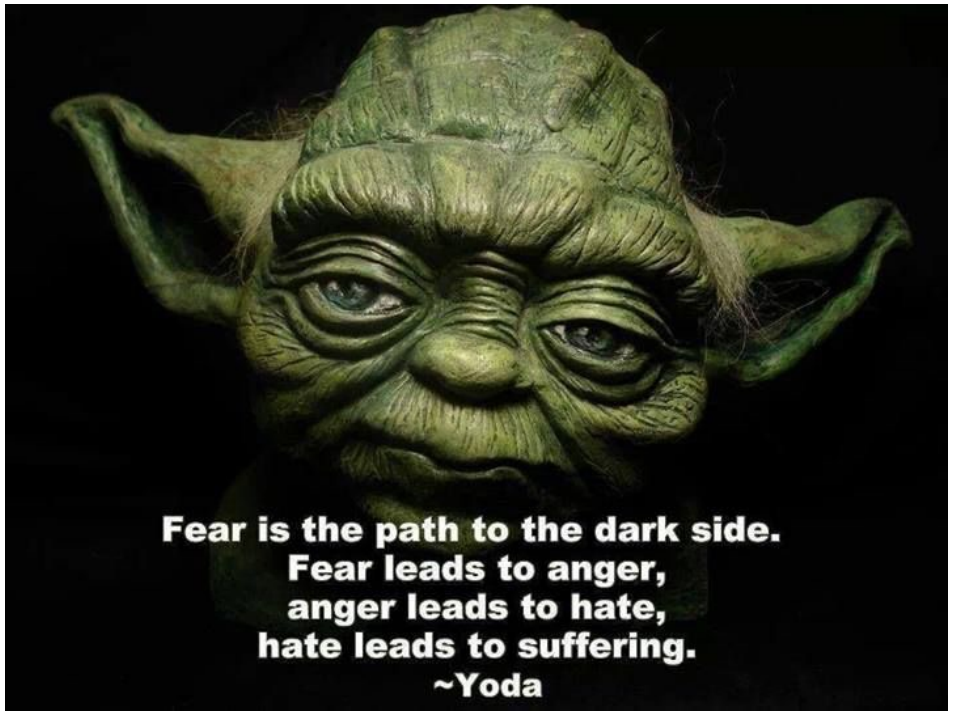
PSYC301:
Dysfunction affecting emotion, stress, and executive functions

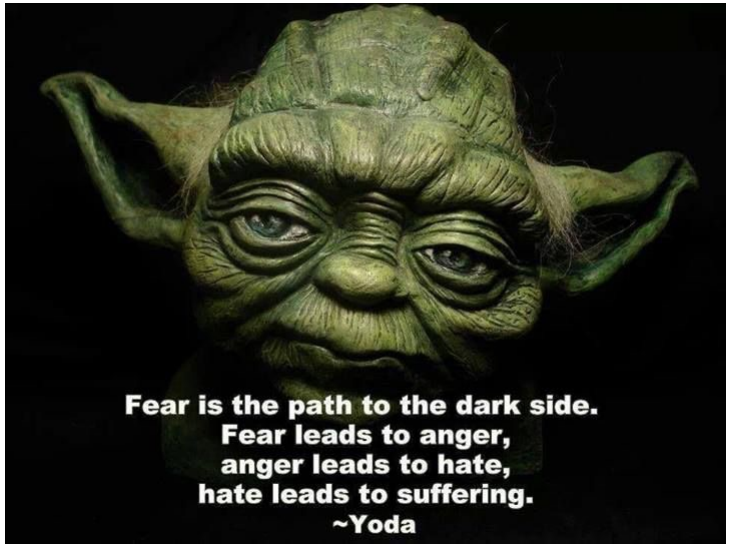
Jay Hosking, PhD



Overview

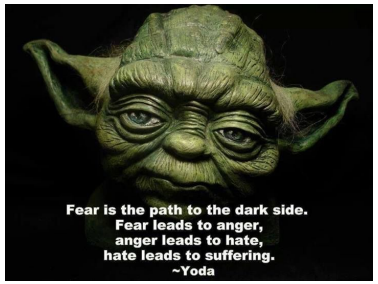
A. What are emotions?
B. The amygdala
C. Emotions are adaptive
D. The prefrontal cortex (PFC) and executive function
E. Stress and the PFC
F. Attention deficit / hyperactivity disorder (ADHD)

https://www.youtube.com/watch?v=npaQXeIeMvo



Learning objectives

1. What are emotions? What are they good for? Does evidence suggest that fear/anger/frustration/etc. are irrational, as is commonly believed?
2. What parts of the brain process emotion? Is emotion lateralized in the brain?
3. Describe some other emotions and their associated brain areas, including the tasks that are used to study these emotions.
4. Describe the prefrontal cortex's role in emotion and executive function, including patients with PFC damage.
5. Is all stress bad for you? Justify your answer with evidence.
6. Describe the impact of acute stress on cognition and behaviour. What are the proposed mechanisms for stress impairing our executive functions? Is this adaptive?
7. Describe the effects of chronic stress on the brain and the person.
8. Describe the effects of poverty on the brain and the person. What does this suggest about poverty?
9. Describe the key symptoms, brain mechanisms, and pharmacological treatment for ADHD. How do these relate to other topics in this lecture?
10. Read the paper by Feinstein *et al*. 2011 on Patient SM. What are the consequences of a life without fear? Describe the amygdala's role in emotion, cognition, and behaviour.



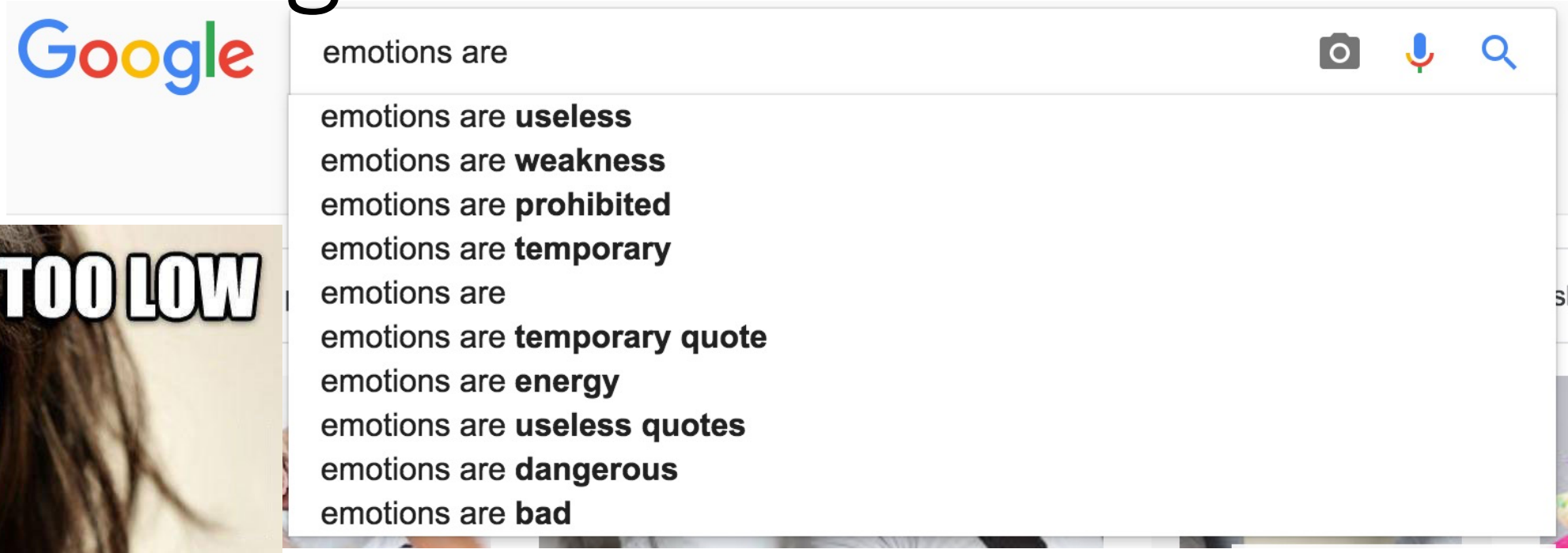
Defining emotion (yeah, right)

Wikipedia: "… a subjective, conscious experience that is characterized primarily by psychophysiological expressions, biological reactions, and mental states."

Davidson (1994):

Emotions influence how we act;
Moods influence how we perceive

“Don’t get so emotional”



Long history of emotions supposedly clouding judgement

Emotions vs. “logic”, emotions vs. “reason”, emotions as “irrational”, emotions as “compromising judgement”

Darwin, James: emotions selected *for*, not against

Most of 20th c.: understudied

Anecdotally: Mr. Spock or Phineas Gage?

Are emotions irrational?

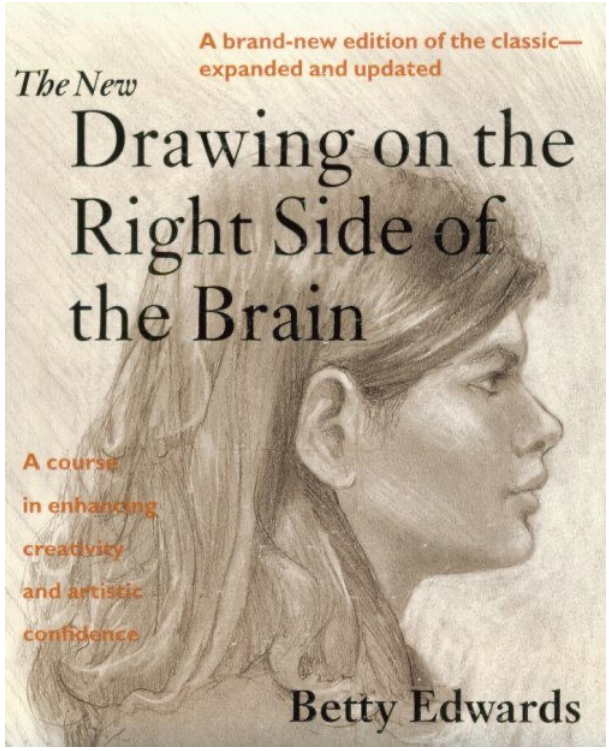
Central thesis:

Emotion is critically linked to value

Disruptions that impair emotion also impair judgement and decision making (sorry, Spock)

What are emotions?

Are emotions lateralized in the brain?



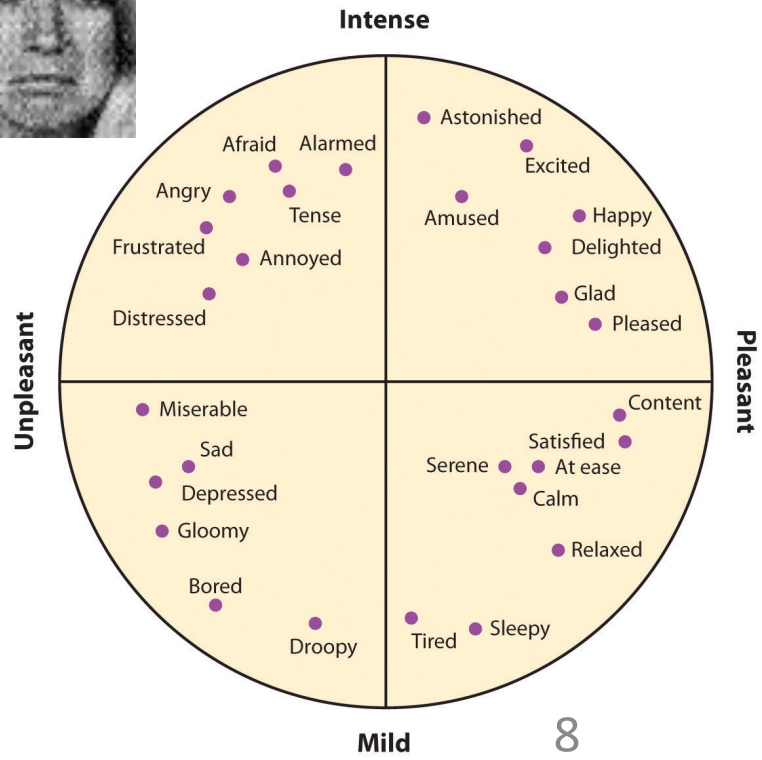
- Right Hemisphere model
- Valence Model

Meta-analyses (e.g. Wager et al. 2003): the truth is more complicated

What are emotions?

