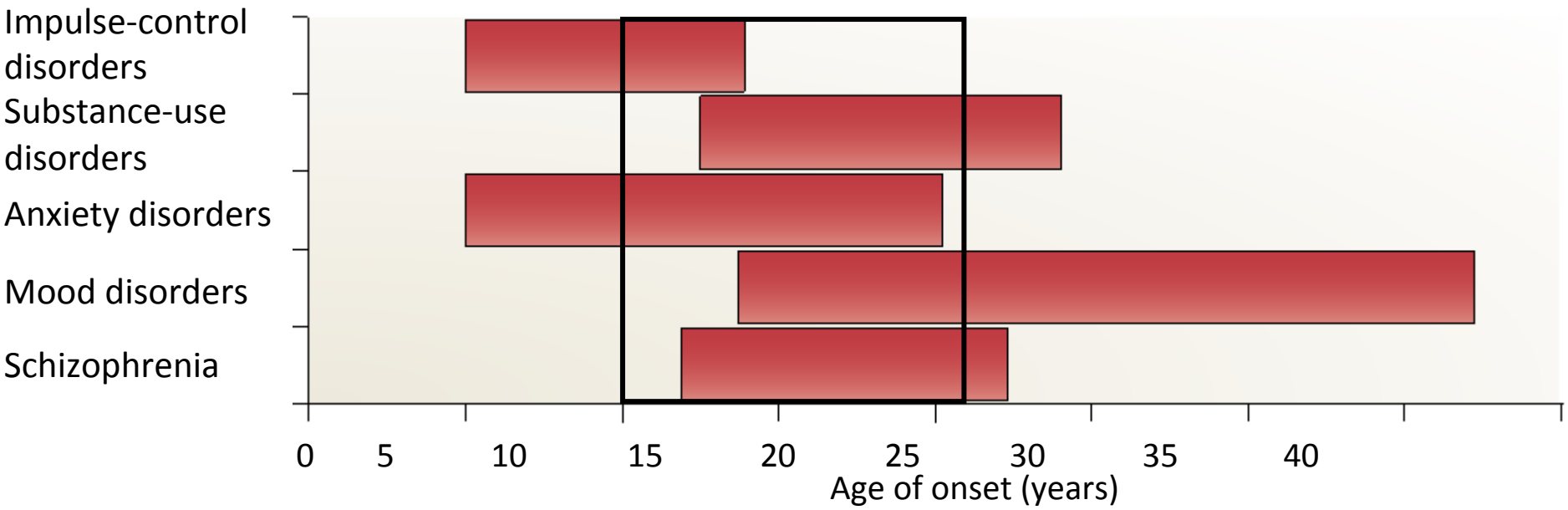
- We don't know exactly what effect they have on brain circuits
- Dopamine levels increase. It regulates…
  - emotional arousal
  - pleasure and reward
  - learning
- Testosterone levels increase. It…
  - promotes search for and maintenance of social status
  - alters appraisal of threats and rewards, esp. when relevant to social status

Individual differences



A James Dean in 10

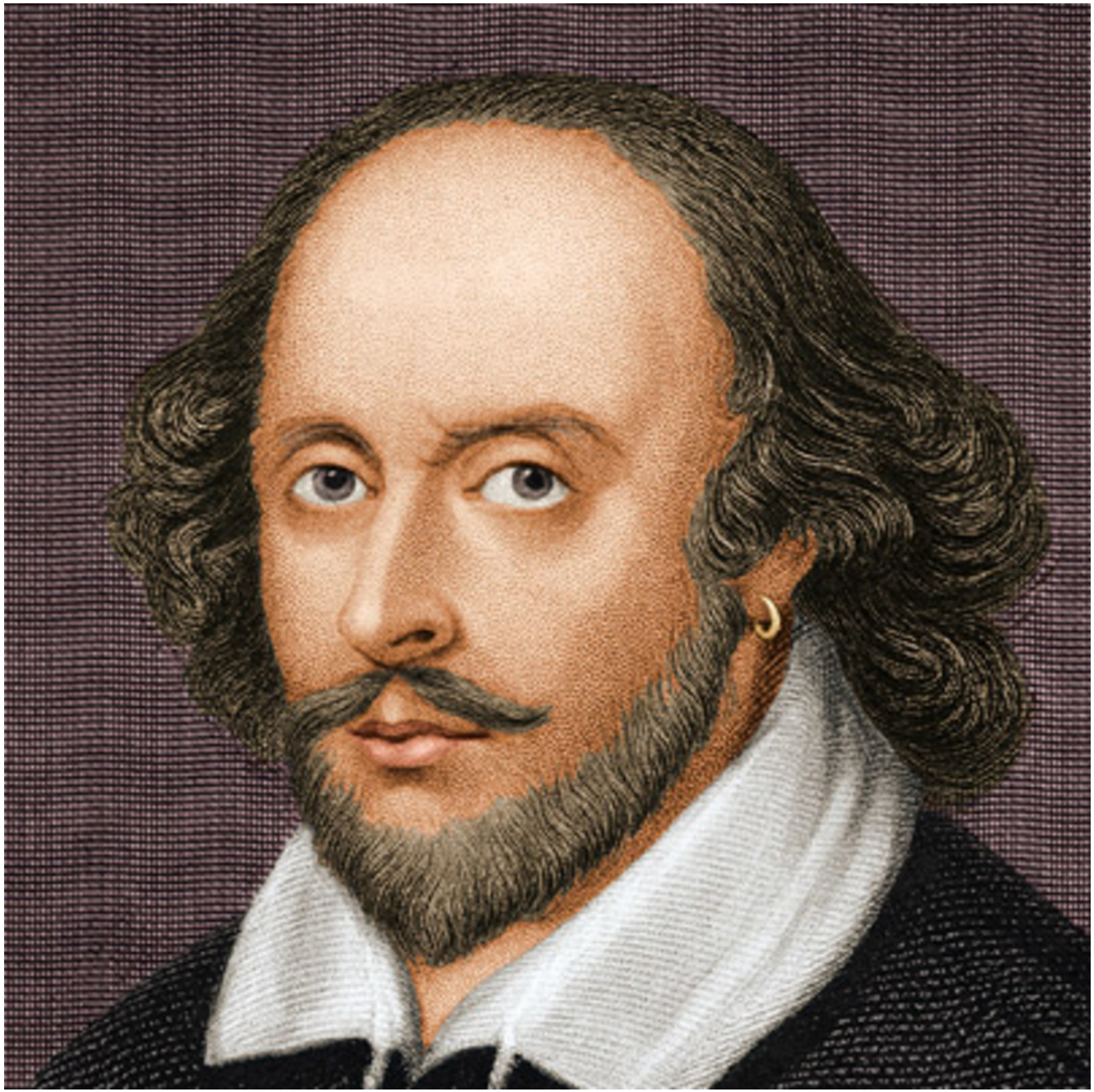
Adolescence and mental health

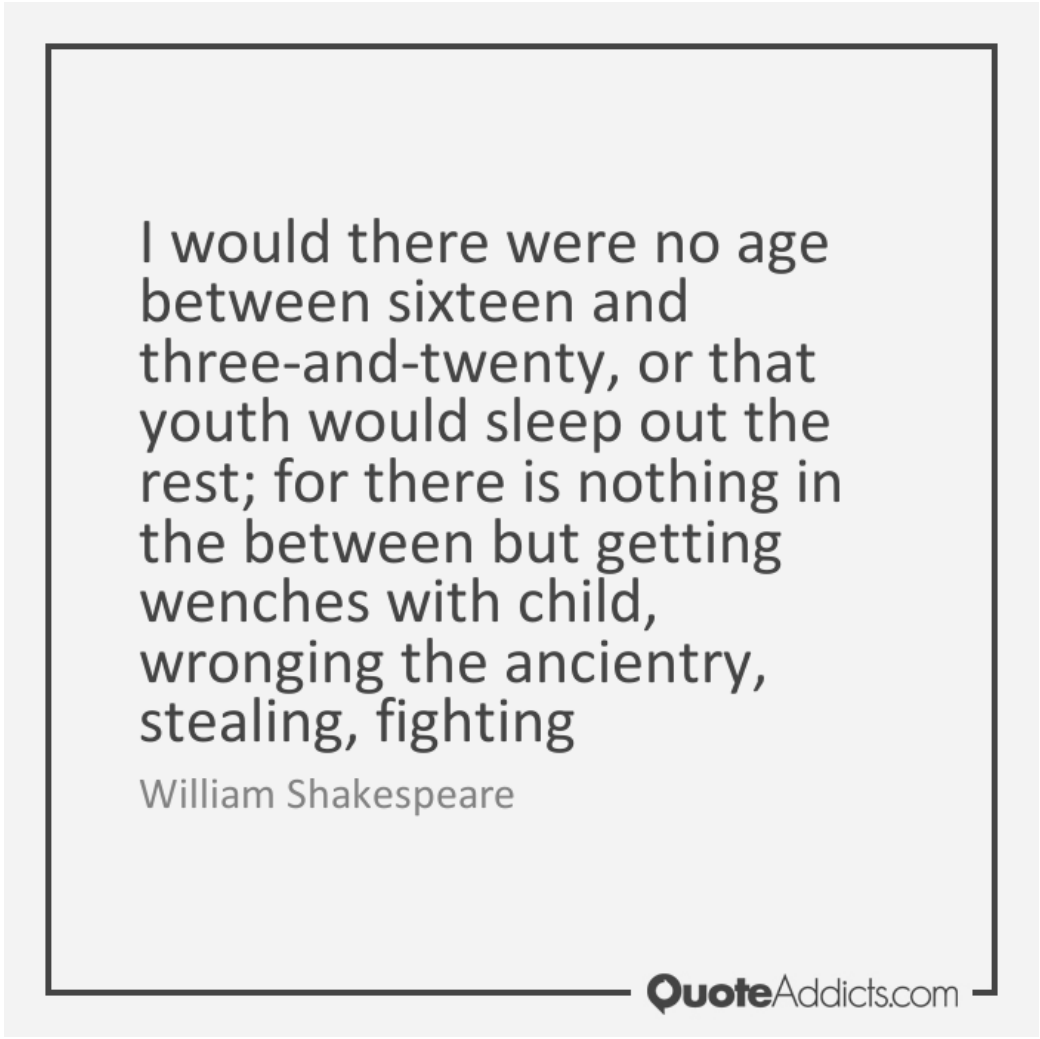


- 75% of adult mental disorder has its onset before 24 years of age; mostly during adolescence (Kessler et al, *Arch Gen Psych,* 2005)
- Leading causes of death in adolescence are: 1) accidents, 2) violence and 3) suicide (Patton et al., *The Lancet,* 2009)

