Wired to be Social

Discoveries in Brain Functioning
and their Implications for the
Evolution of Social Intelligence

CHARLES J. VELLA, PHD

OCTOBER 25, 2021

Our perceptions of the social world

- Do you base your belief about the attitude of others about you on
  - Thomas Hobbes (“continual fear and danger of violent death; and the life of man, solitary, poor, nasty, brutish, and short.”)
  - Lord of the Flies,
  - Machiavelli,
  - the Stanford Prison Experiment,
  - the Kitty Genovese incident,
  - the ‘Broken Windows’ theory (visible indicators of disorder, such as broken windows, invite criminal activity)
  - gun-toting, anti-lockdown, anti-vax, Trumpist protesters
  - a lifetime of being trained & reminded not to trust ‘others’ in our ‘dog eat dog’ world.
- Or is there an alternate view?

When a brain is
not wired to be social…

Psychopaths

Are these people psychopaths?

- • Serial killer
- • Door to door sales person
- • Wall street or corporate executive (3-21%)
- • Skilled crime solver
- • Politician: Trump

  What differentiates “failed” from adaptive psychopaths?

- • Impulsive antisociality
- • Fearless dominance
- Average American male scores 4 of 40 on Hare Psychopathy Scale (1%); 30+ score = psychopath (grandiosity, glib, promiscuous, liar, manipulative, lack of guilt, no empathy, impulsive, childhood cruelty, childhood conduct disorder)

Kent Kiehl, PhD & his 3500 Psychopaths

Kent Kiehl in front of the semi-trailer that houses a portable MRI scanner at the Western New Mexico Correctional Facility.

Kiehl grew up a few blocks from Ted Bundy's home.

Kiehl on Psychopaths

- Psychopathy: Score of 30 of 40 on Hare's Psychopathy Checklist-Revised (PCL-R); trait must be pervasive
- Psychopaths typically exhibit impulsivity, poor planning, little insight and an utter absence of guilt or empathy.
- Sexual activity by the age of 12
- Early signs of violence, including a predilection for arson and animal torture.
- Psychopaths:
  - 1-2% of the general population (1 in 100)
  - 15 to 20 % of prisoners in minimum to medium security prisons,
  - 30 percent for those in maximum security.

Psychopathy: “Suffering Souls”

- Condition of moral emptiness
- Their main, concealed, defect is "severe emotional detachment"--a total lack of empathy and remorse.
- P average convictions for four violent crimes by the age of forty.
- Criminal lifestyle factor (lower after age 40): SES, bad friends, substance abuse
- Callous aggressive narcissism: predator-prey

Kent Kiehl

Kiehl on Psychopaths:

- Children with CU (callous & unemotional) traits:
  - fail to activate amygdala when viewing fearful faces (produces more aggression)
  - impairments in engaging OFC during learning tasks (punishment does not restrain behavior)

- Decreased amygdala size – reduced activation in psychopathy; no psychopaths with OCD

Kiehl's Paralimbic Dysfunction Theory

- Paralimbic Dysfunction in Psychopathy:

- Psychopathy is result of combined deficits in:
  - amygdala,
  - hippocampus,
  - anterior and posterior cingulate,
  - orbital frontal cortex,
  - insula, and
  - temporal pole
  - (= primary social brain functional areas).

- Paralimbic damaged pts: Damage to any part of this system can precipitate ASPD+P sxs: problems with aggression, motivation, empathy, impulsivity, irresponsibility, lack of behavioral control

Paralimbic theory: early onset and/or damage

- Can be born with and/or inherit paralimbic damage
- Incarcerated youth with elevated CU traits have same brain abnormalities as adult psychopaths: majority of paralimbic system has reduced gray matter
- Can also be triggered by TBI, dementia, CTE

Psychopaths: Less Gray matter

- Damage to these areas is associated with
  - impaired empathizing with other people,
  - poor response to fear and distress
  - lack of 'self-conscious' emotions such as guilt or embarrassment

Kiehl on causation

- The best physiological indicator of which young people will become violent criminals as adults is a low resting heart rate; a lack of fear or distress
- Nature/Nurture?: "It seems to be 50-50," Kiehl says.
- "It's absolutely possible that some psychopaths are more genetically predisposed than other people, but there is no good evidence for a trigger theory. Psychopathy is a developmental disorder, so even as kids they are very different."