Dimensions of emotion

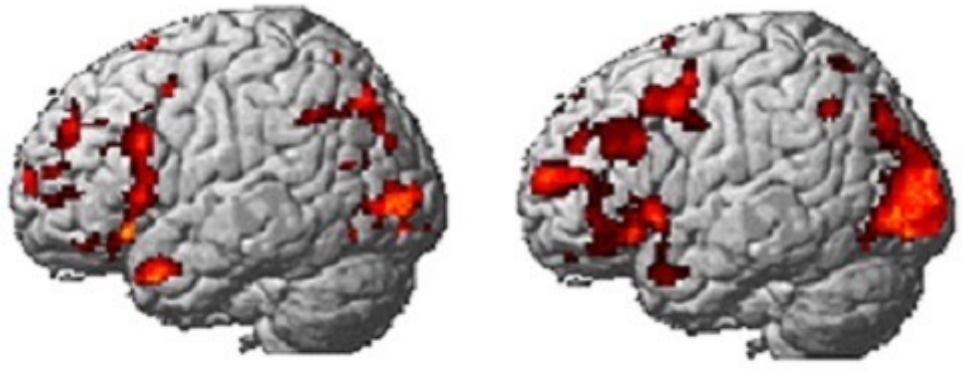
- Some (e.g. Paul Ekman) argue for discrete emotions
- Others suggest emotions are comprised of dimensions (e.g. valence and intensity)
- These dimensions are thought to guide perception and action (e.g. approach/avoid)
- But consider: Why approach sad music? Why approach frustration? What about ambivalence?

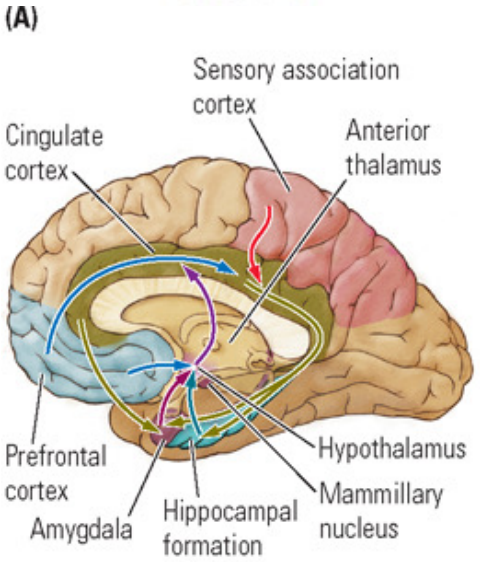


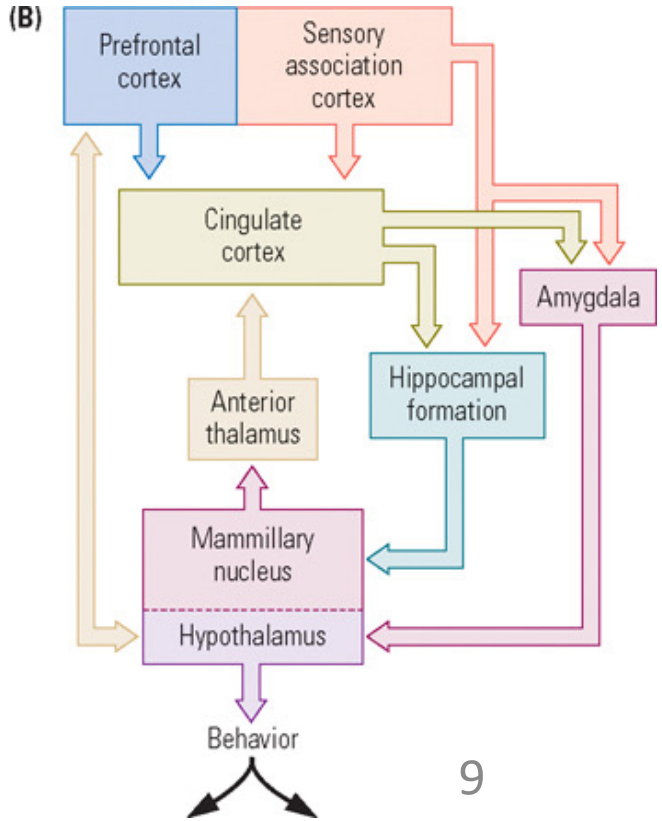
Regions of emotion

- Diffuse, overlapping yet distinct
- Many, big areas
- Do these areas encode value? emotion? both? more?
- Often not 1:1 for function:cell

  (i.e. population coding)

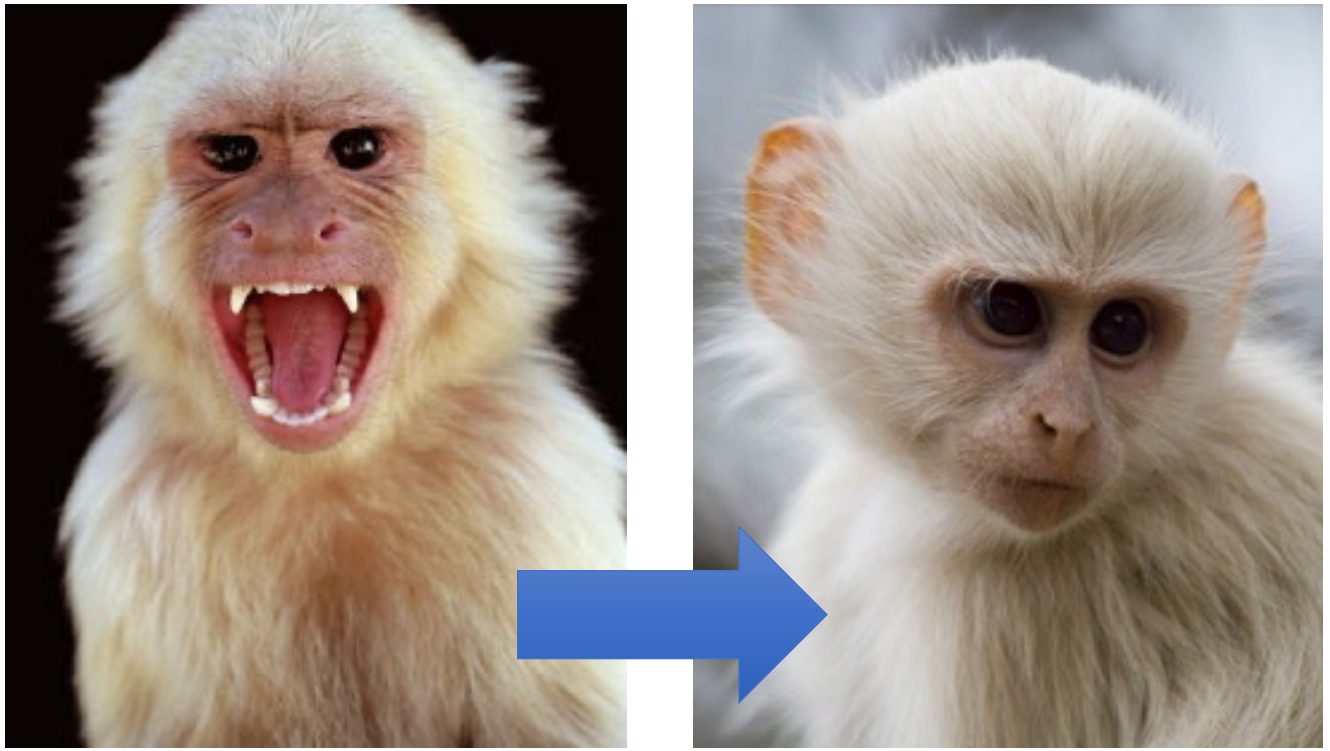






What are emotions?

Kluver-Bucy syndrome



Anterior temporal lobectomy

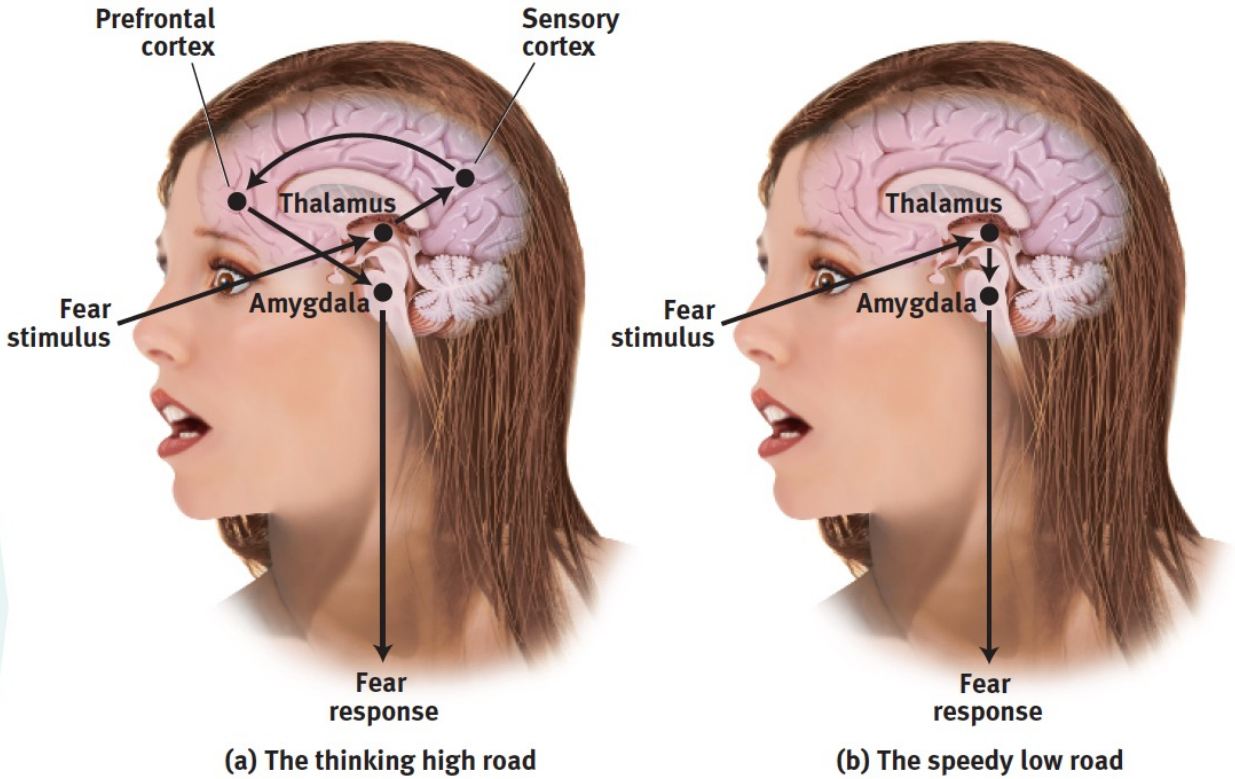
Loss of fear thought to be
due mainly to amygdala damage

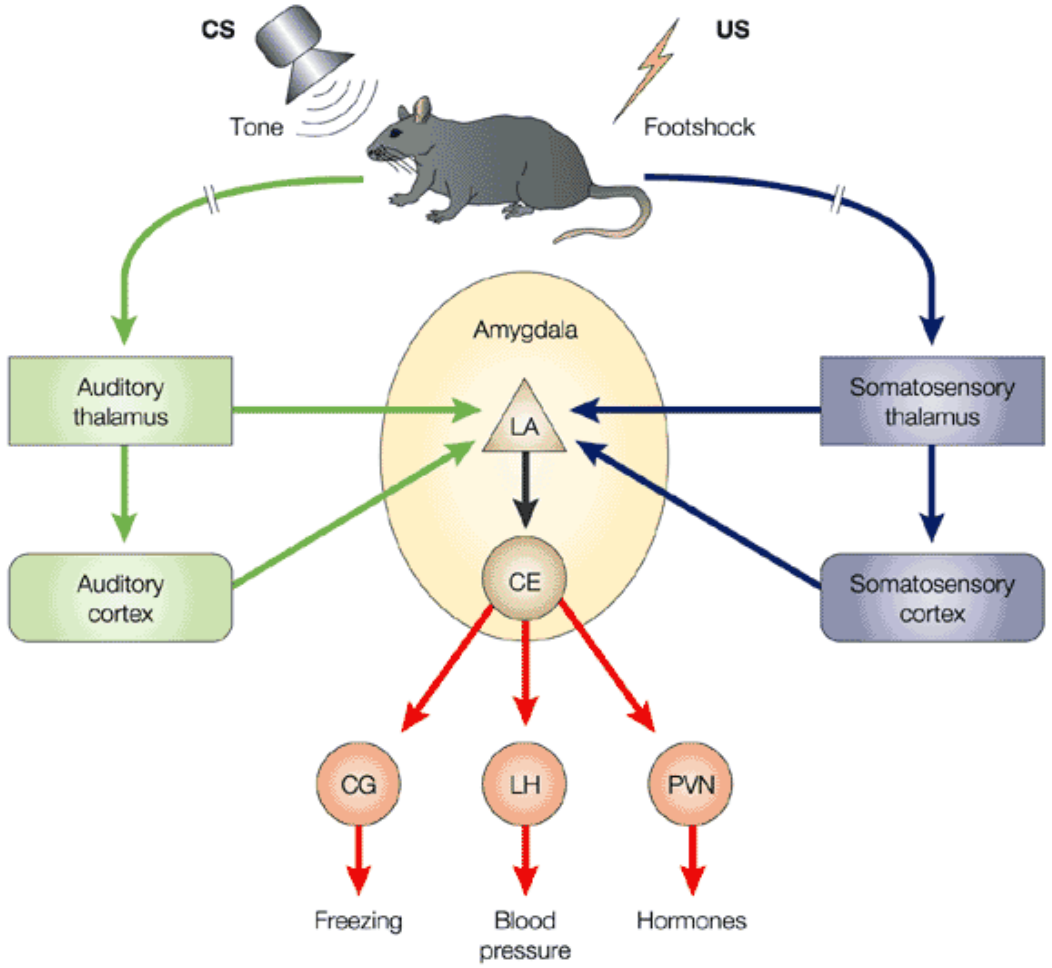
- **Lack of fear**
- Hyperorality
- Misdirected hypersexuality
- Repeatedly investigating familiar objects