Dr. Iroise Dumontheil

Four theoretical views of the teenage years





The Winter's Tale, III.iii

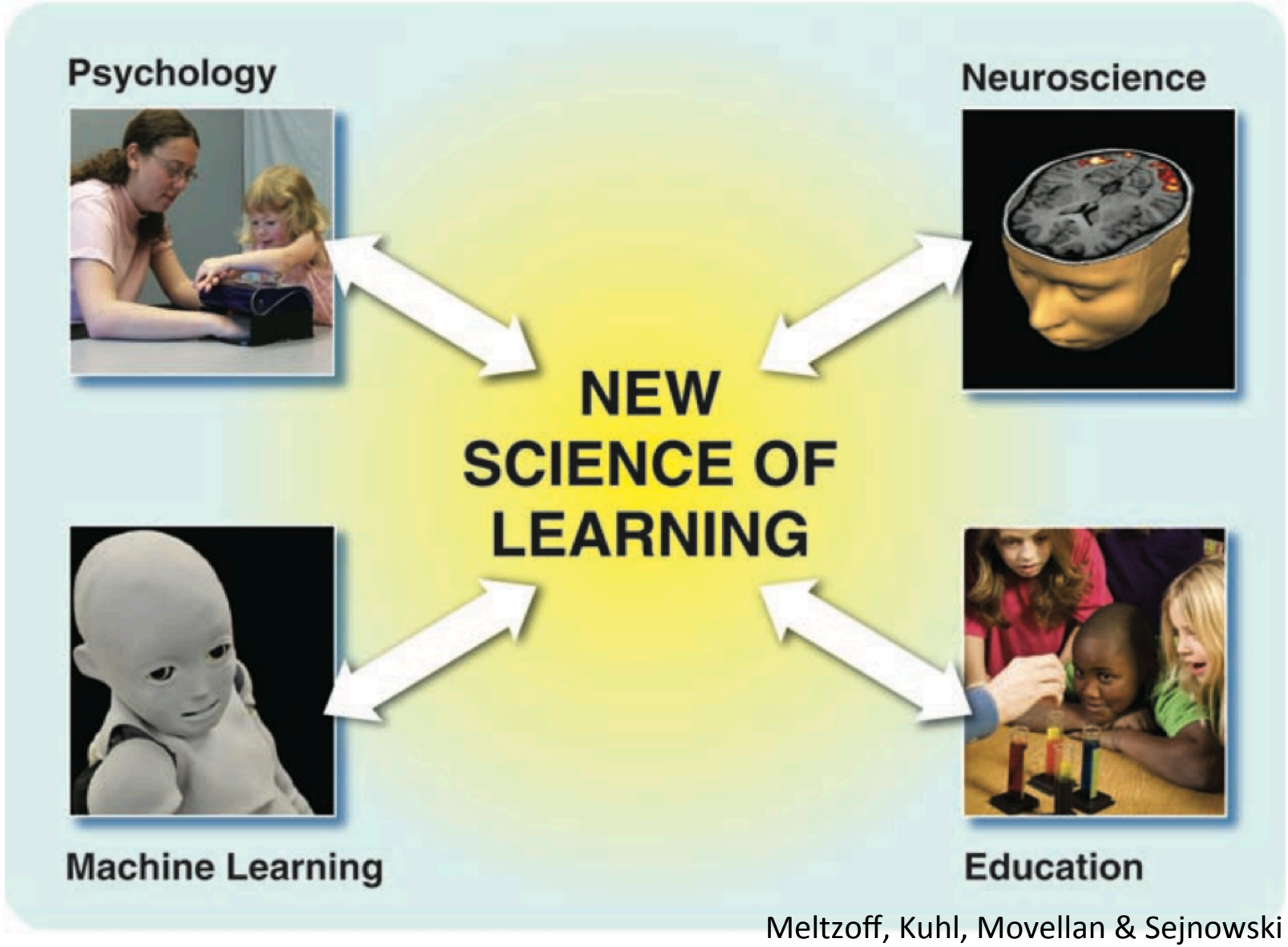
1960s and identity

Adolescent egocentricism
(Elkind, 1967)

- Teenagers can spend a lot of time thinking about themselves and their social circumstances
- **Personal fable**: overestimation of uniqueness of their feelings and experience
  - 'My parents can't possibly understand how I really feel', 'Nobody's ever felt love as deeply as ours'
- **Imaginary audience**: oversensitivity to social evaluation
  - Feeling always 'on stage', and that 'everybody's going to notice' how they look and what they do

Enter neuroscience

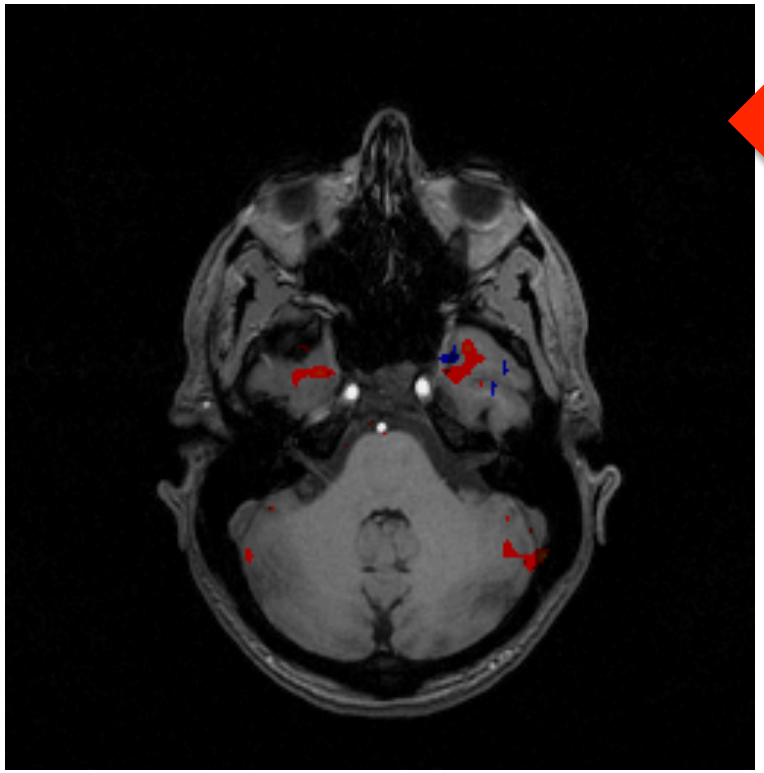
Educational neuroscience integrates different disciplines in a dialogue



Meltzoff, Kuhl, Movellan & Sejnowski (2010)

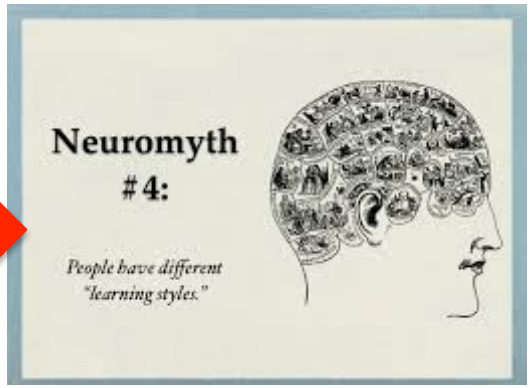
WARNING!

The Seductive Allure of Neuroscience



Don’t be impressed by this!

Don’t believe in these!



Different types of abilities appear to be manipulable at different ages. IQ scores become stable by age 10 or so, suggesting a sensitive period for their formation below age 10

There is evidence that adolescent interventions can affect noncognitive skills. This evidence is supported in the neuroscience that establishes the malleability of the prefrontal cortex into the early 20s. This is the region of the brain that governs emotion and self-regulation.

James Heckman
Nobel Prize winning economist

Heckman, James J. 2007. ''The Technology and Neuroscience of Capacity Formation.''
Proceedings of the National Academy of Sciences 104(3):13250–13255

IQ fixed by age 10? – neuroscience say no!

theguardian

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Teenagers' IQ scores can rise or fall sharply during adolescence

A study suggests IQ is not stable during teenage years as was thought but shifts in step with changes in particular brain areas

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Ed Yong
guardian.co.uk, Wednesday 19 October 2011 18.40 BST
Article history

A larger | smaller

The IQ findings indicate teachers should be wary of predicting academic success based on early educational tests. Photograph: Don McPhee/Guardian

Scores on IQ tests can change dramatically during teenage years, rising or falling in parallel with changes to specific parts of the brain, according to a study in which adolescent volunteers had their brains scanned.

The research suggests that teachers should be cautious about predicting academic success based on early educational tests such as the 11+ exam, which is used to select students for grammar schools.

IQ, the most common measure of intelligence, was thought to be stable across a person's lifespan, and childhood scores are often used to predict a person's educational and employment prospects as an adult. But the new study suggests that these scores are surprisingly variable.

"A testing industry has developed around the notion that IQ is relatively

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SO UNFAIR: Teenagers are known for their wild mood swings and surging hormones – but now it seems their intelligence is also prone to such fluctuations. IQ, the standard measure of intelligence, can rise or fall significantly during adolescence, tests have shown. The shifts relate to changes to the structure of our brains, according to a University College London report in the journal Nature.

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19 October 2011 Last updated at 19:41

IQ 'can change in teenage years'

The mental ability of teenagers can improve o decline on a far greater scale than previously thought, according to new research.