James Fallen on Psychopathy: Combination of Factors

1 – Low Orbital Frontal activation/atrophy

2 - MAO-A gene (monoamine oxidase A):
high-aggression variant (low Serotonin)

3 – Mother transmission to son
(X chromosome), too little Serotonin:
higher rates among males

3 – History of childhood abuse or
seeing lots of traumatic violence

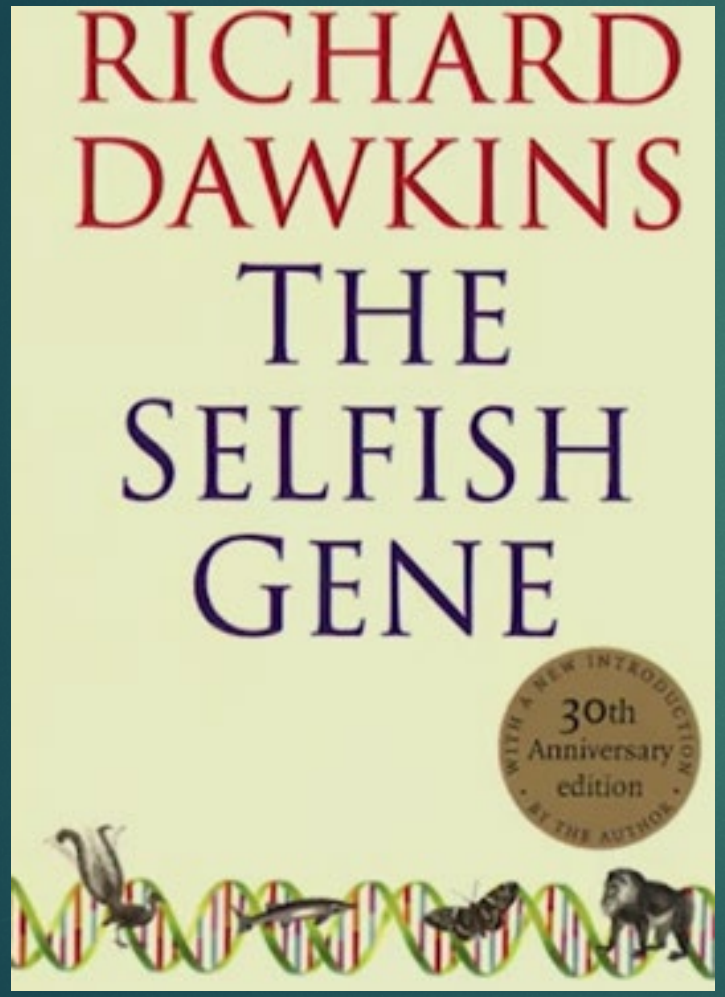
Primates are social

Social grooming: 20% of day

The evolution of human sociality is the fundamental conundrum of biology.

EO Wilson 1975

The opposition



"Let us try to teach generosity and altruism, because we are born selfish."

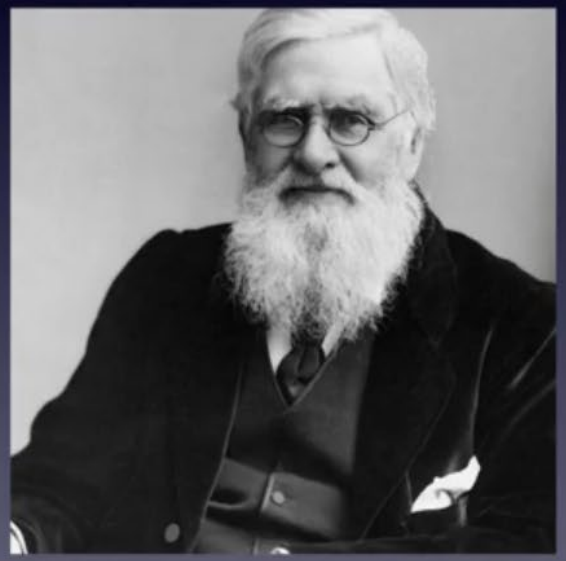
Sociality in mammals

- Primates and rats show prosocial choice
- Orphan adoption in marmosets & male chimps