The amygdala in emotional learning

High roads and low roads to fear (LeDoux)

Amygdala as coincidence detector





Patient SM

Complete bilateral amygdala loss

Virtually no experience of fear

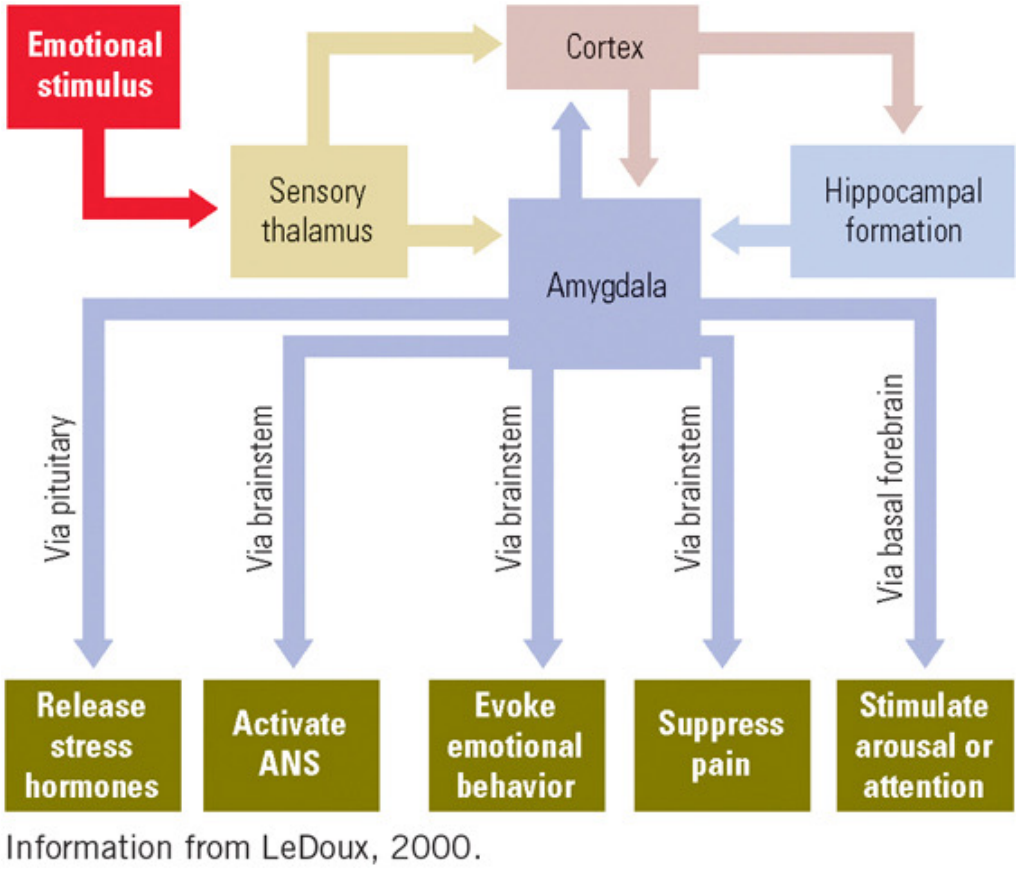
Does not learn fear conditioning

(But can still experience it under the right conditions, i.e. CO_2 inhalation)

Impaired quality of life?

What is the
functional utility of fear?

Note: other patients with
amygdala damage have
less fear impairment
(age at damage onset?)



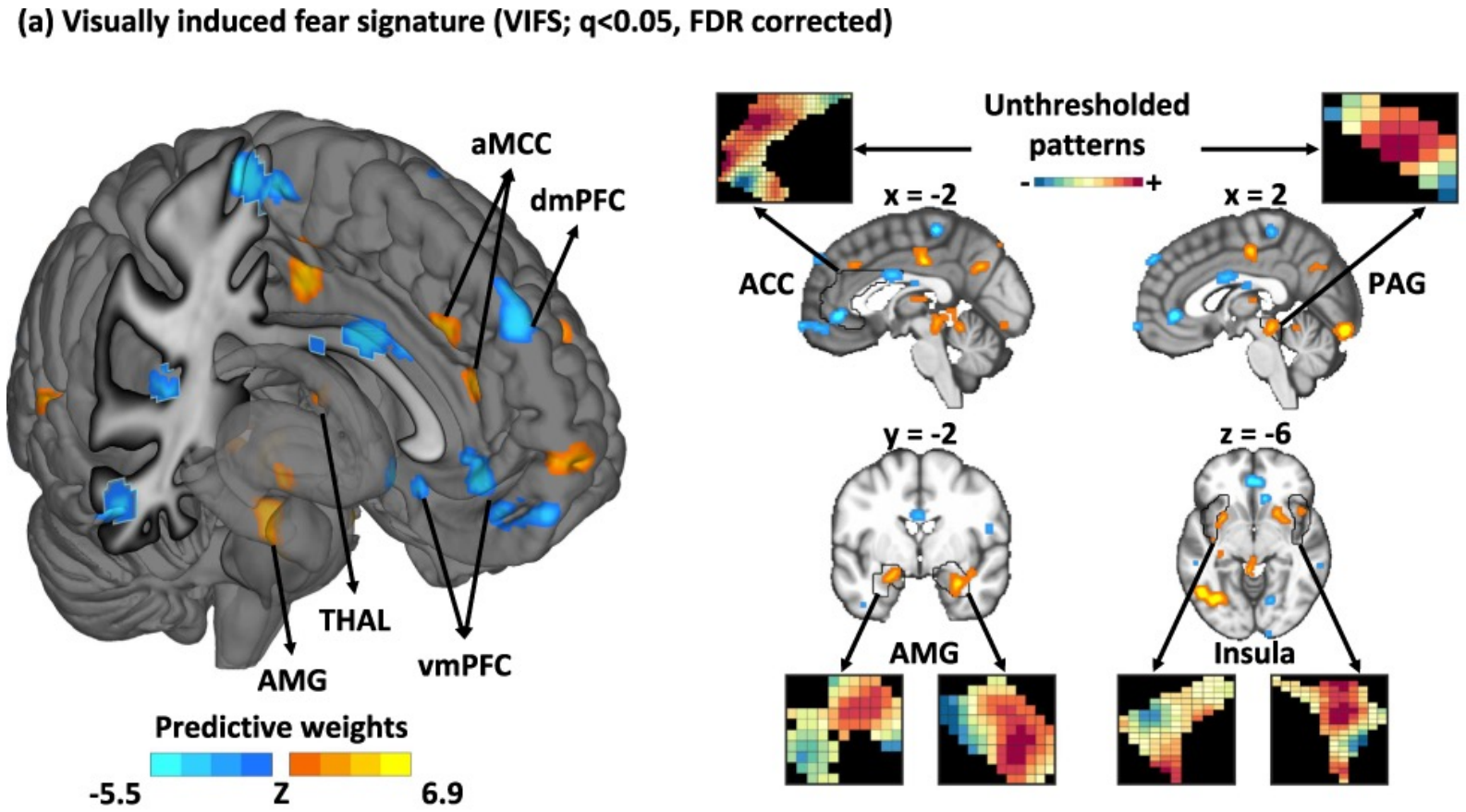
Information from LeDoux, 2000.

The amygdala

Is the amygdala negatively valenced?

- Primate/rodent electrophysiology
  - Roughly equal numbers of cells that respond to appetitive versus aversive stimuli
  - Some cells respond for both (i.e. for arousal, not valence)
- Often implicated in *updating* value
  - e.g. During stimulus de-valuation (satiation)
- Appetitive versus aversive values: not equal?
  - Small punishment “worth” large reward?
  - Makes interpretation difficult

Fear is more than the amygdala



Zhou *et al*. 2021

The subjective experience of fear!

i.e. There is no “fear centre”

Emotional activation in the brain is large, distributed, and overlapping

All lobes of the neocortex

Heterogeneity in results (due to methods/evocation of emotion?)

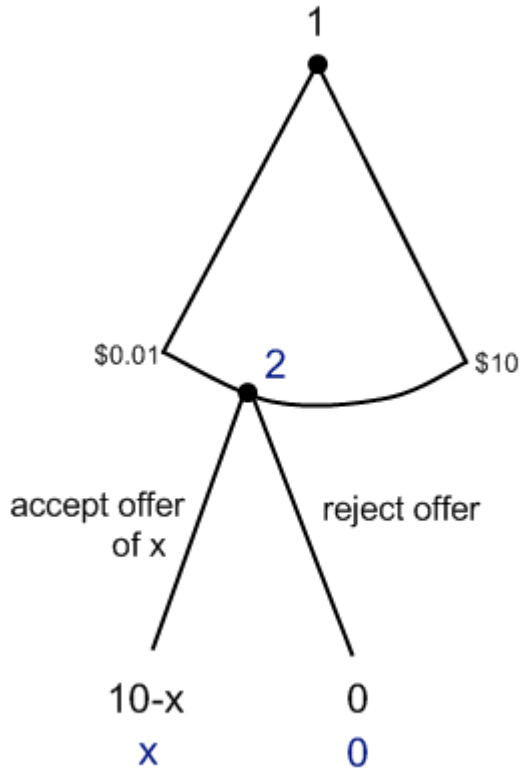
PFC usually important

What's the functional utility of anger?

https://www.youtube.com/watch?v=meiU6TxysCg

Emotions as adaptive

The Ultimatum Game



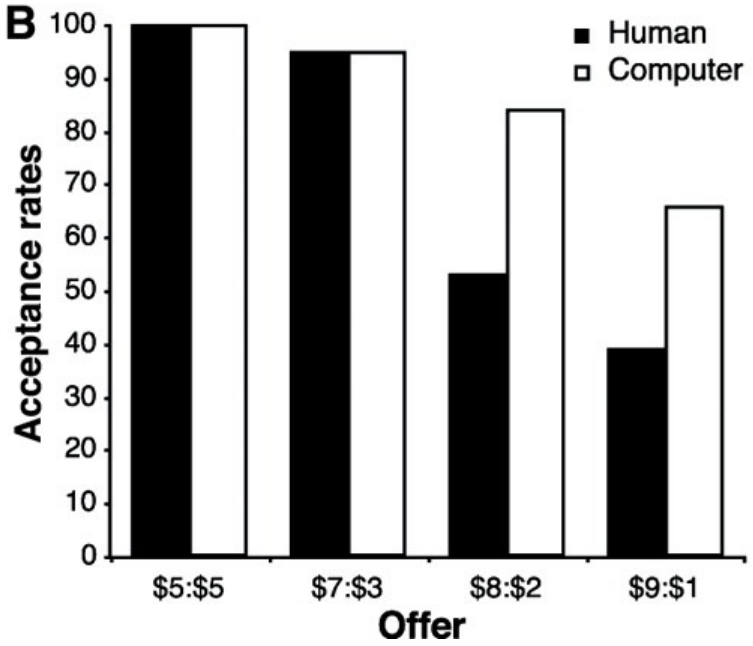
Proposer (1) and Responder (2)

What's "rational"?

How do people actually behave?