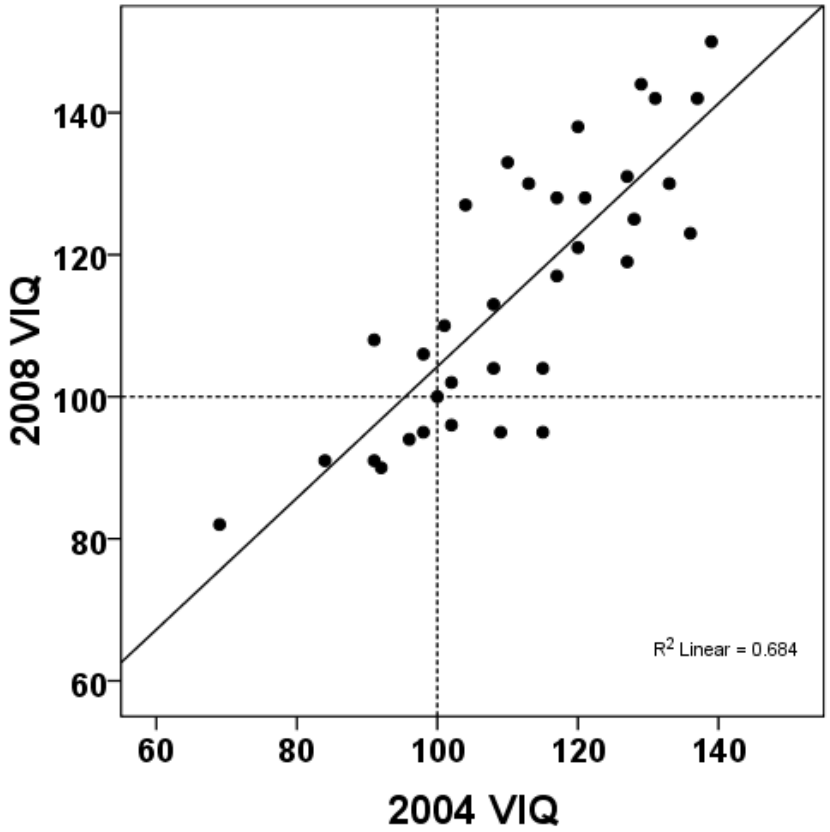
Scots carbon capture scheme scrapped

Within individuals,

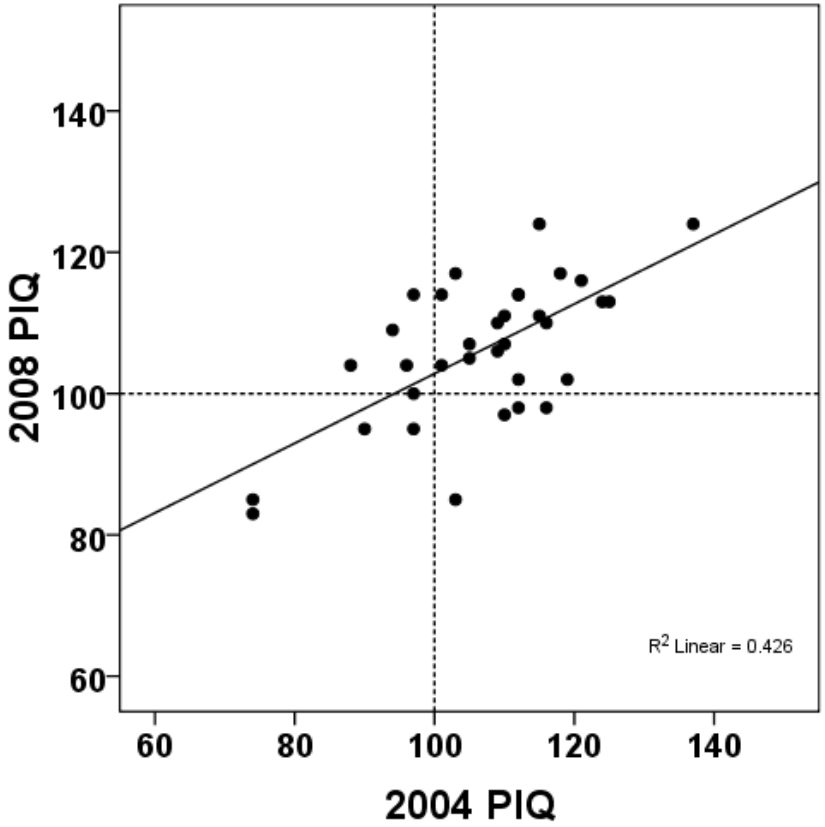
IQ is remarkably constant over time

2004: Age 13-15; 2008: Age 17-19

Verbal IQ

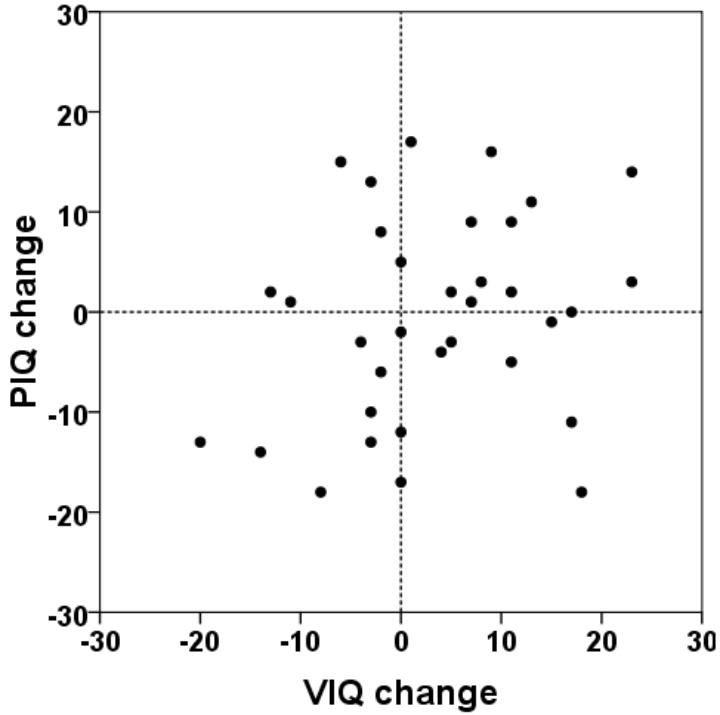


Performance IQ

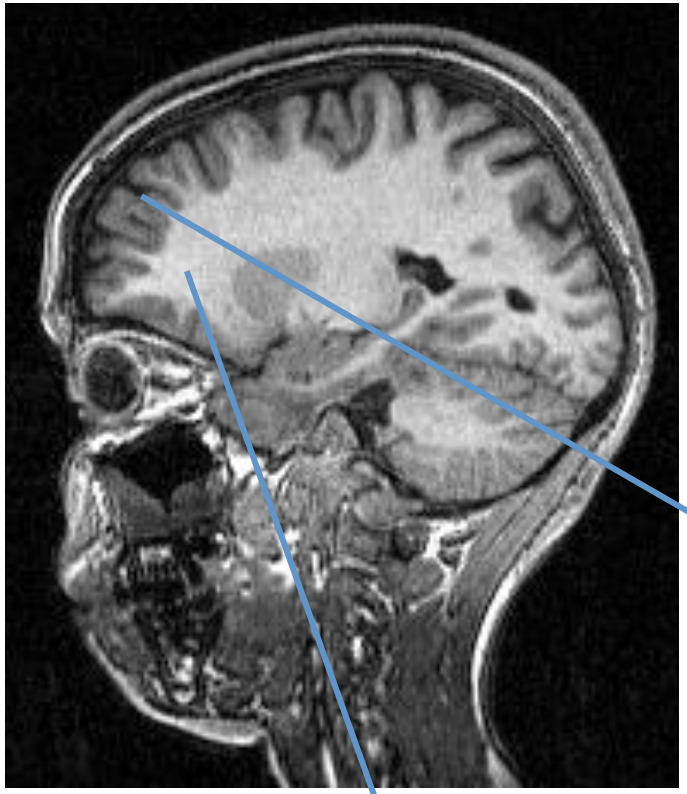


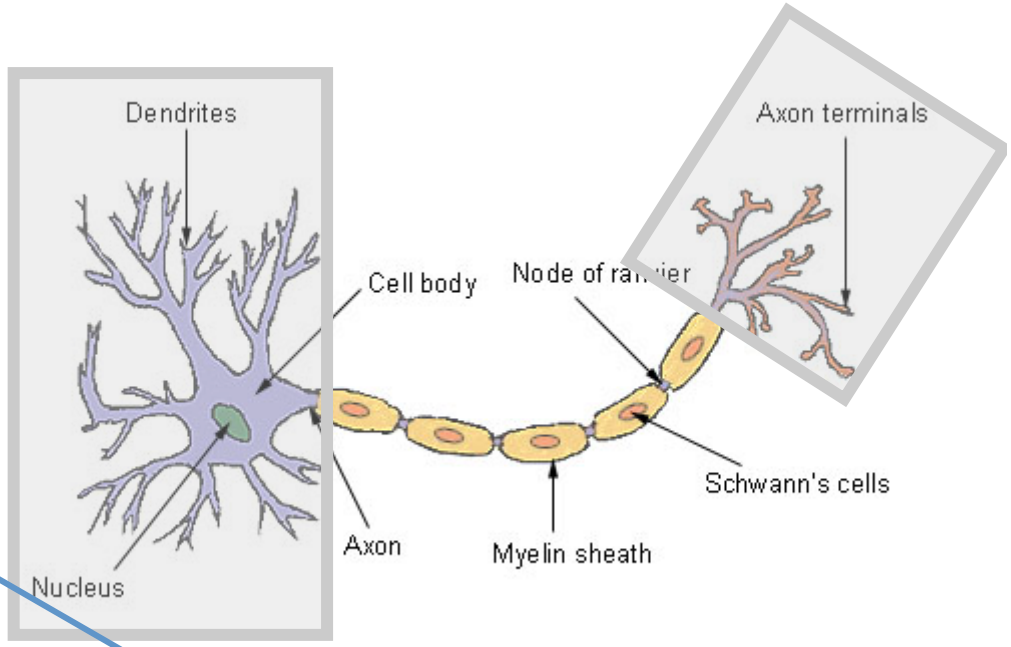
But there is some change over time: Meaningful or measurement error?

VIQ change & PIQ change (across years) are not correlated



Grey and white matter

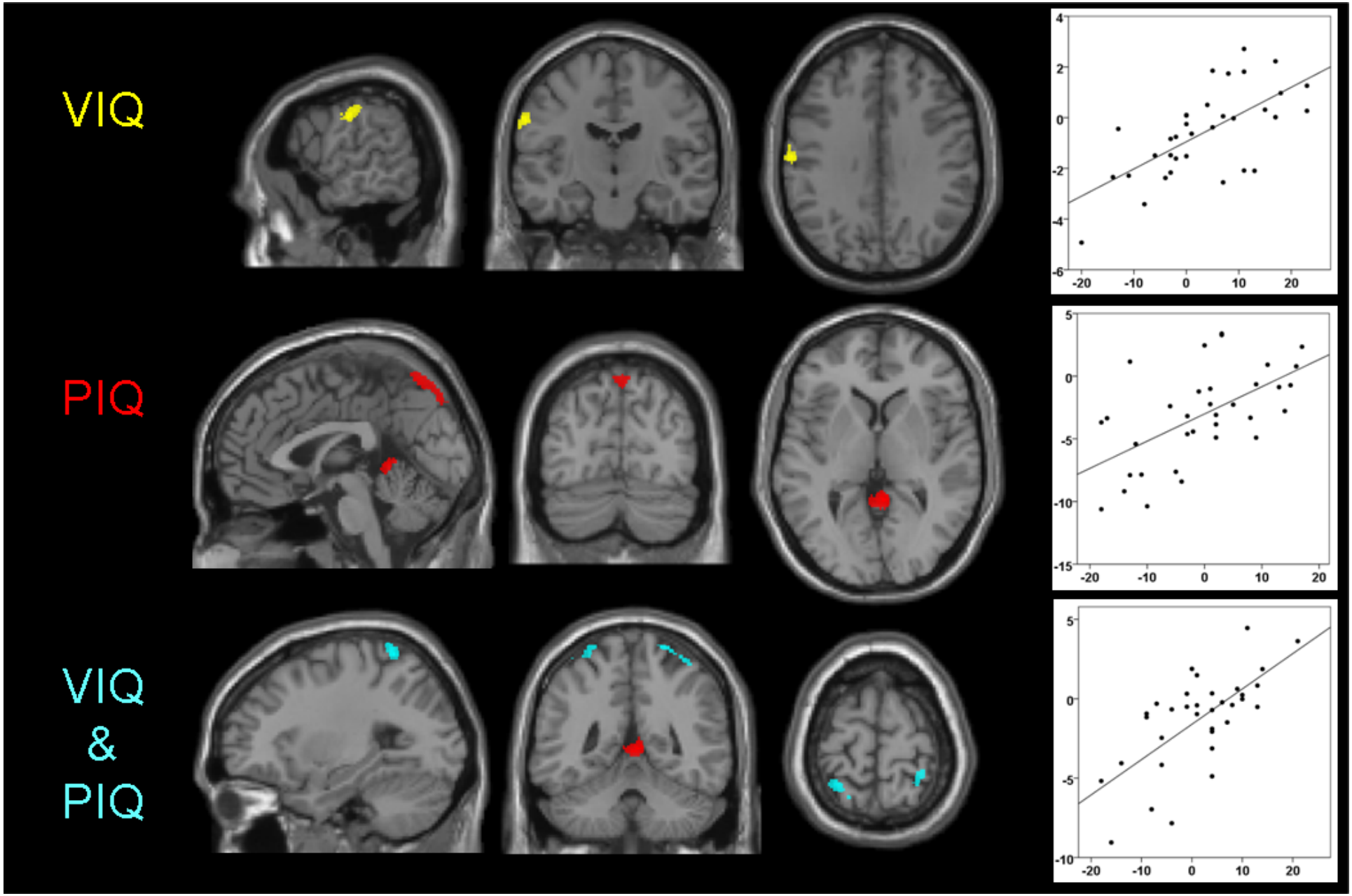




White matter comprises long fibres that carry signals between brain regions

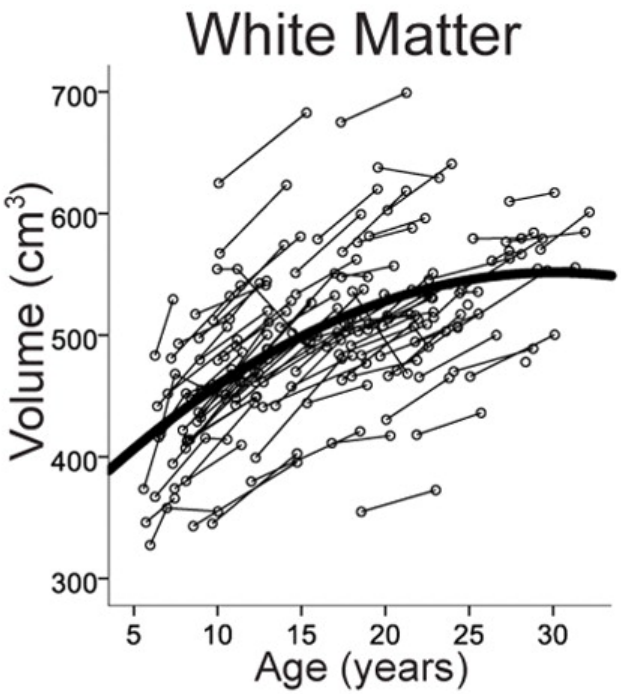
Grey matter contains brain cells and connections