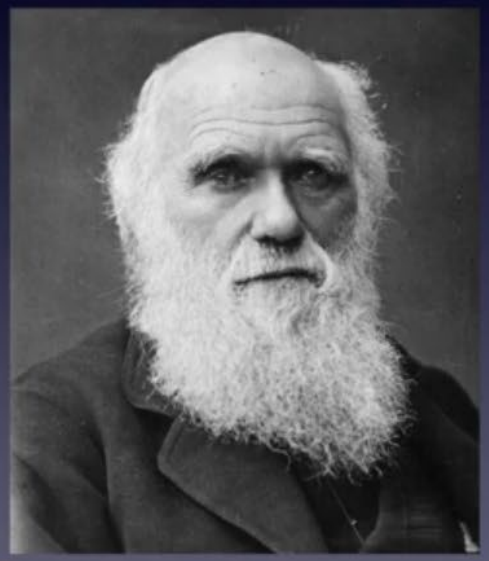
- Primates exhibit: social reconciliation, empathy, fairness, self-control, cooperation
- 3rd party (altruistic) punishment of social transgressions

Why are brains so big

Four Theories



Wallace
Creationism

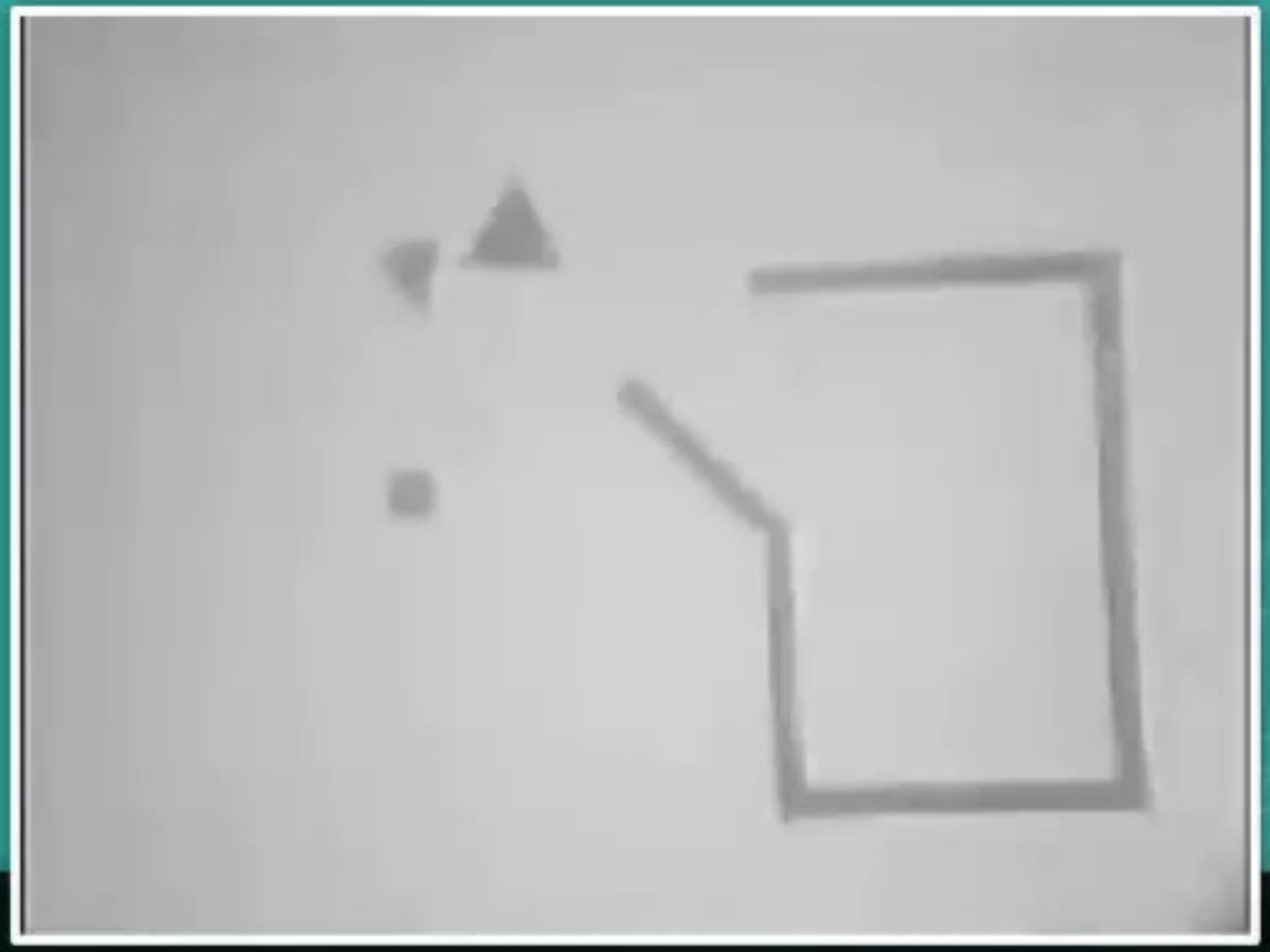


Darwin
Sexual Selection

Dunbar
Social Brain
Hypothesis

Henrich
Cultural Brain
Hypothesis

Social Objects: We perceive sociality



HEIDER & SIMMEL (1944) "AN EXPERIMENTAL STUDY OF APPARENT BEHAVIOR"

American Journal of Psychology 57, 234-259

Interpretation of prior slide by normal control subject

“I saw a box, like a room, that had an opening to it. There was a large triangle chasing around a smaller triangle, and a circle...got into the box, or the room, and lid. And the big triangle chased the little triangle around. Finally he went in, got inside the box to go after the circle, and the circle was scared of him...but maneuvered its way around and was able to get out of the opening, and they shut it on him. And the little circle and the little triangle were happy that they got that, the big one, caught. And they went off on their way, and the big triangle got upset and started breaking the box open.”

Patient SM: atrophy of amygdala

Atrophied Amygdala:
Pt SM does not use eye region in assessing emotion in others

Size of amygdala correlates with number of friends you have

- Her story: “OK, so, a rectangle, two triangles, and a small circle. Let’s see, the triangle and the circle went inside the rectangle, and then the other triangle went in, and then the triangle and the circle went out and took off, left one triangle there, and then the two parts of the rectangle made like an upside-down V and that was it."

Wired to be Social

- Newborns come into the world wired to socially interact.
- The Social Brain Hypothesis: Brain size and Intelligence is for managing our social relationships.

Imitation is learned – social brain areas need to be programmed

- If infants also increase their tongue protrusions when an adult models a happy face or finger pointing, then it's not a case of imitation, but probably excitement at seeing an adult do something interesting,

- Imitation isn't an innate behavior, but one that is learned in babies' first months.

- In fact, babies might learn to imitate other people based on watching other people imitate them. Parents imitate their babies once every two minutes on average;

Empathic Rat:

Busting friend out of jail & sharing chocolate

"Empathically motivated pro-social behavior" exhibited. Basis unclear.
Rats recognize their peers' pain—show emotional contagion (mimic emotional behavior)

Inbal Ben-Ami Bartal, Jean Decety, Peggy Mason ,2011

Harvard Study of Adult Development: Longest Prospective Study

- 75 year prospective study (724 men; 60 still alive; & 2000 children; 4 directors) – Group 1 (sophomores at Harvard); Group 2 (disadvantaged Boston teenagers); every 2 years reexamined