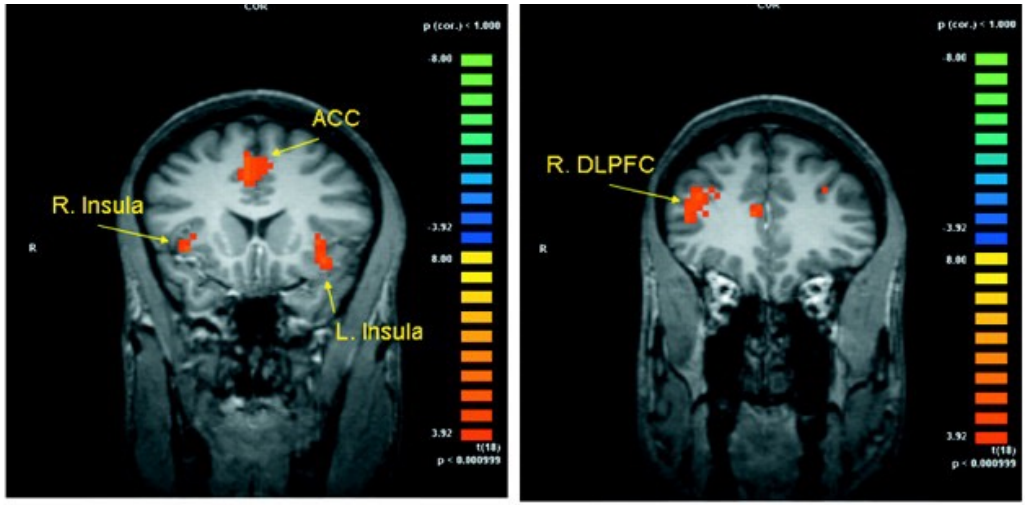
Emotions as adaptive

The Ultimatum Game



Why reject any offer?

Anterior insula BOLD correlates with rejecting unfair offers



Sanfey *et al.*, 2003

Anger guides behaviour toward altruism (?!?)

- SCR, self-report

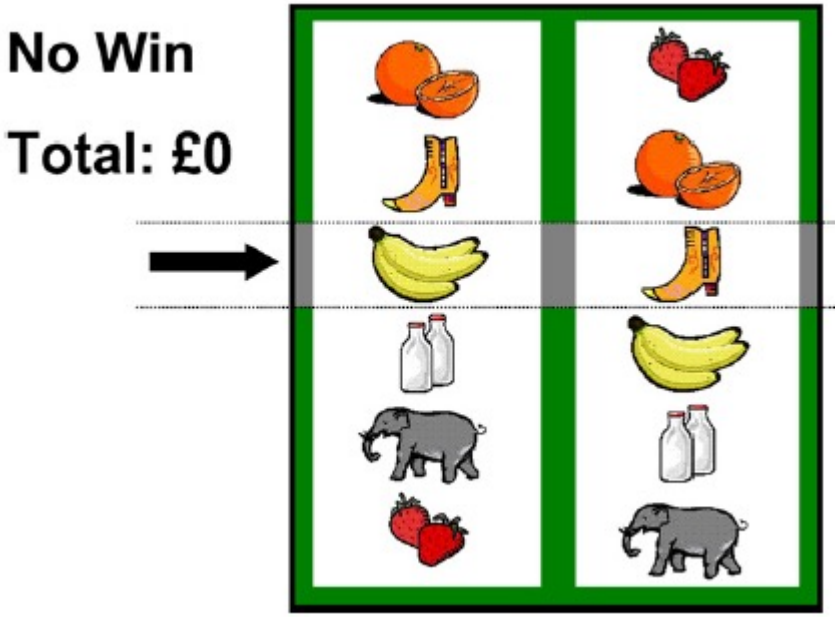
Emotions as adaptive

What's the functional utility of frustration?

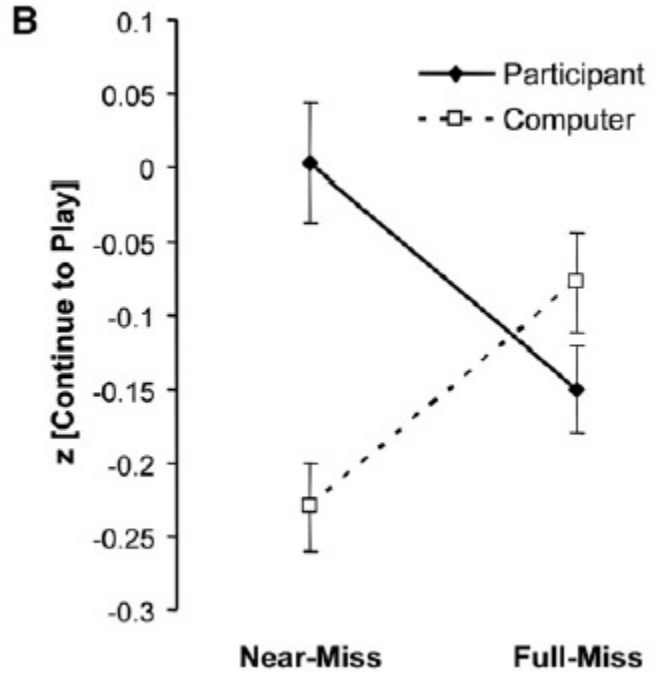
Emotions as adaptive

A slot-machine task:

The Near-Miss Effect



UBC's own Luke Clark! (2009)

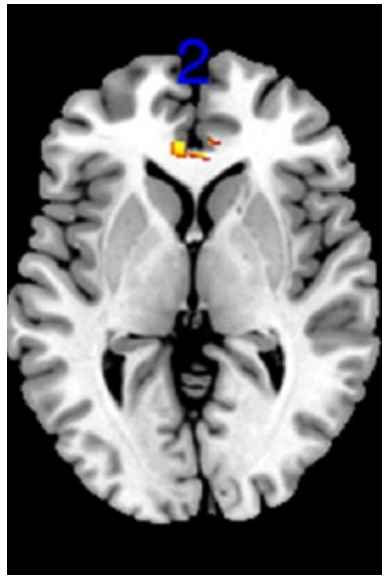


Near misses feel bad but spur further play

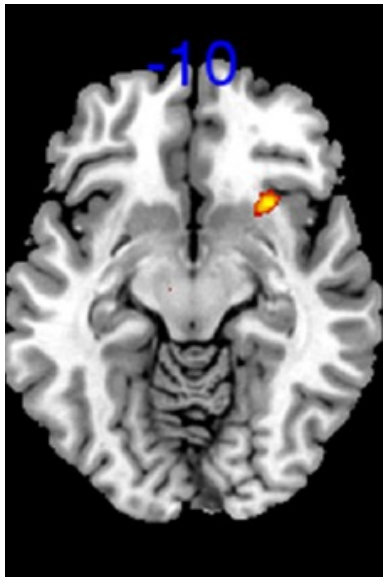
Emotions as adaptive

A slot-machine task:

The Near-Miss Effect



ACC BOLD higher for near- vs. full-miss



Anterior insula BOLD correlated with subjective effects of near miss

These responses may be enhanced in individuals with pathological gambling disorder (e.g. Limbrick-Oldfield *et al.* 2018)

Phineas Gage revisited: brain dysfunction *and* recovery

Little reason to doubt a pronounced change in behaviour

BUT

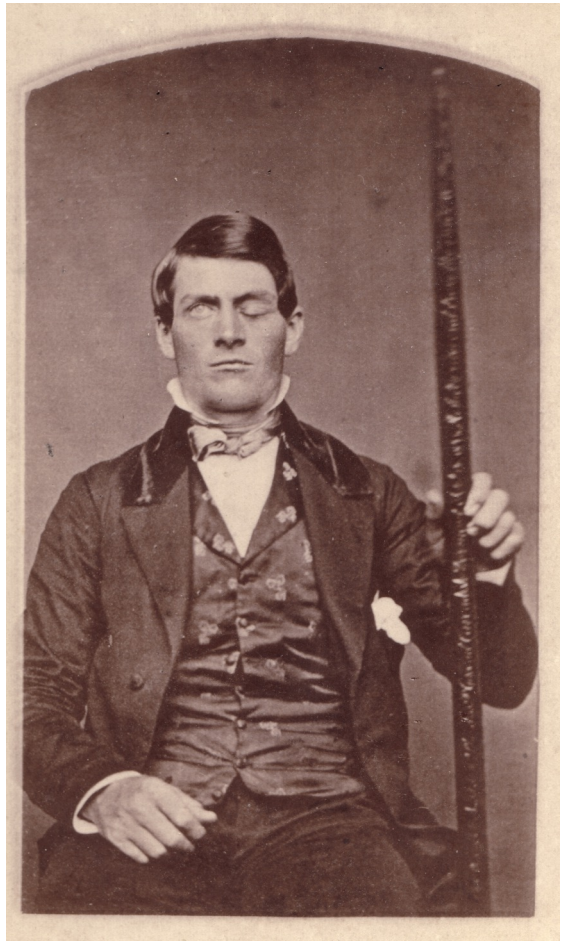
While he did work for a carnival, this was in line with his previous behaviour

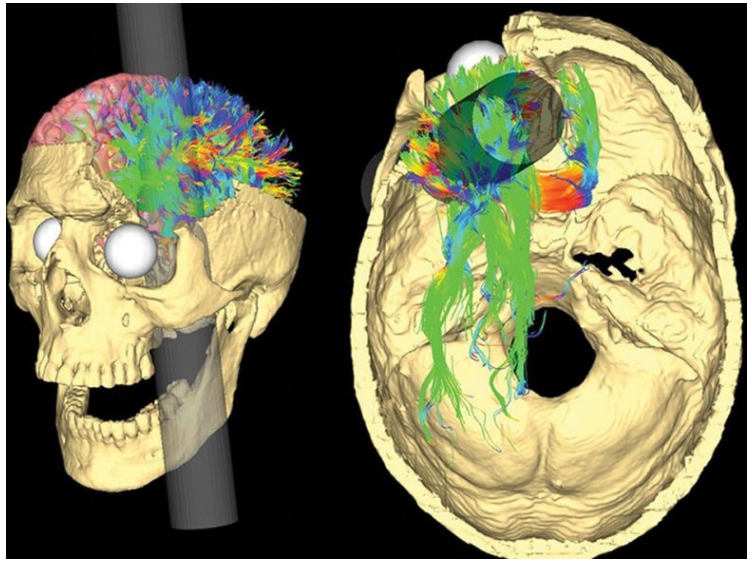
And he maintained a job as a horse-carriage driver in Chile

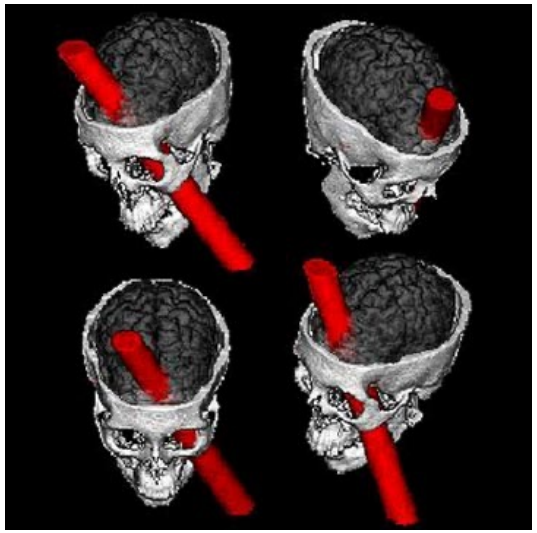
Previously thought to have bilateral damage, but more recently thought unilateral

A good example of *recovery*, and similar to contemporary patients

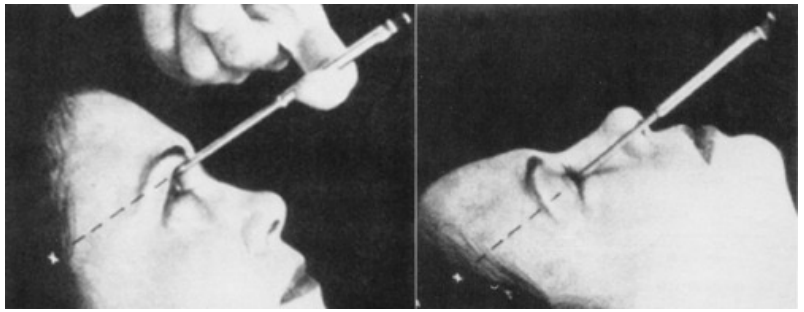
Ultimately, he developed severe epilepsy and died