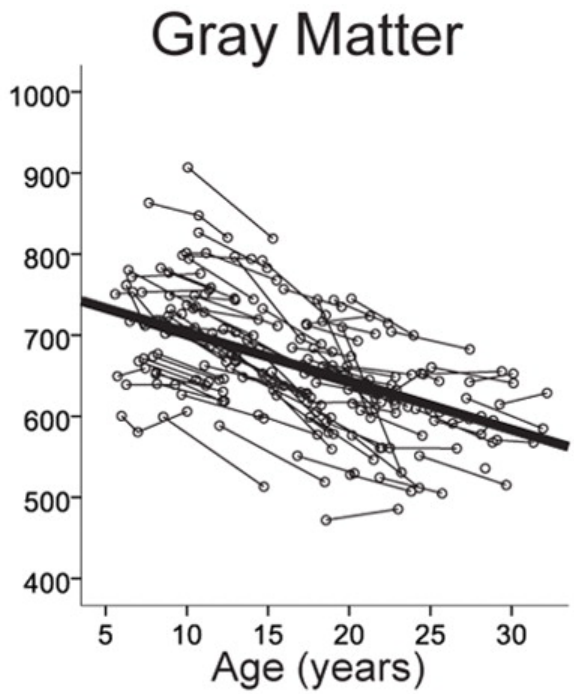
Change in brain structure with Change in IQ

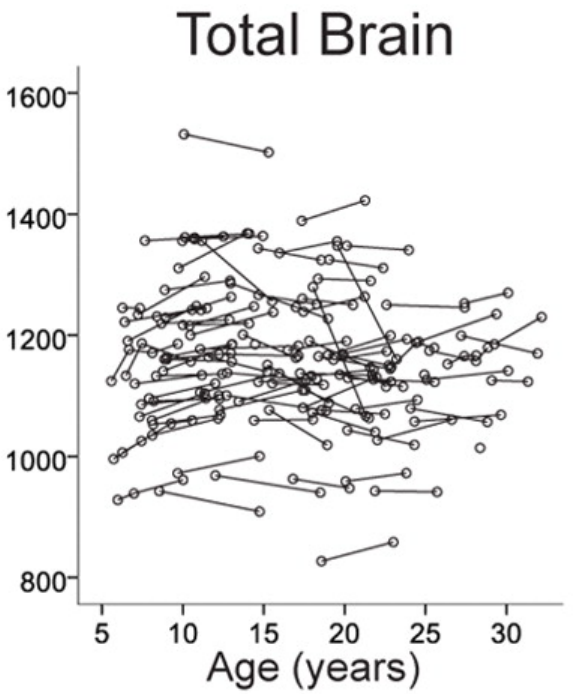


Implications for education

- Teachers should be cautious about predicting academic success based on early educational tests such as the 11+ exam, which is used to select students for grammar schools







Insulating

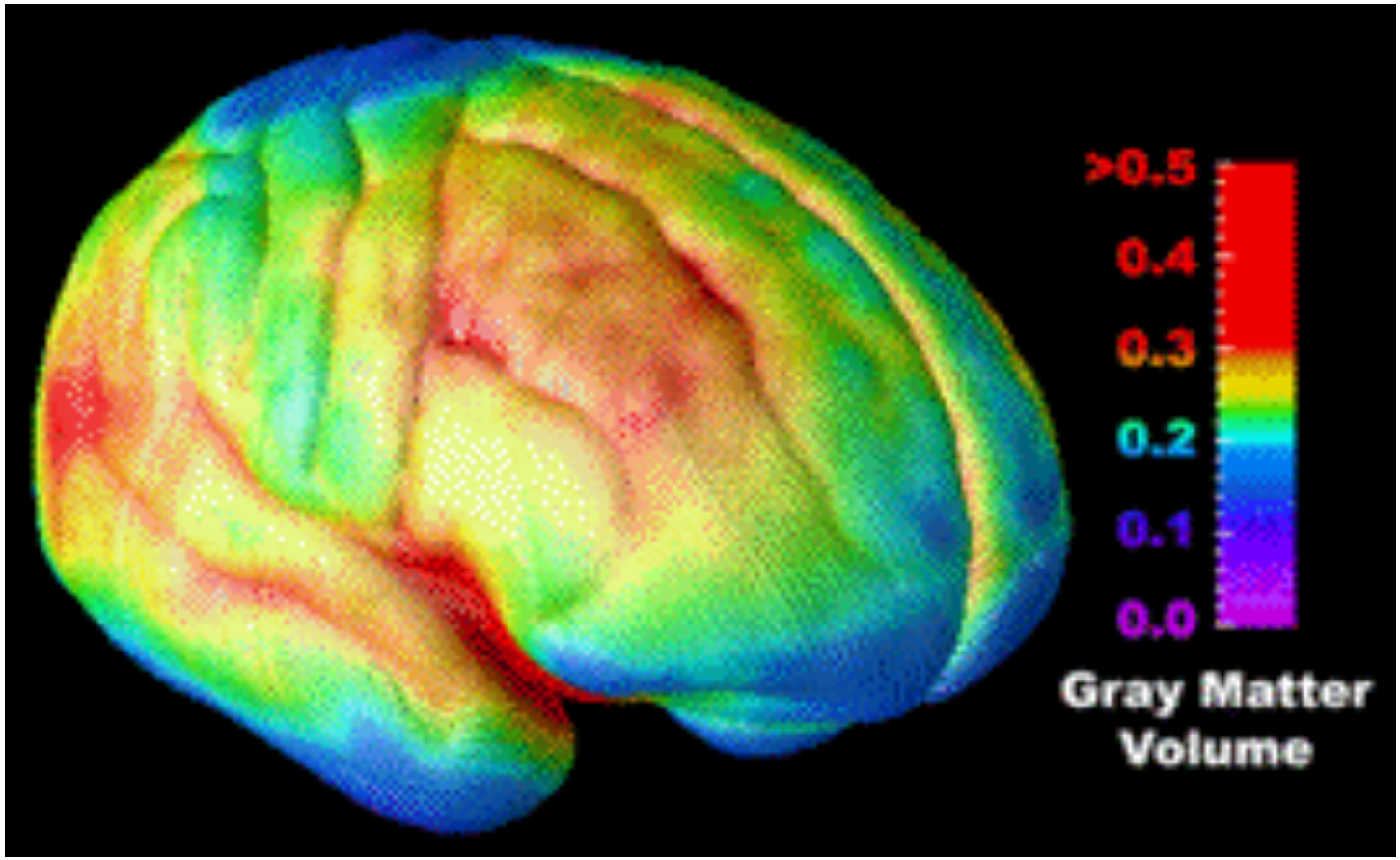
Corresponds partly to myelination and increasing axon diameter.
> Speeds up signalling between neurons
Facilitates processing speed and learning

Streamlining

Corresponds partly to synaptic reorganisation
> Fine-tuning of grey matter tissue according to experience & environment

Lebel & Beaulieu *Journal of Neuroscience* 2011

Gotgay et al. (2004)



Last regions to mature (lose grey matter): frontal regions, superior temporal and parietal regions, involved in cognitive control and social cognition

Skills that are still developing in adolescence

- Social cognition
  - How we process, store and use information about other people, and how this in turn influences our behaviour, feelings and social interactions
- Cognitive control
  - The ability to flexibly adapt one's behaviour in the pursuit of an internal goal by the coordination of a collection of cognitive processes
- Ability to pass GCSEs and A-levels …

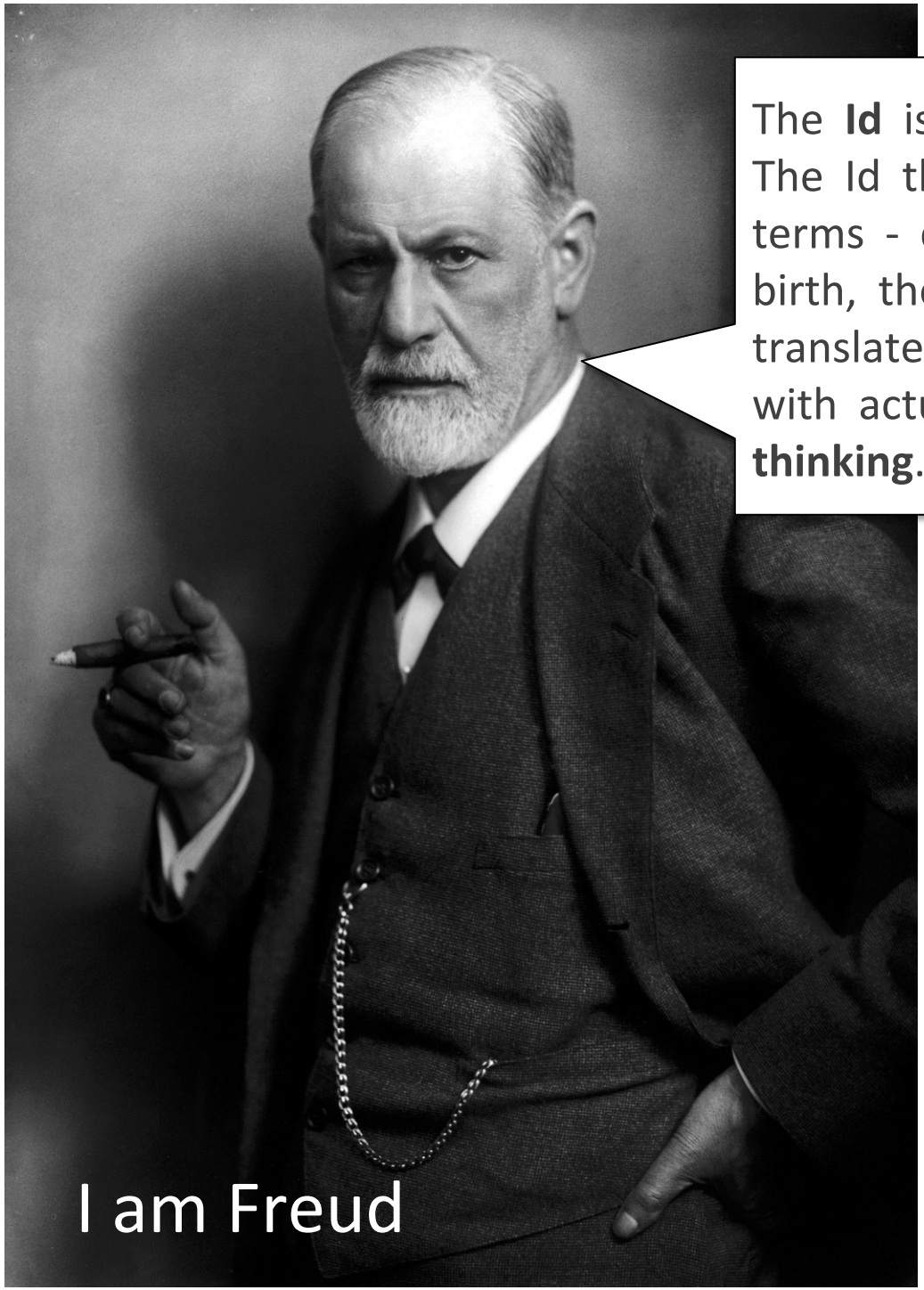
Improvements during late adolescence (16-19 years) in a range of cognitive tasks