- Conclusion: Good relationships keep us happier and healthier
  - Social relationships (family, friends, community) are really good for us
  - Loneliness kills: isolation is toxic (less happy, health declines earlier in midlife, brain declines sooner, die sooner); 1 in 5 Americans

Harvard study

- Quality of close relationships counts: living in conflict with no affection is toxic, & worse than divorce; warm relationships are protective

- Those who were most satisfied in their relationship at age fifty were most healthy at age 80

- Physical pain is magnified if in unhappy relationships

- Being in securely attached relationship (can depend on the other person, even if bicker a lot) in your 80s is protective of brain and memory functioning

What is the ‘social brain’?

- Concept of the “social brain” evokes a brain that evolved in the selective pressures of social group living

- Each person shows complex propensities to be in social settings
  - As during childhood relationships
  - Our brain is continually shaped by our social experiences

Social Brain Description

- A growing body of research and theoretical thinking supports the view of the human brain as
  - Created by evolutionary processes
  - Is developmentally formed
  - Molded by continuing life-long social interactions
  - Embedded in an evolving cultural environment

Psychiatric Disorders = Social disorders

- Psychiatric Dysfunctions: socially maladaptive cognitive-emotional interpretations & behaviors
- Psychiatric sxs affect social interactions
  - Disruptions of conduct disorder
  - Interpersonal alienation of schizophrenia
  - Impaired social interactions of personality disordered people
  - Substance abuser abandons social norms & responsibilities
  - Social deficits = major feature of autism