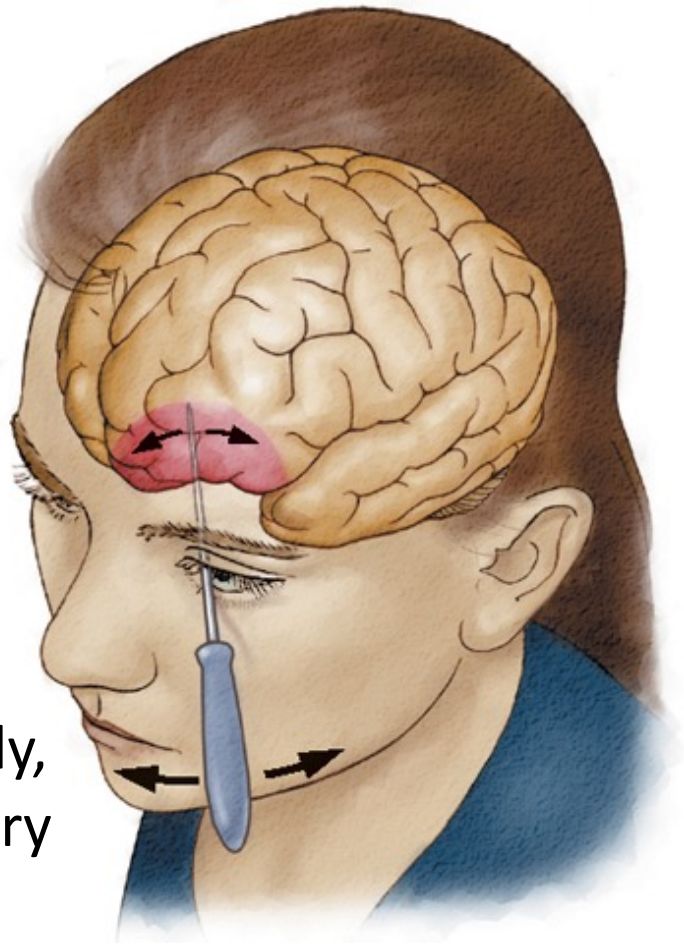


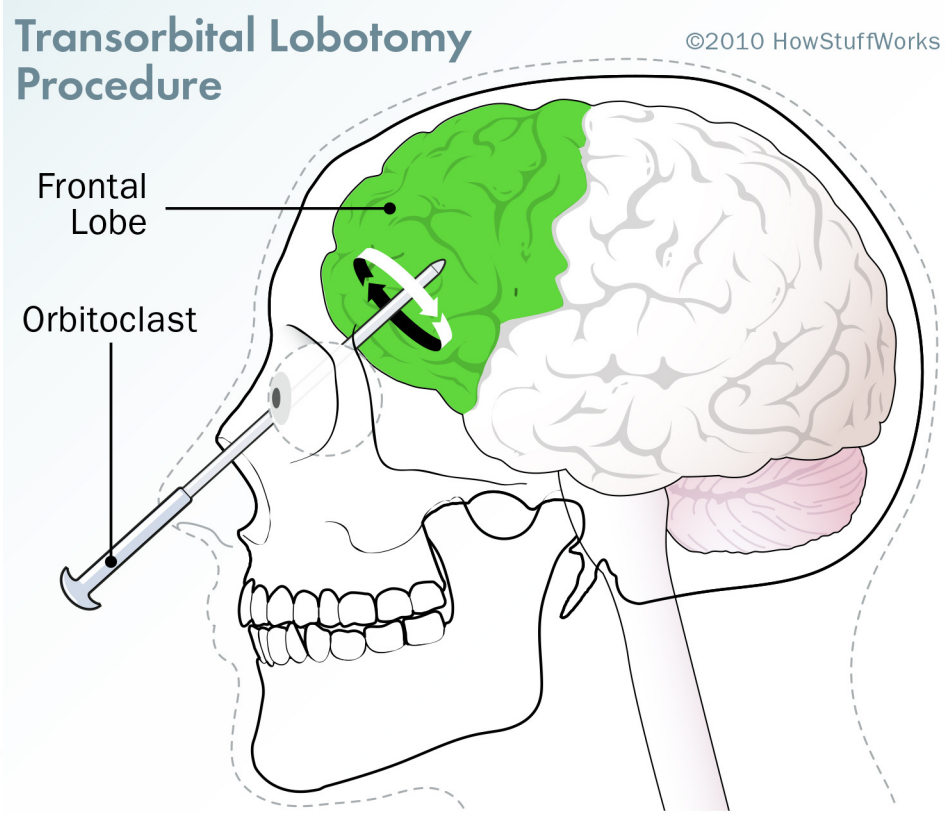




The prefrontal lobotomy





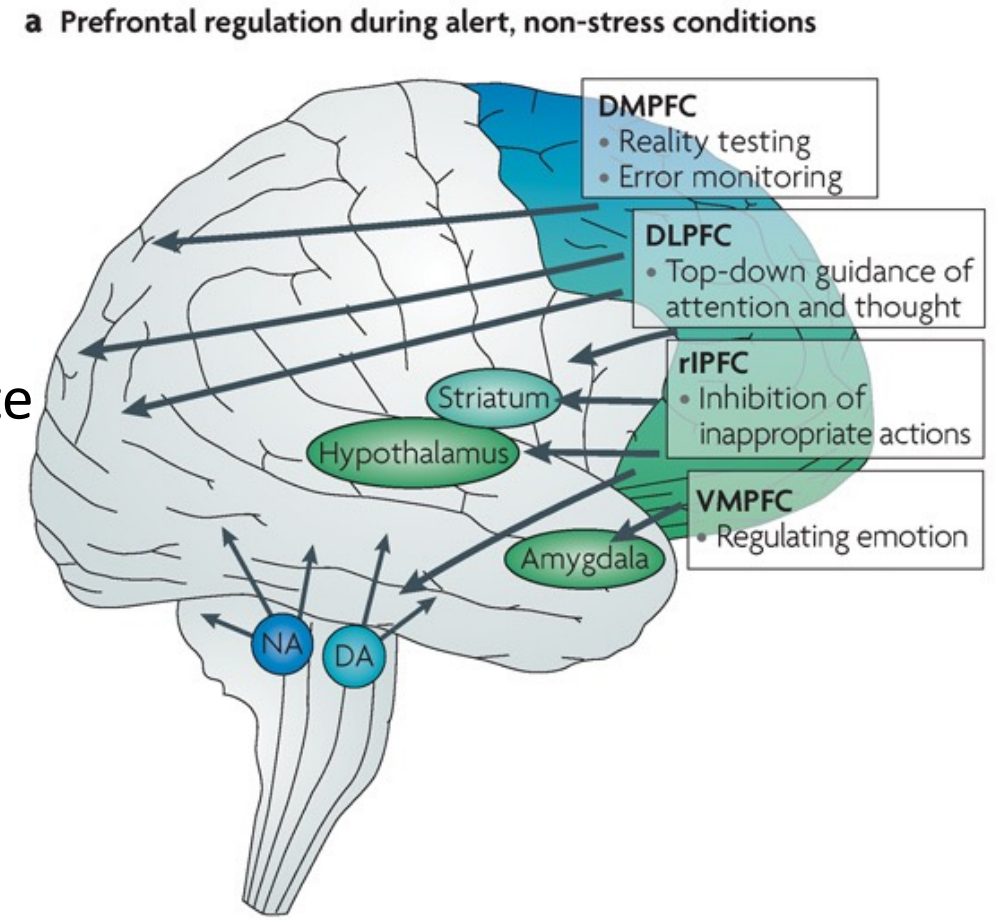


Effects on life varied drastically, from incapacitation to recovery

Executive functions

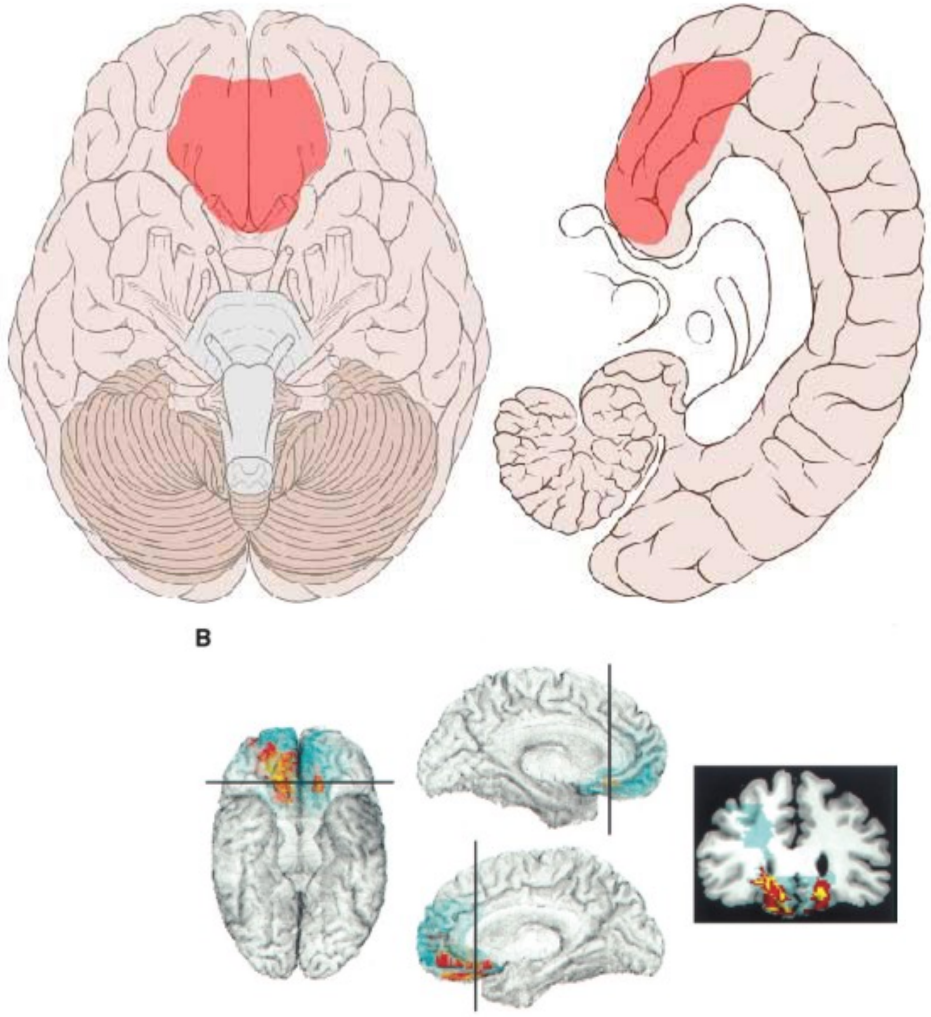
- Planning
- Organization
- Flexible thinking
- Monitoring performance
- Multi-tasking
- Solving unusual problems
- Self-awareness
- Learning rules
- Social behaviour

- Decision making
- Motivation
- Initiating appropriate behaviour
- Inhibiting inappropriate behaviour
- Regulating emotions
- Concentrating



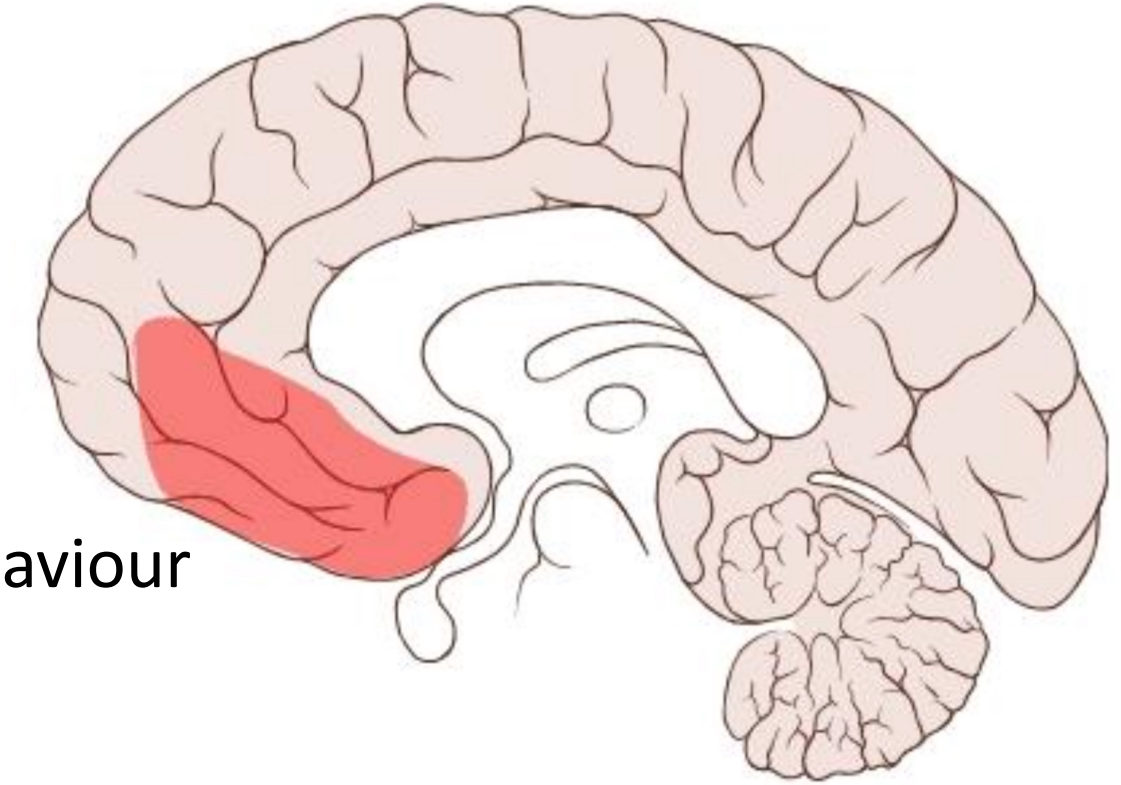
Executive dysfunction: bilateral vmPFC damage