- Planning ahead (Steinberg et al. *Child Development* 2009)
- Inhibiting inappropriate responses (Tamm et al. *Journal of the American Academy of Child & Adolescent Psychiatry* 2002)
- Understanding how current actions have future consequences – impulsivity (Steinberg et al. *Child Development 2009)*
- Assessing risk (Burnett et al. *Cognitive Development* 2009)
- Taking another person's perspective (Dumontheil et al. *Developmental Science* 2010)
- Resistance to peer influence (Gardner & Steinberg, *Developmental Psychology* 2005)

Fronto-cortical immaturity

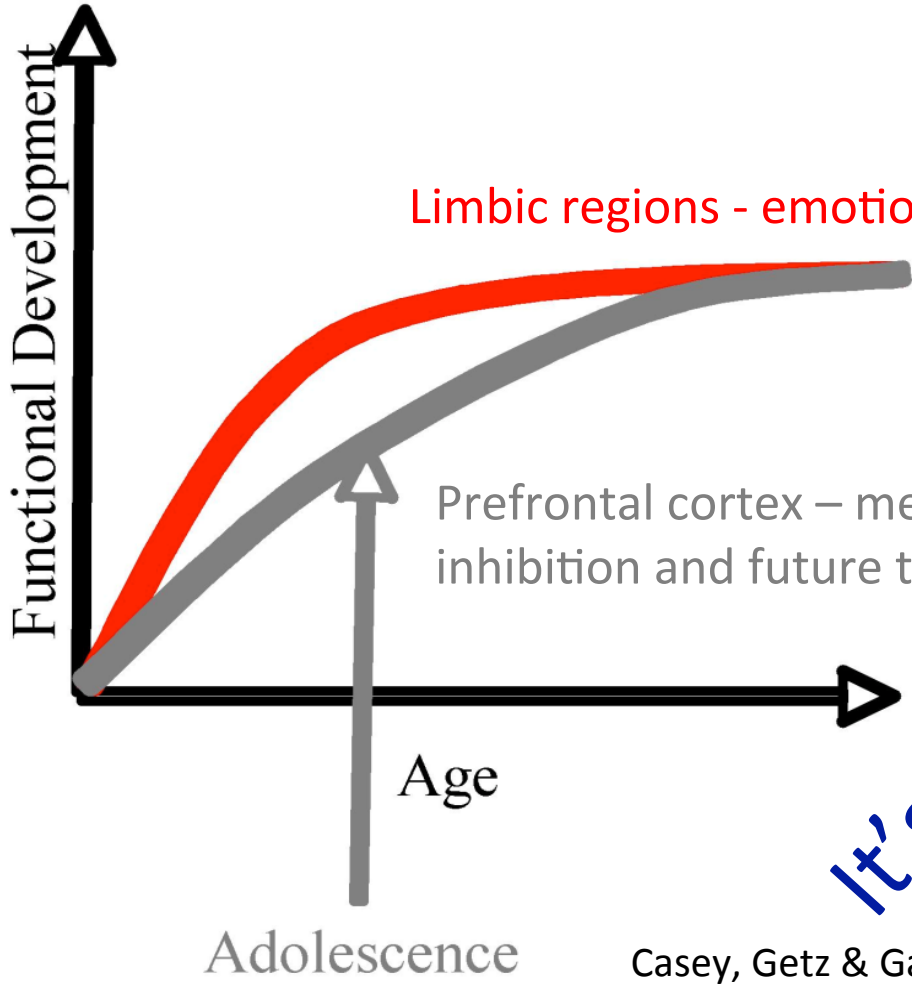
Fronto-cortical immaturity hypothesis

- The subcortical brain areas for emotion (including risk and threat processing) develop faster than the frontal cortical areas for cognitive control
- Produces more emotional / less rational decisions (not sufficiently weighting long-term outcomes)
- Greater risk of impulsive and dangerous behaviour



The **Id** is a psychic structure present at birth. The Id thinks primarily in visual and irrational terms - called **primary process thinking**. After birth, the **ego** differentiates. Its function is to translate the id's internal wishes into contact with actual objects. This is **secondary process thinking**.

Mismatch between prefrontal and limbic system development in adolescence



It's *like* an adult brain, but broken!

Casey, Getz & Galvan *Developmental Review* 2008

Peer influence during adolescence

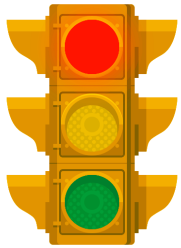
- Adolescent girls are more sensitive to social exclusion
  - (Sebastian et al., Brain and Cognition 2010; Sebastian, Tan, Roiser, Viding, Dumontheil, Blakemore, NeuroImage 2011)

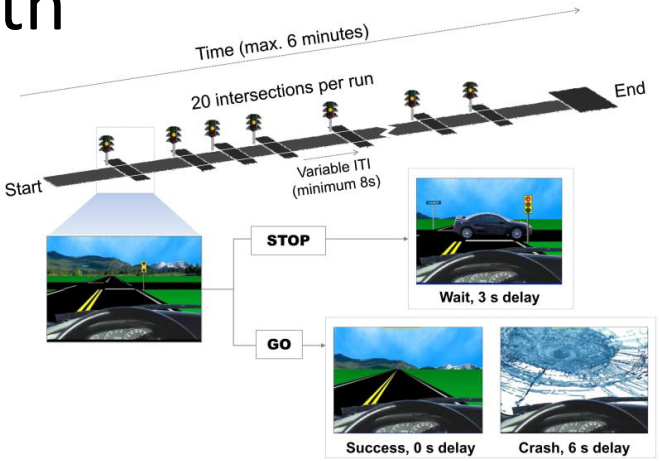
- Adolescents mostly commit crimes when they are in company of their peers, whereas adults tend to be alone
  - (Erickson & Jensen 1977; Zimring 1998)

- Risk-taking behaviour

Driving computer game

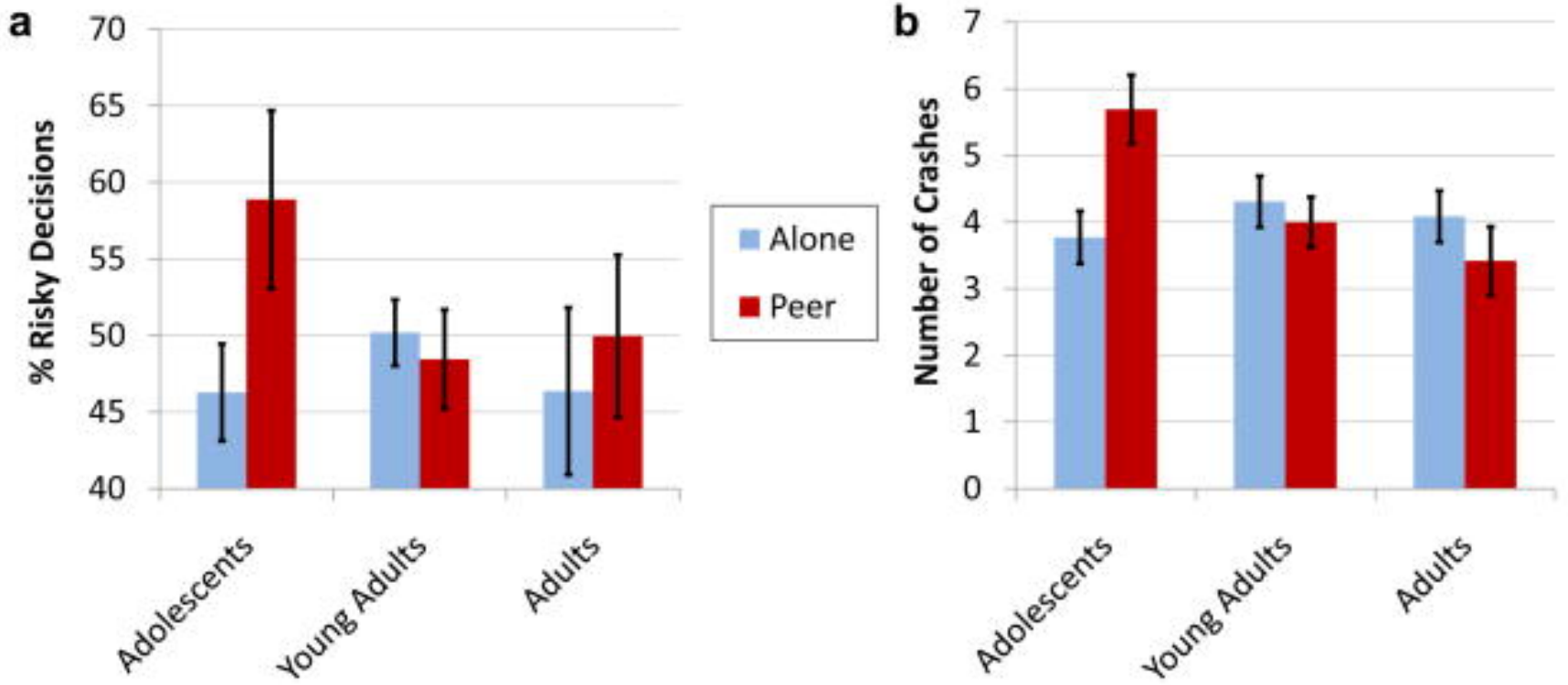
- Get to the end faster to win prizes!
- Got to cross junctions where there's a risk of an accident
  - Do you accelerate when the traffic lights go amber or brake?
- Play the game on your own or with peers watching you
- Can be carried out while in the brain scanner





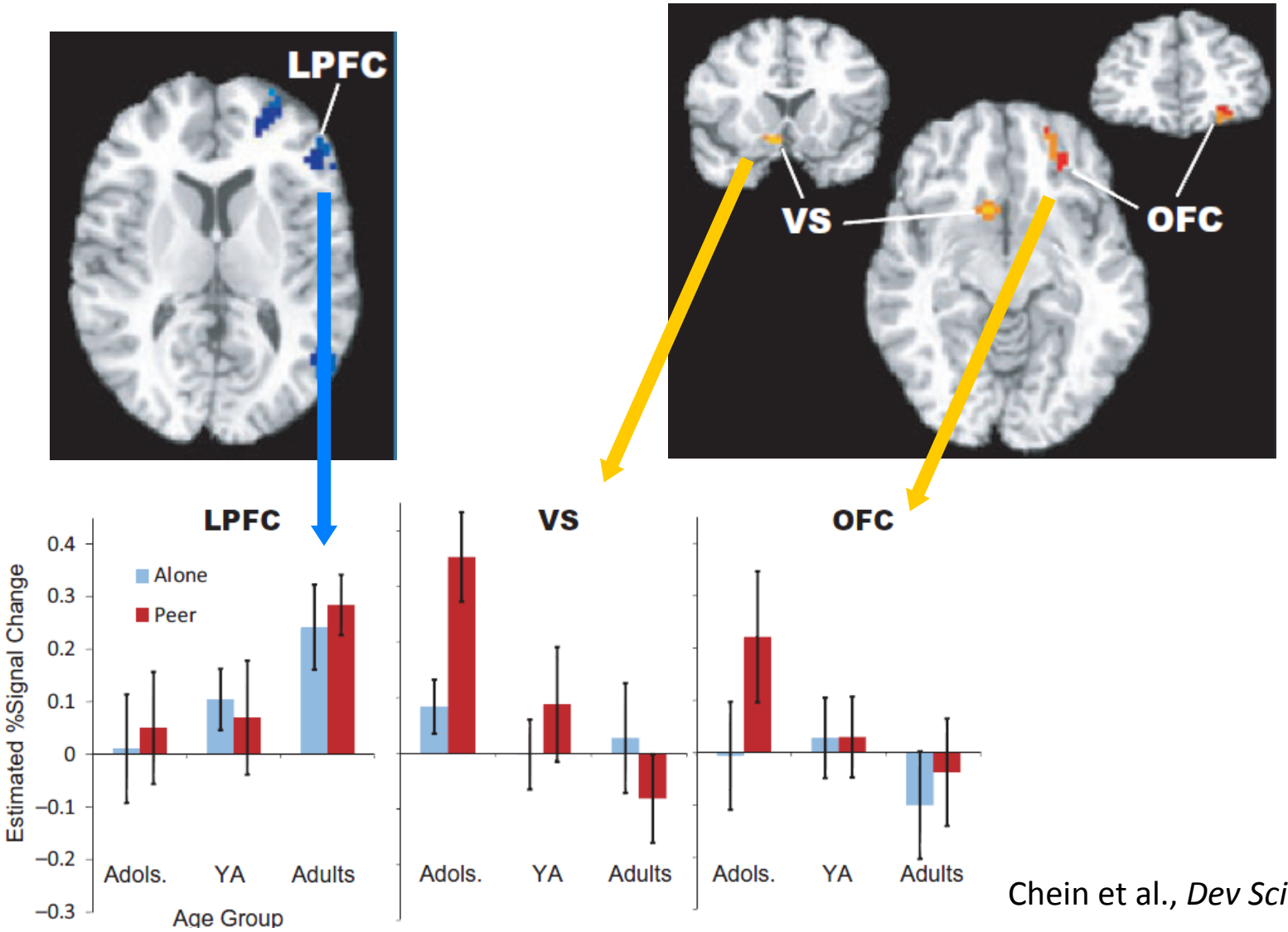
Chein et al., *Dev Science* 2011

- Adolescents crashed more when driving in company of peers
- They performed the same as adults when driving solo



Chein et al., *Dev Science* 2011

Neural substrates of peer influence on risk taking



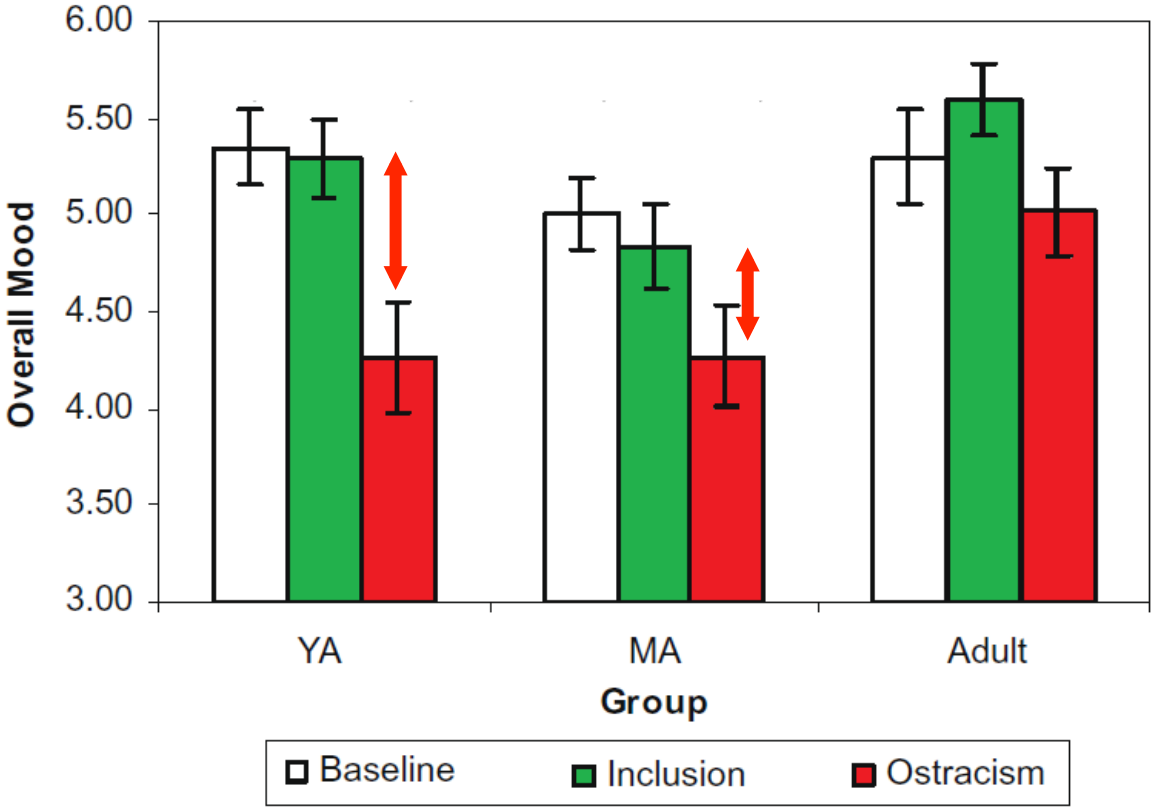
Chein et al., *Dev Science* 2011

The social exclusion game: Cyberball

N= 26 young adolescents (11-13y), 25 mid-adolescents (14-15y), 26 adults (22-47y)

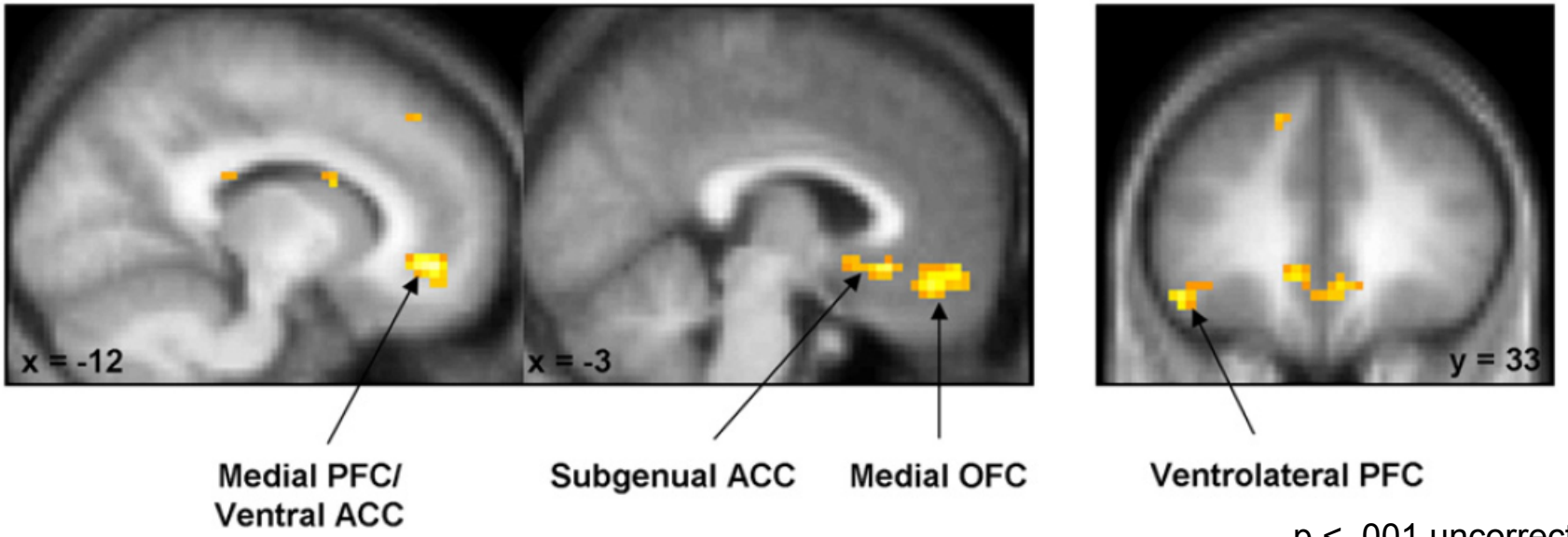
Sebastian, Viding, Williams, Blakemore, *Brain and Cognition* 2010

Hypersensitivity of female adolescents to social exclusion



Sebastian, Viding, Williams, Blakemore, *Brain and Cognition* 2010

What happens in the brain during social exclusion?



p < .001 uncorrected

Greater activations associated with poorer resistance to peer influence in the adolescents only

Greater activations in exclusion in adults may be related to regulation of social distress

Sebastian, Tan, Roiser, Viding, Dumontheil, Blakemore, *NeuroImage* 2011

Neural activity associated with protective and risk factors

- In Cyberball game to elicit feelings of rejection, early adolescents (10-12 years) showed more activation in the sub-genual ACC during rejection than adults (Gunther Moor et al., 2012)
- Activity in the insula was reduced in individuals who have many friends in daily life (Masten et al., 2012)
- Increased sub-genual ACC and medial PFC activity to social exclusion in the 12-13 year olds predicted increased depressive symptoms in the following year (Masten et al., 2011)

Fronto-cortical immaturity idea all well and good, but

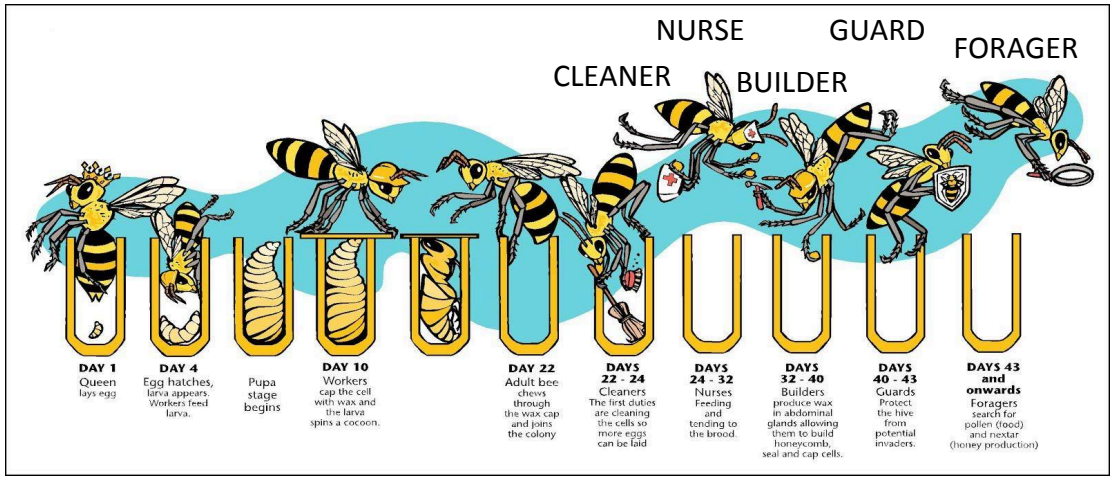
Three reasons for dumb choices

1. Impulsive, lack of control
2. I thought it was worth the risk
3. I knew it was wrong, but I was just so angry / excited / in love (etc.)