- Commonly studied: **vmPFC** damage
- But executive dysfunction can happen from a variety of PFC damage
- Most studied: **bilateral damage**, as it's more commonly observed in patients
- Most intellectual ability preserved
- Problems with prioritization (e.g. lost in the filing cabinet)
- Emotional dysregulation
  - e.g. "**acquired sociopathy**" in some dementia
- Repeat mistakes despite often "knowing" it's suboptimal
- Loss of "get up and go"
- Problems thinking ahead, sequencing steps for a task
- Rigidity in thoughts and actions
- Problems with attention and concentration



Unilateral vmPFC damage

- Use overlay (overlapping structural MRI) method
- Right Side
  - Disturbances just described
  - i.e. Executive dysfunction
- Left Side
  - Typical social and interpersonal behaviour
  - Stable employment
  - Personality relatively unchanged
  - Decision making ability relatively intact



Stress

Can be significant life events (e.g. death of a loved one, marriage)

But also “the daily grind” (Lazarus, 1981), lives of “quiet desperation”

Can be active or passive, short-term or long-term

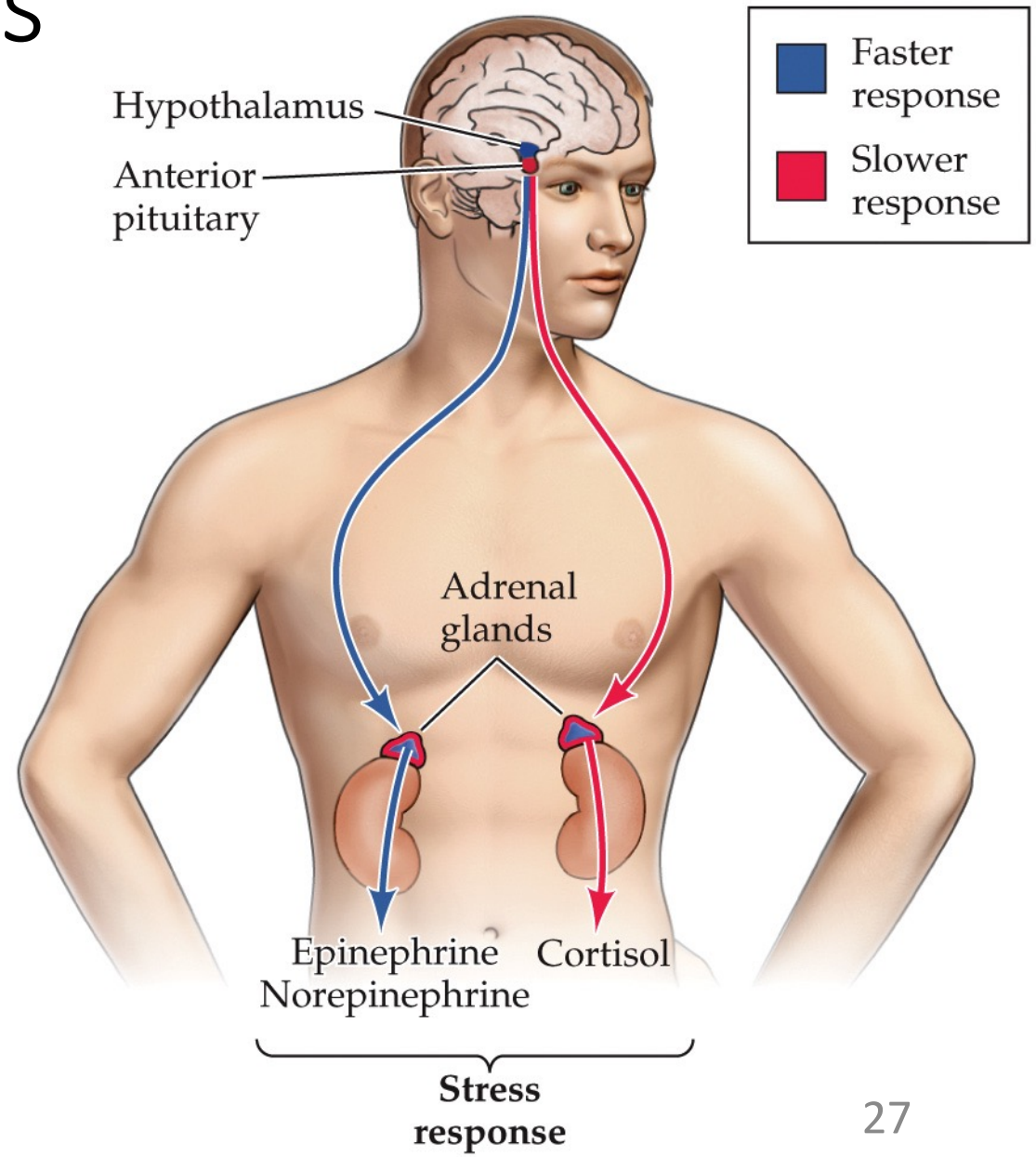
Stress immunization — i.e. exposure to controllable stress

cf. exposure to uncontrollable stress

Stress

Sympathetic response

HPA axis



Acute stress has some drawbacks, but is generally beneficial for us

Stress is an adaptive response to threat!

Mild levels of stress are beneficial across the board

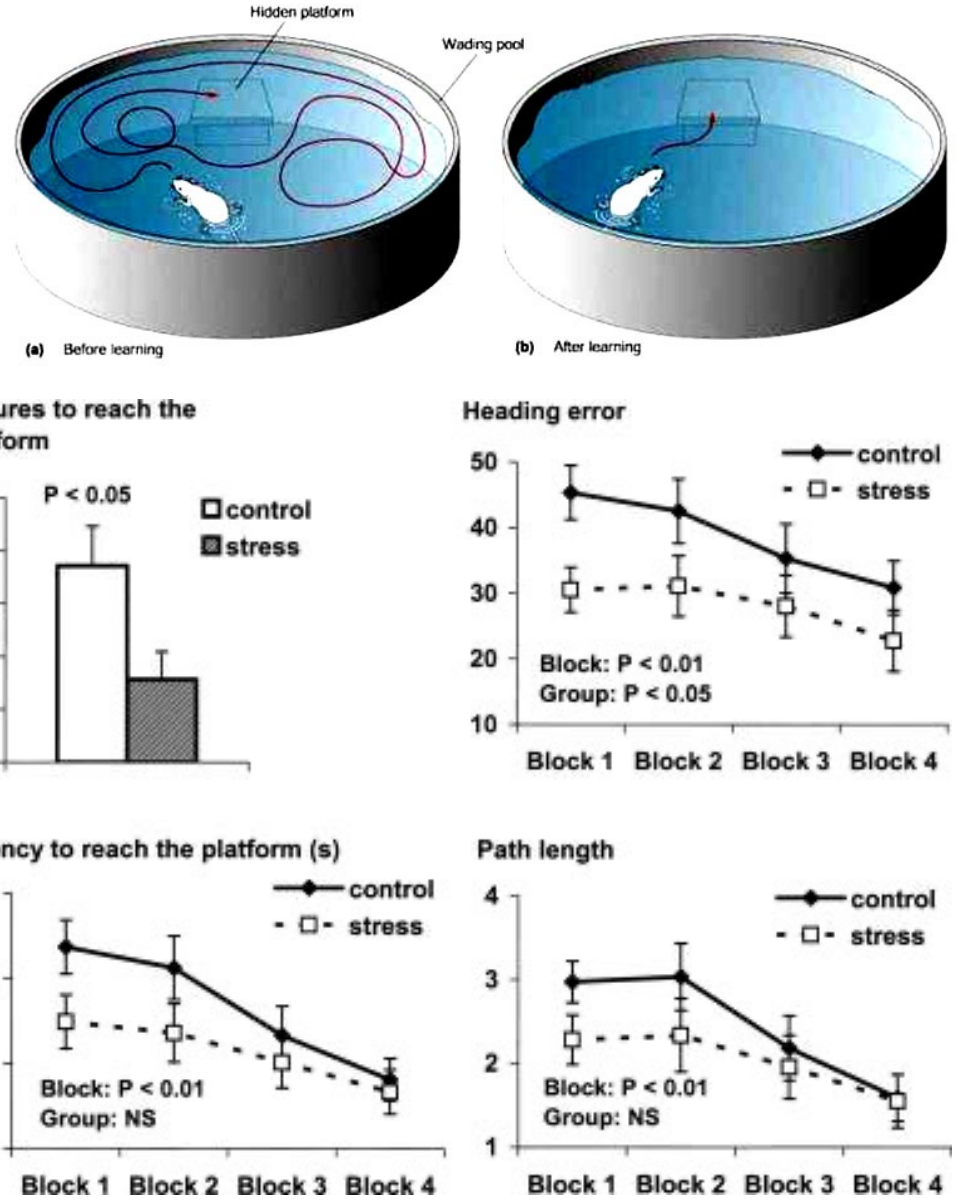
Higher levels of stress have benefits & costs

Benefits: implicit memory, simple tasks, habitual and well-rehearsed tasks, immune system? (short-term)

Costs: cognitive flexibility, working memory, executive functions

Stress is generally beneficial when acute, especially for our habits and skills,
but detrimental when chronic (more in a sec)

Implication for your studying and exams?

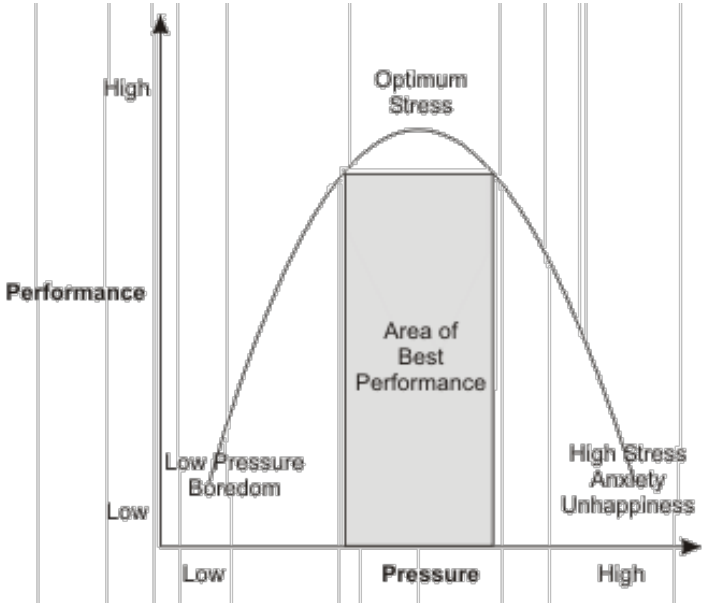


Men performing a virtual Morris Water Maze!

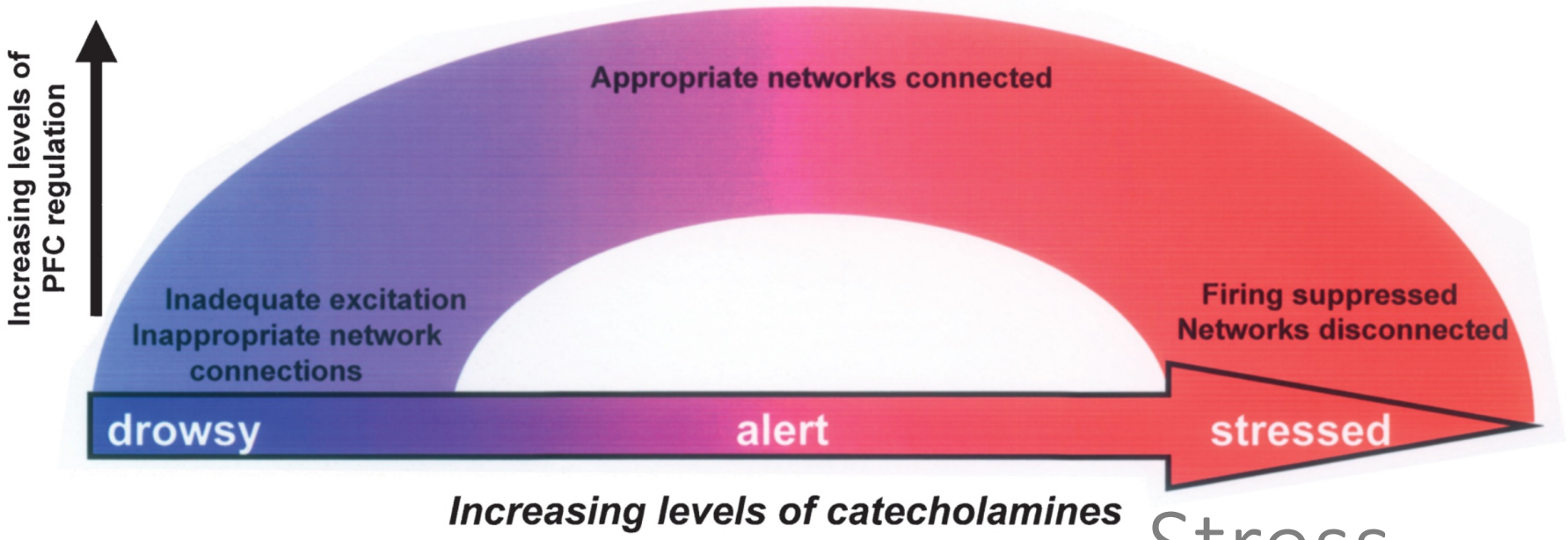
Duncko *et al*. 2007

Stress affects the prefrontal cortex via catecholamine release

- i.e. DA and NE
- Relationship between stress/arousal and performance (Yerkes-Dodson curve)
- We all sit at different levels of baseline catecholamine function
  - Implication?