- Evidence that teens' decisions predicted by their (subjective) risk-reward analysis − not a lack of control! (Reyna & Doherty, 2012)
- Sometimes, estimation of risk better than adults − 'hyper-rational'

The social primate

Q. How do you genetically build something to later transform its behaviour?



A. Use hormones to change motivation; new motivation puts individual in new environment; create new brain plasticity to learn behaviours relevant to new environment

Crone & Dahl (2012)

- “Hormones in puberty contribute to adolescent risk taking in two ways:

1. Increasing the motivational salience of acquiring social status
2. Increasing the tendency to seek novel and high-intensity affective experiences, esp. in social contexts with opportunities to gain peer admiration”

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OPINION

Adolescence as a Sensitive Period of Brain Development

Delia Fuhrmann, Lisa J. Knoll, Sarah-Jayne Blakemore

PlumX Metrics

DOI: http://dx.doi.org/10.1016/j.tics.2015.07.008

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A Window of Opportunity for Cognitive Training in Adolescence

Lisa J. Knoll, Delia Fuhrmann, Ashok L. Sakhardande, more...

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Abstract

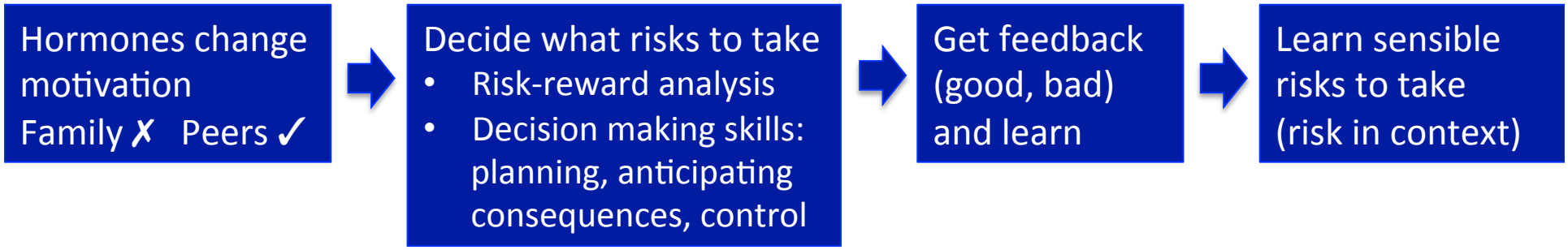
In the current study, we investigated windows for enhanced learning of cognitive skills during adolescence. Six hundred thirty-three participants (11–33 years old) were divided into four age groups, and each participant was randomly allocated to one of three training groups. Each training group completed up to 20 days of online training in numerosity discrimination (i.e., discriminating small from large numbers of objects), relational reasoning (i.e., detecting abstract relationships between groups of items), or face perception (i.e., identifying differences in faces).

A caveat on the comparative view: Complex humans social hierarchies

"Humans are not hierarchical in the linear, unidimensional manner of many species. For example, humans belong to multiple hierarchies and tend to value most the one in which they rank highest (for example, a low-prestige employee who most values his role as a deacon in his church). Furthermore, the existence of internal standards makes humans less subject to the psychological consequences of rank"

- Sapolsky (2005)

What happens



Adolescence:
normal social primate behaviour
(nothing broken)

Missing wisdom

- Sometimes adolescents are ‘hyper-rational’! Naively idealistic!
- What is missing is the ability to draw on experience-based intuition to understand the meaning of the risks in context (‘heuristics’)

- There’s knowing the odds, and then there’s playing poker!

“Should I have unprotected sex with my girlfriend?”

Outcomes:
Technology, culture, skills, and consequences

Technology

- Mobile phones and social media may alter the social environment and consequences of choices

Culture

- Same hormone changes produce different behaviours in different cultures
- Being highly competitive in a Buddhist monastary makes you the kindest!

Skills

- Decision-making and executive function skills can be improved through training, role play, etc.

Consequences

- Environment determines what the consequences of risky choices may be
- Embarrassment vs. car crash vs. drug overdose

Centre for Educational Neuroscience

Study of Cognition, Adolescents and Mobile Phones

Independent Research Commissioned by the Department of Health

Dr Mireille Toledano
Prof Paul Elliott
Imperial College London

Dr Iroise Dumontheil
Prof Michael Thomas
Birkbeck, University of London

MRC-PHE
Centre for Environment & Health

Public Health England
MRC Medical Research Council
Imperial College London
King's College London

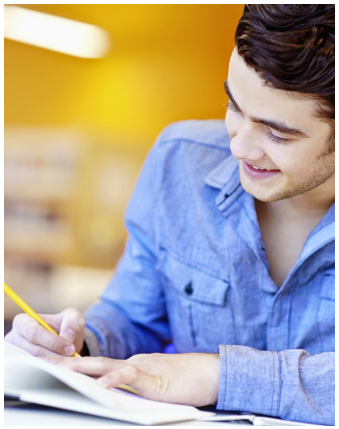
Peer influence in adolescence

- Harness peer pressure for beneficial outcomes:
  - Academic performance and motivation improve when students spend time with academically high achieving peers (Ryan, 2001)
  - Adolescents' prosocial behaviour increases when they spend time with friends with higher levels of prosocial behaviour (Wentzel et al. 2004)

What can I do in the classroom on Monday morning?

Enhancing and Practicing Executive Function Skills with Children from Infancy to Adolescence





Center on the Developing Child HARVARD UNIVERSITY

"As children develop executive function and self-regulation skills, they need practice reflecting on their experiences, talking about what they are doing and why, monitoring their actions, considering possible next steps, and evaluating the effectiveness of their decisions"

"Adults play a critical role in supporting, or "scaffolding" the development of these skills, first by helping children complete challenging tasks, and then by gradually stepping back to let children manage the process independently – and learn from their mistakes – as they are ready and able to do so"

https://developingchild.harvard.edu/

Executive function activities for adolescents

Goal setting, planning and monitoring

- **Focus on the planning process by identifying meaningful goals**
- **Help teens develop plans for these goals**
- **Taking on large social issues – support organisations give advice for concrete actions**
- **Remind adolescents to periodically monitor their behaviour against plans**

Tools for self-monitoring

- **Self-talk is a powerful way to bring thoughts and actions into consciousness**
- **Encourage self-talk that focuses on growth**
- **Help adolescents be mindful of interruptions**
- **Improve understanding the motivation of others by identifying hypotheses about others' motivations and then consider alternatives**
- **Writing a personal journal to foster self-reflection**

Activities to practice self-regulation skills

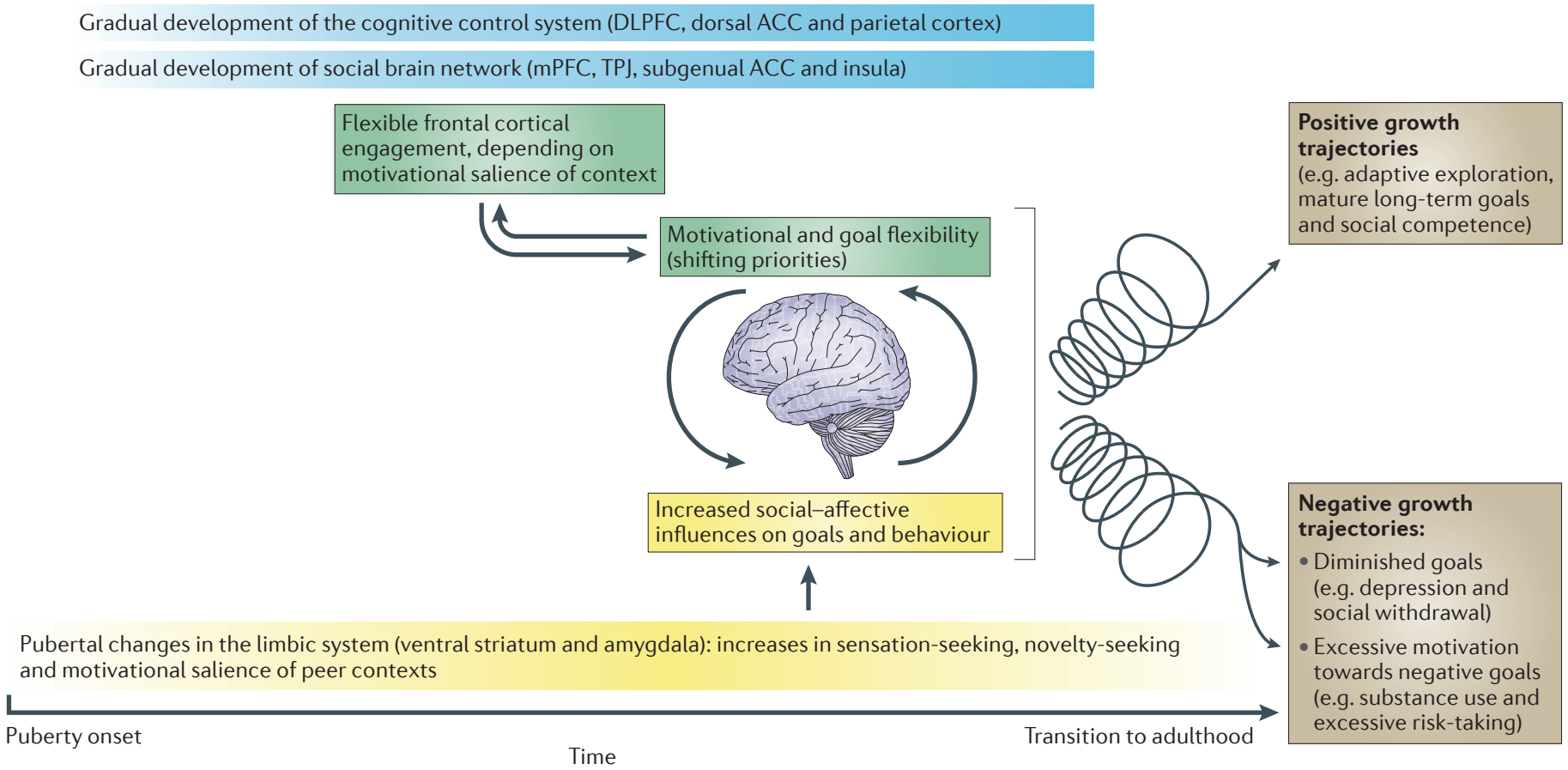
- Sports
- Yoga and meditation
- Music
- Theatre
- Strategy/games and logic puzzles
- Action computer games