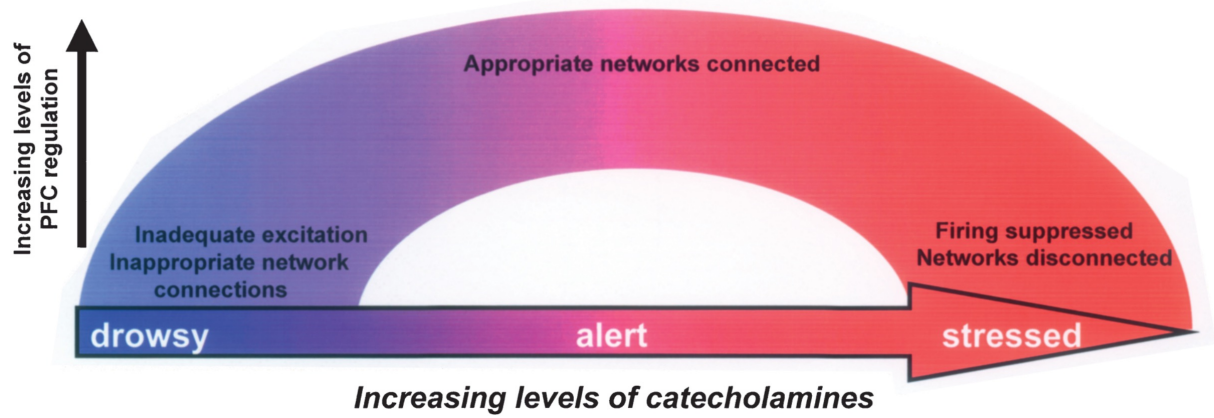


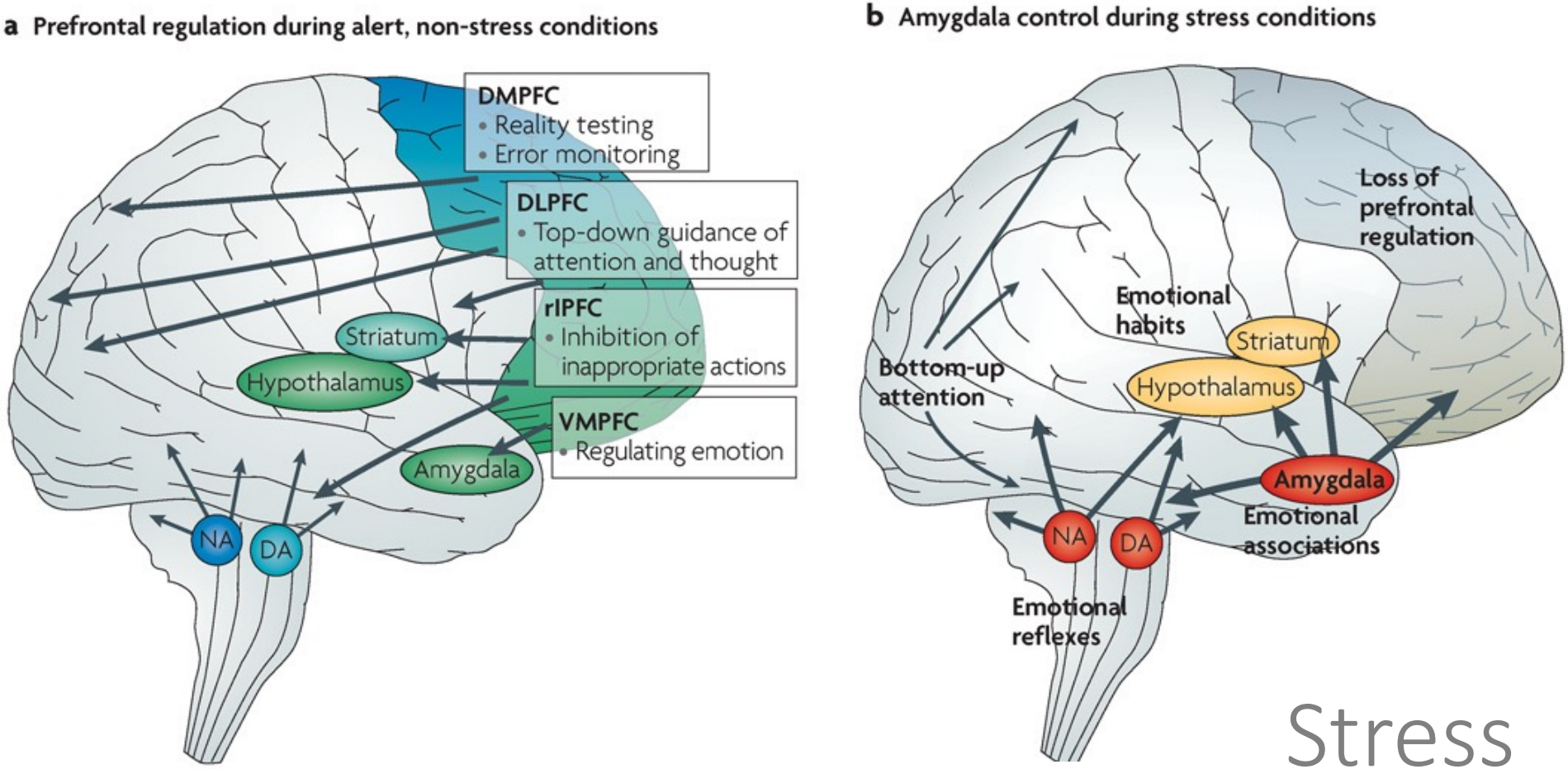
Yerkes-Dodson curve



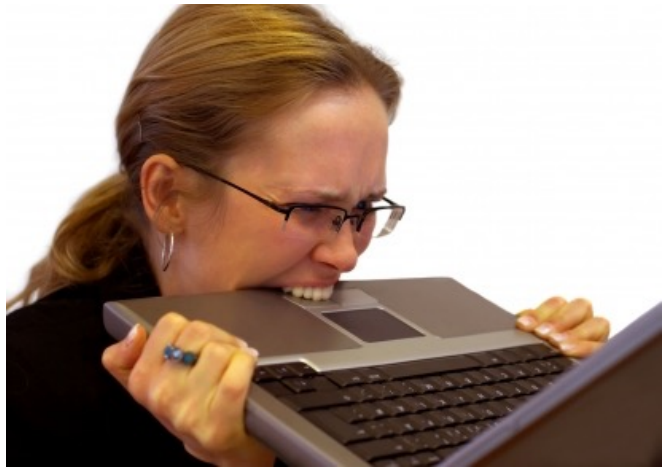
Stress and the PFC

- Amy Arnsten (2000s)





Chronic stress is *real bad*



Compromises immune functioning, mental health

Reduces hippocampal volume, thins PFC

Reduces performance on hippocampal- or PFC-dependent tasks

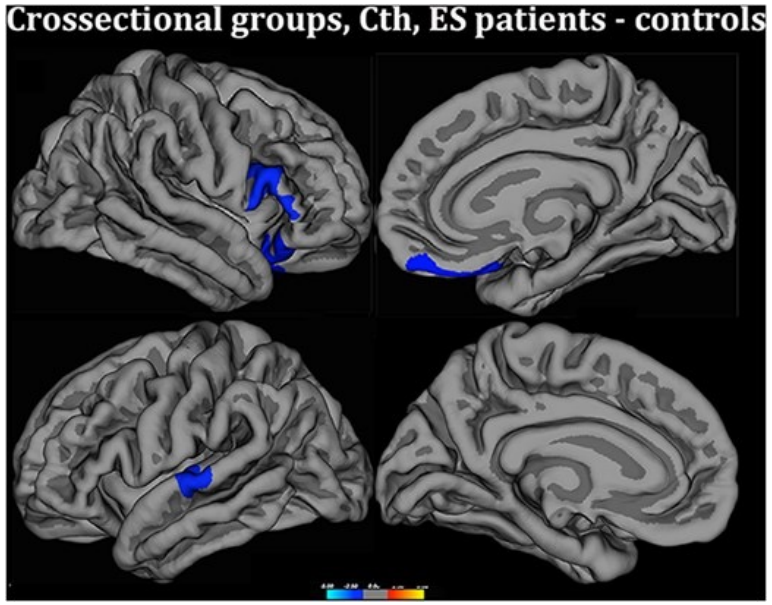
Requires more PFC activity to have same level of performance (e.g. Gavelin *et al.* 2017)

Shifts more reliance to subcortical structures (e.g. amygdala)

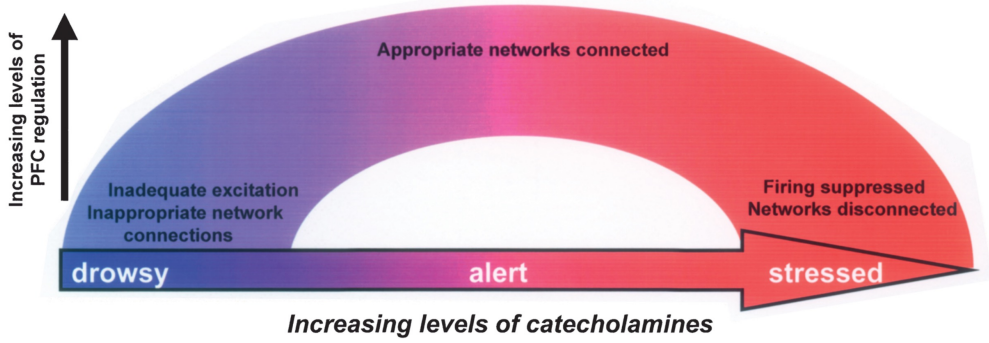
May decrease baseline DA function (Baik 2020, Bloomfield *et al.* 2019)

Then there's also the exposure to stress (and catecholamine release)

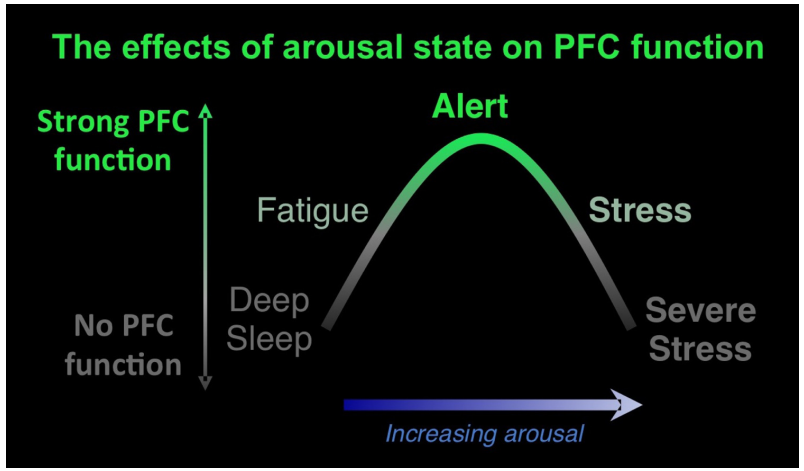
Effects often more pronounced in women (e.g. Savik *et al*. 2018)



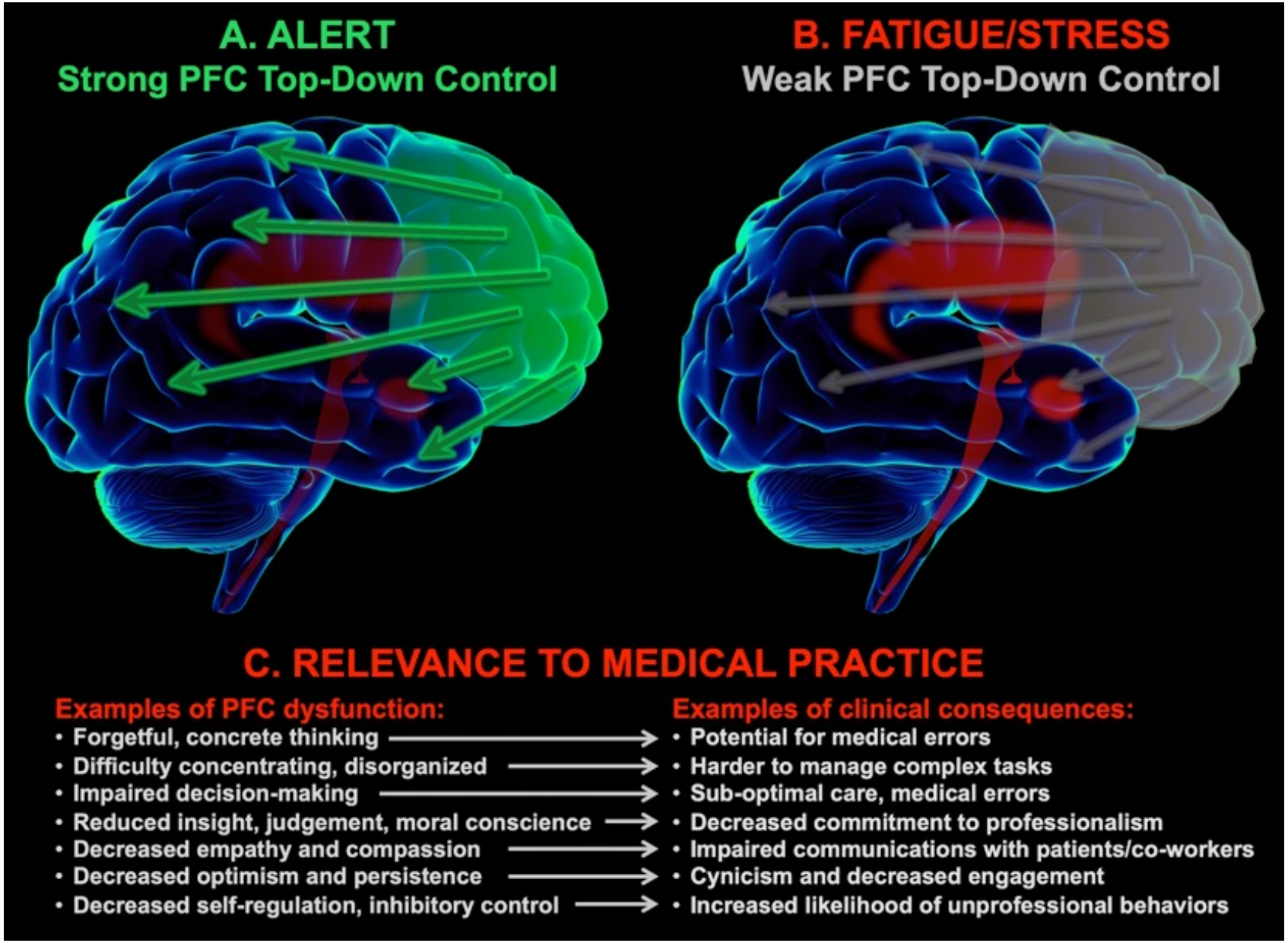
Burnout thins the PFC: Savik *et al*. 2018



Chronic stress is *real bad*

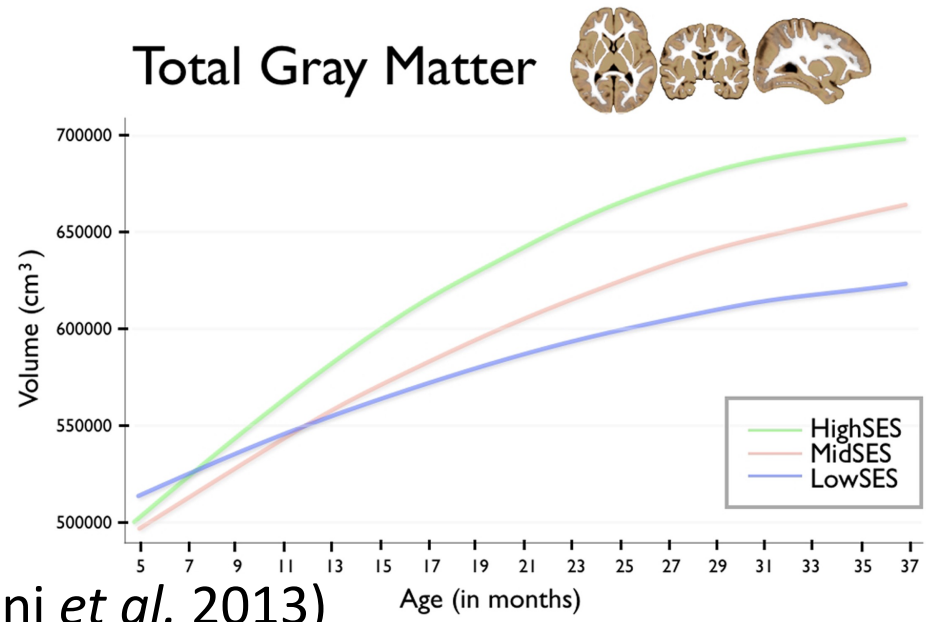


- This is the reality of "burnout" and "hustle culture"
- BUT these effects are shown to be reversible!



Arnsten and Shanafelt 2021

The chronic stress of poverty



An implication of modern society:
people are poor because they are bad decision makers

BUT

Poverty affects cognitive performance on unrelated tasks (Mani *et al.* 2013)

Exposure to irregular reward intervals guides even individuals with high baseline self-control to act impulsively (Kable & McGuire 2012, 2013)

Poverty disproportionately affects children and their brains
(Noble & Farah 2006, Hanson *et al.* 2013)

Stress negatively affects immune, endocrine, and nervous system health, and financial stress sometimes observed to be the *most* detrimental of all stresses (Hamilton *et al*. 2024)

To reframe: poverty is chronic exposure to uncontrollable stress → effect on brain?

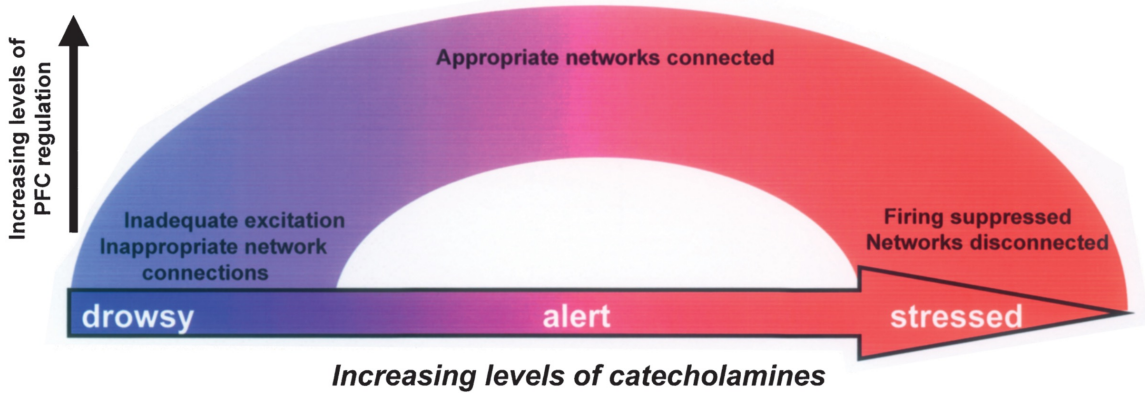
"The evidence indicates that poverty causes stress and negative affective states which in turn may lead to short-sighted and risk-averse decision-making, possibly by limiting attention and favoring habitual behaviors at the expense of goal-directed ones." (Haushofer & Fehr 2014)

Attention deficit / hyperactivity disorder (ADHD)

- Key symptoms: extreme inattention, hyperactivity, impulsivity
- Intersects with development, maturity, and societal norms (more on that later)
- 5-11% of children & teenagers receive diagnosis, 2:1 boys:girls
- Younger children in class ~40% more likely to be diagnosed with ADHD (Morrow *et al*. 2012, Whitely *et al.* 2019)
- Adult population: 2.5-3% (Song *et al.* 2021), 1.6:1 men:women
- Girls and women more often the inattentive subtype and have historically been underdiagnosed
- Individuals from marginalized communities less likely to receive diagnosis/treatment (Coker *et al*. 2016)
- Adult diagnoses of ADHD have risen more than 100% since 2007 (Chung *et al.* 2019)
- Psychostimulants (amphetamine, methylphenidate) improve symptoms
  - Paradoxical?

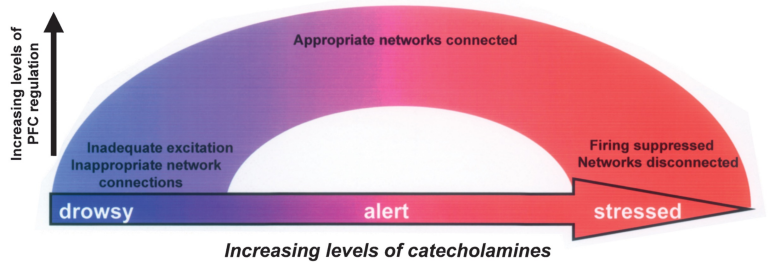
Evidence suggests a hypoactive DA system in ADHD

- Yerkes-Dodson / Arnsten revisited!
- PET studies suggest DA system is hypoactive (Volkow *et al*. 2009), but no changes to NE system (Vanicek *et al.* 2014)
  - Note: ligand doesn't bind in cortex, so only describes subcortical function!
- Many studies suggest changes to prefrontal cortex, DA system, basal ganglia (e.g. Castellanos *et al*. 2012)
- Many symptoms of ADHD relate directly to executive dysfunction
- Medication for ADHD (amphetamines, methylphenidates) blocks DAT and NET, increasing function of catecholamines
- In other words: evidence points toward people with ADHD sitting far to the left on the Yerkes-Dodson curve



Overlap between ADHD and chronic stress/burnout

- Symptoms overlap
- At low doses, psychostimulants provide modest cognitive benefits to most of us, not just those with ADHD
- Burnout exacerbates symptoms for those with ADHD
- And ADHD may also increase risk of burnout (Turjeman-Levi *et al*. 2024)
- Requires nuance
- >50% of ADHD social media posts classified as misleading (Yeung *et al*. 2022)
- In any case, reducing chronic stressors will benefit most of us



Understand the symptoms

Some common symptoms of ADHD in adults include the following:

- Struggling with organisation and managing responsibilities
- Difficulties in prioritising tasks
- Procrastinating and finding it difficult to finish tasks and keep to deadlines
- Struggling to focus in busy or noisy environments or for a long time
- Being forgetful and struggling with your short term memory
- Losing keys, wallet, work papers and forgetting appointments
- Being restless and finding it difficult to relax
- Having difficulties listening, and speaking out of turn in conversations
- Experiencing mood swings, irritability and extreme impatience
- Struggling to cope with stress
- Taking risks and having a reduced sense of danger

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Concluding thoughts on emotions, stress, and executive functions

Emotions are complex in their manifestation and their underlying neurobiological structures

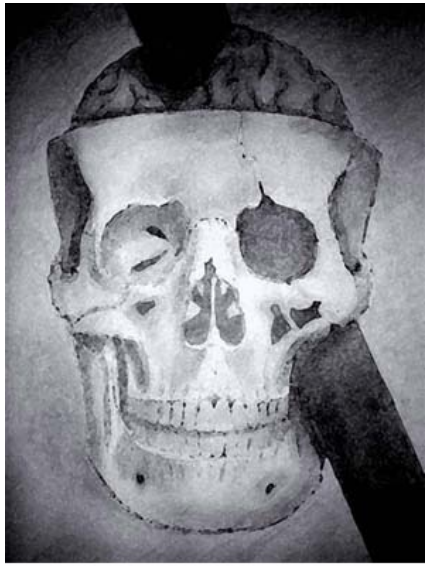
Emotions are clearly linked to value and motivation, and guide our actions

Impairments to emotion impair our ability to successfully navigate our world

Stress is a beneficial adaptation that is maladaptively triggered in contemporary society

While acute stress is beneficial, chronic stress is severely detrimental, especially in its effects on the PFC and hippocampus

ADHD acts on similar systems to stress, namely catecholamine release in the PFC and executive function



Artistic Representation of the Skull of Phineas Gage