Study skills

- Break down a project in to manageable pieces
- Identify reasonable plans
- Self-monitor while working
- Be aware of critical times for focused attention
- Use memory supports for organising tasks
- Keep a calendar of project deadlines
- After completing an assignment, reflect on what worked
- Think about what was learned from assignments not completed well

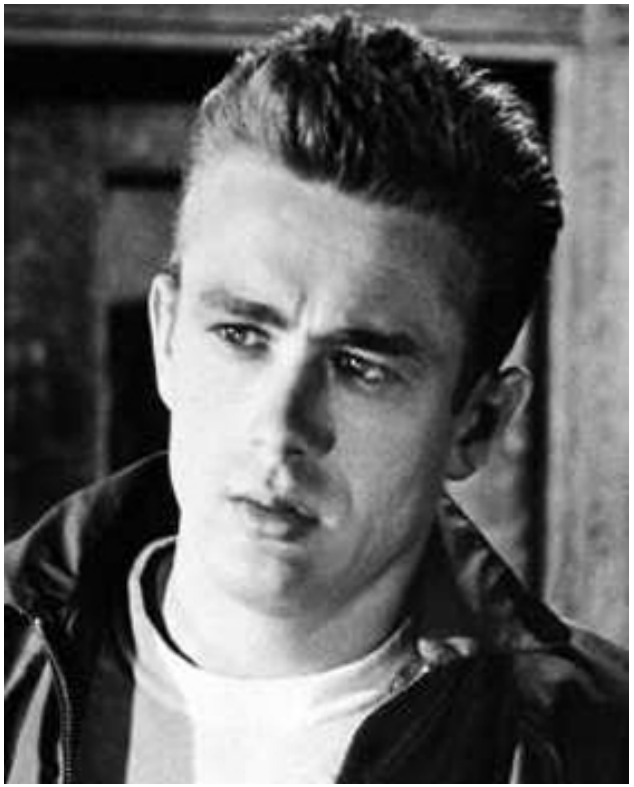
https://tinyurl.com/yd7apblo

Conclusion

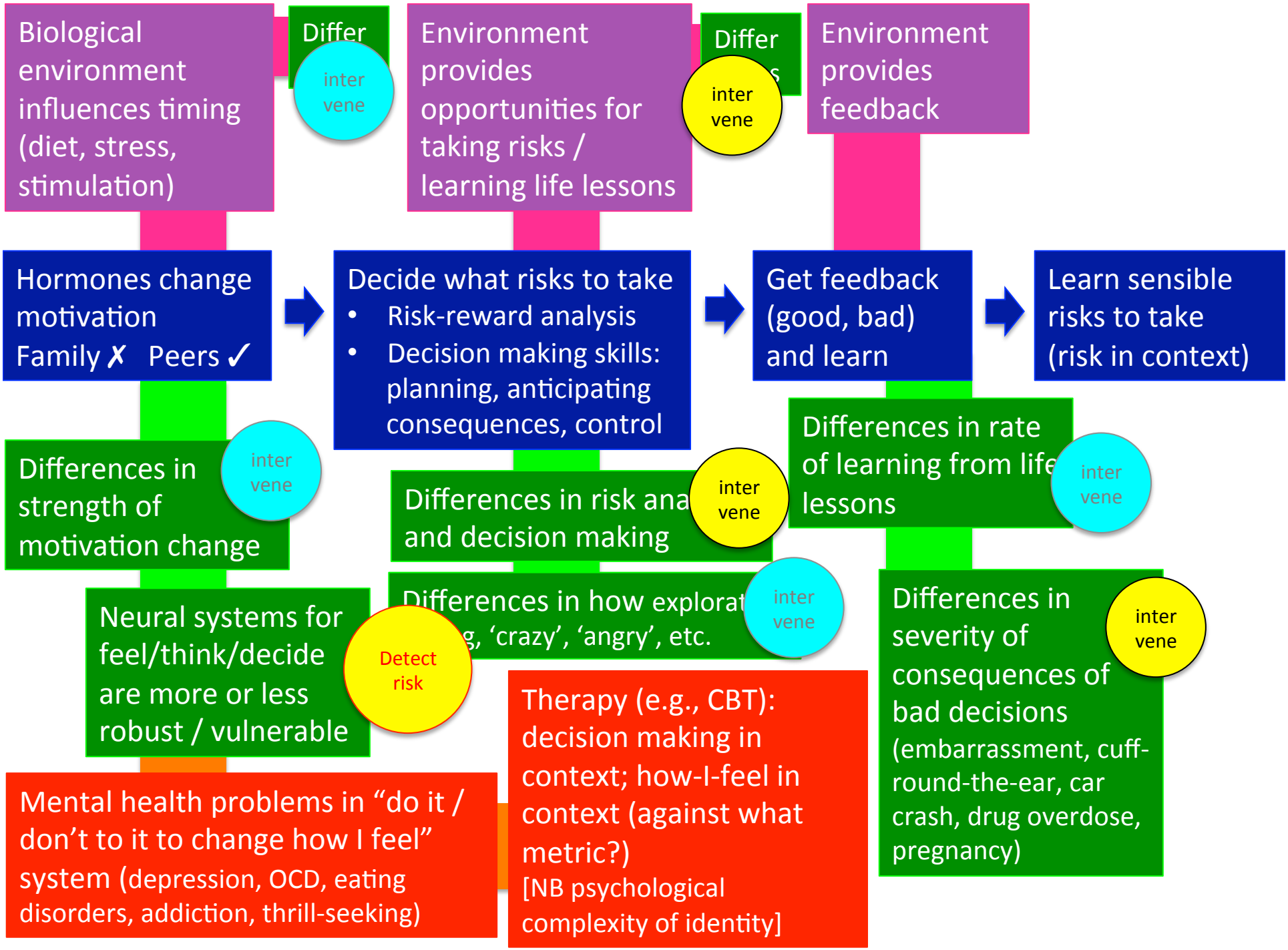


Crone & Dahl (2012)

Individual differences



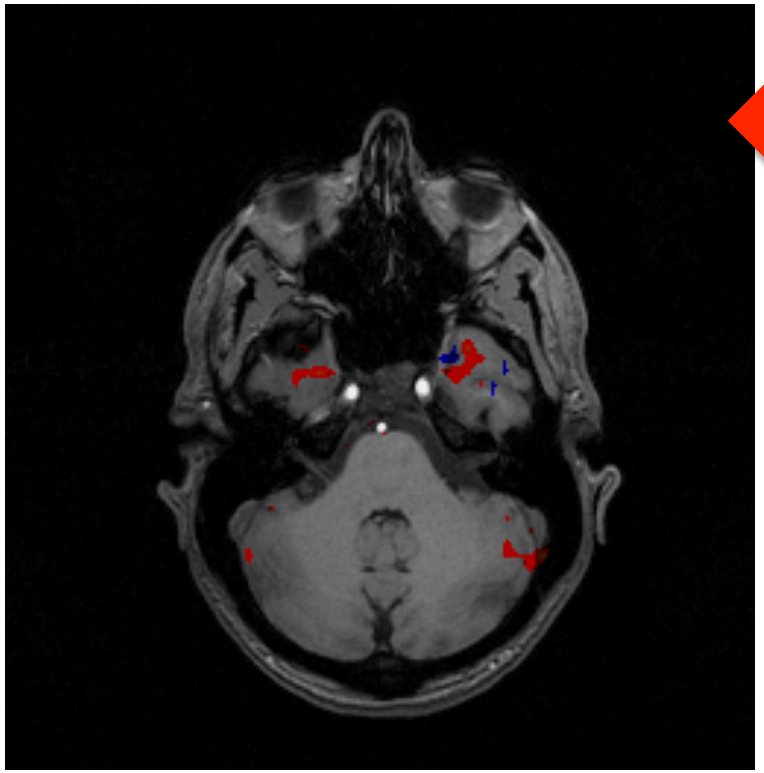
A James Dean in 10


Biological environment influences timing (diet, stress, stimulation)
Differ
inter vene
Environment provides opportunities for taking risks / learning life lessons
Differ
inter vene
Environment provides feedback
Hormones change motivation
Family ✗ Peers ✓
Decide what risks to take
• Risk-reward analysis
• Decision making skills: planning, anticipating consequences, control
Get feedback (good, bad) and learn
Learn sensible risks to take (risk in context)
Differences in strength of motivation change
inter vene
Differences in risk ana and decision making
inter vene
Differences in rate of learning from life lessons
inter vene
Neural systems for feel/think/decide are more or less robust / vulnerable
Detect risk
Differences in how explorat g, 'crazy', 'angry', etc.
inter vene
Differences in severity of consequences of bad decisions (embarrassment, cuff-round-the-ear, car crash, drug overdose, pregnancy)
inter vene
Mental health problems in "do it / don't to it to change how I feel" system (depression, OCD, eating disorders, addiction, thrill-seeking)
Therapy (e.g., CBT): decision making in context; how-I-feel in context (against what metric?)
[NB psychological complexity of identity]

What does neuroscience add?

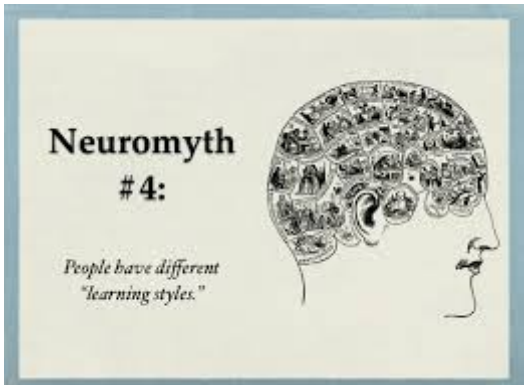
REMEMBER!

The Seductive Allure of Neuroscience

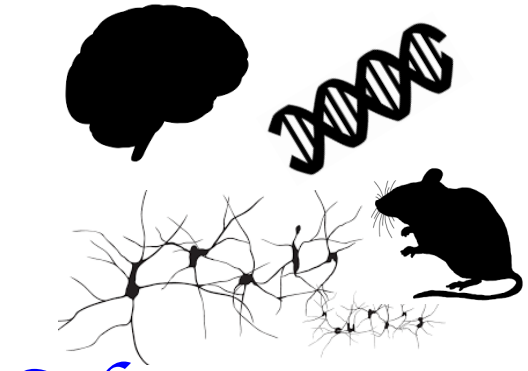


Don’t be impressed by this!

Don’t believe in these!



Routes from neuroscience to education
(avoiding neuromyths…)



Neuroscience

direct

Education

indirect

Psychology

What does neuroscience add?

- Independent evidence about what is changing (IQ, executive functions, social cognition)
- Mechanistic explanation integrated with biology
- Interventions
  - Biology before psychology (sleep, diet, exercise, stress)
  - Executive function training (risks in context)
  - Environment (opportunities to learn, consequences)
- What is changeable requires broader conception of education within societal structures
- Advances via a dialogue between educators, psychologists, and neuroscientists

Birkbeck UNIVERSITY OF LONDON

Centre for Educational Neuroscience

Thank you for your attention

- Thanks to…
- Iroise Dumontheil for letting me borrow some of her slides!

Iroise's Development and Cognitive Neuroscience lab

https://sites.google.com/site/idcnlab/