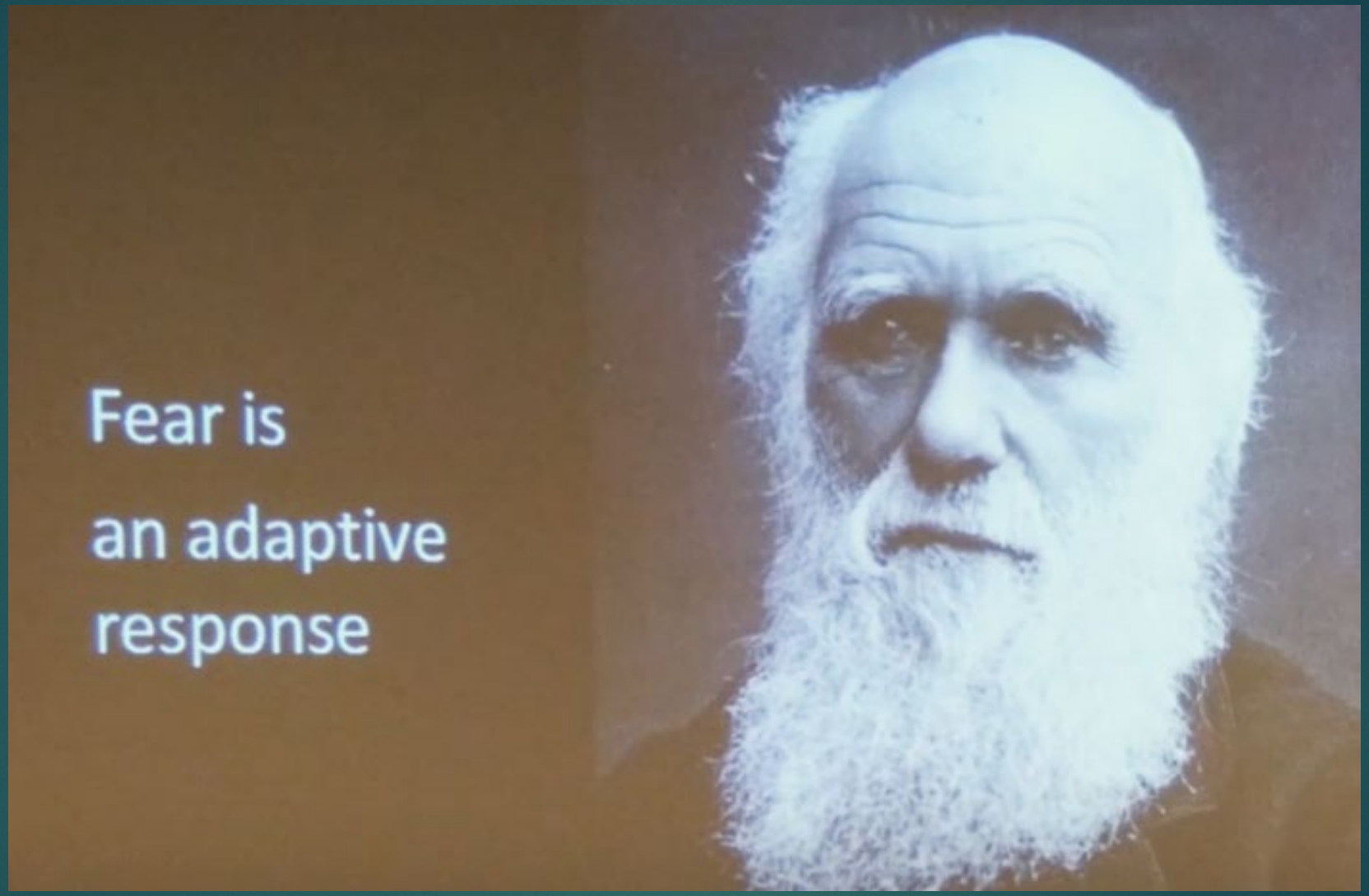
Covid as test of how social we are

- Before 2020, psychiatric disorders were leading causes of the global health-related burden, with depressive and anxiety disorders being the leading contributors to this burden.
- Systematic review of data reporting the prevalence of major depressive disorder and anxiety disorders during the COVID-19 pandemic:
- Daily SARS-CoV-2 infection rates and reductions in human mobility, were associated with increased prevalence of major depressive disorder and anxiety disorders. Females and younger age groups were affected more by the pandemic than males
- Increase in depression of 27% and in anxiety of 25%

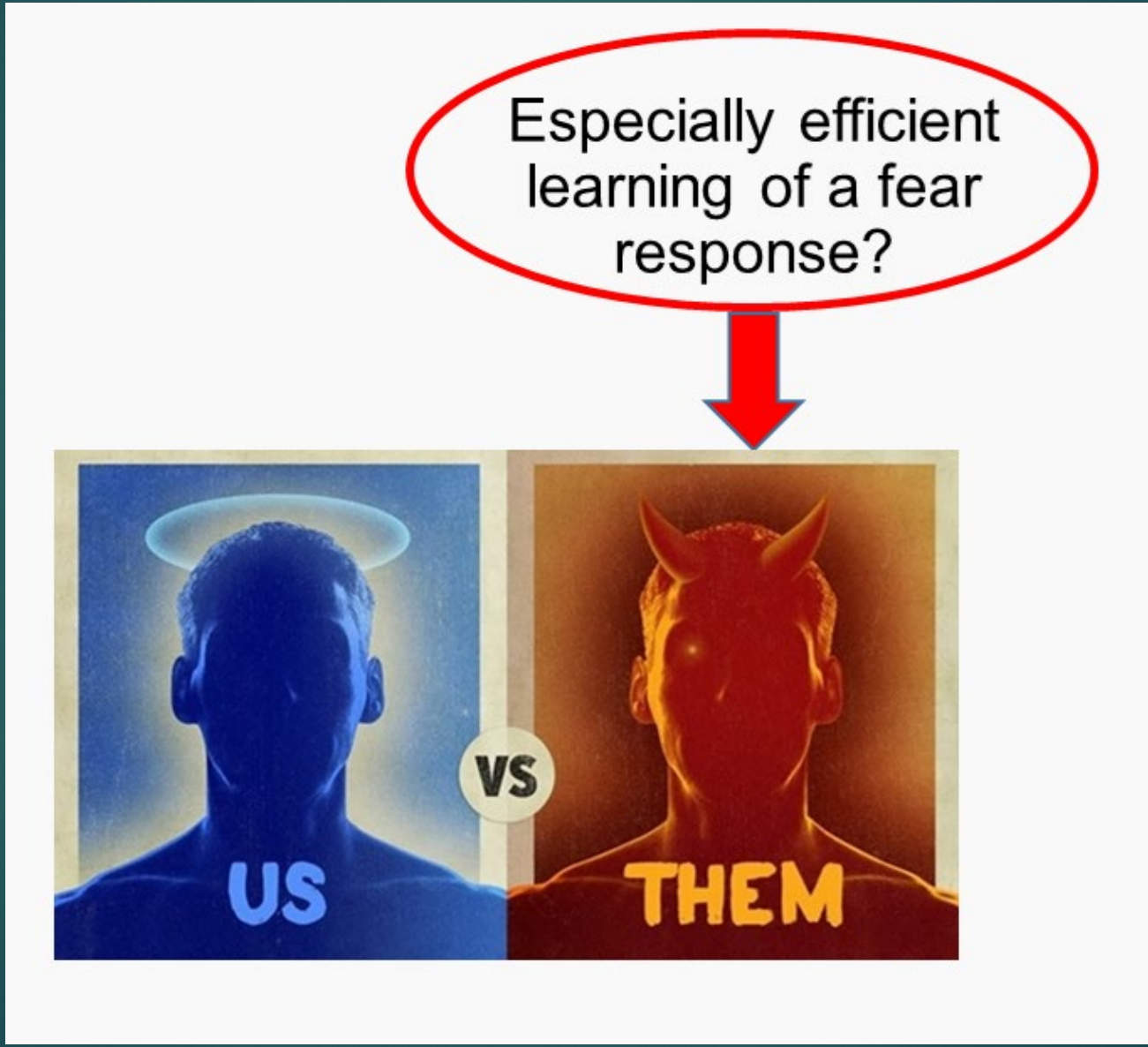
Development of social ability:

We need a long childhood
with social dependence to program our
hardwired social brain processors

Takes about 20 years to develop a
functioning adult *Homo sapiens'*
social brain


Fear is
an adaptive
response

Ancestral interactions within groups and between groups

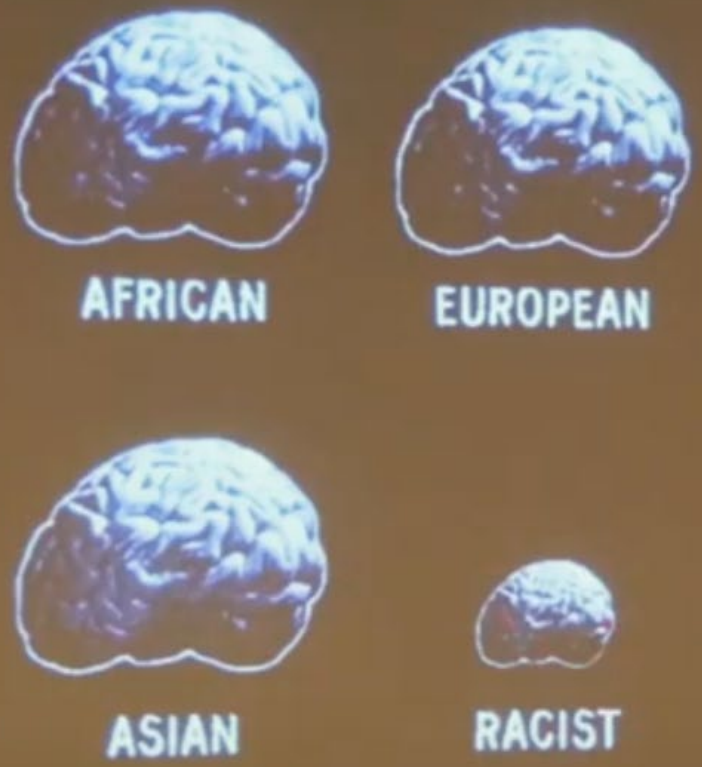


Us vs. They

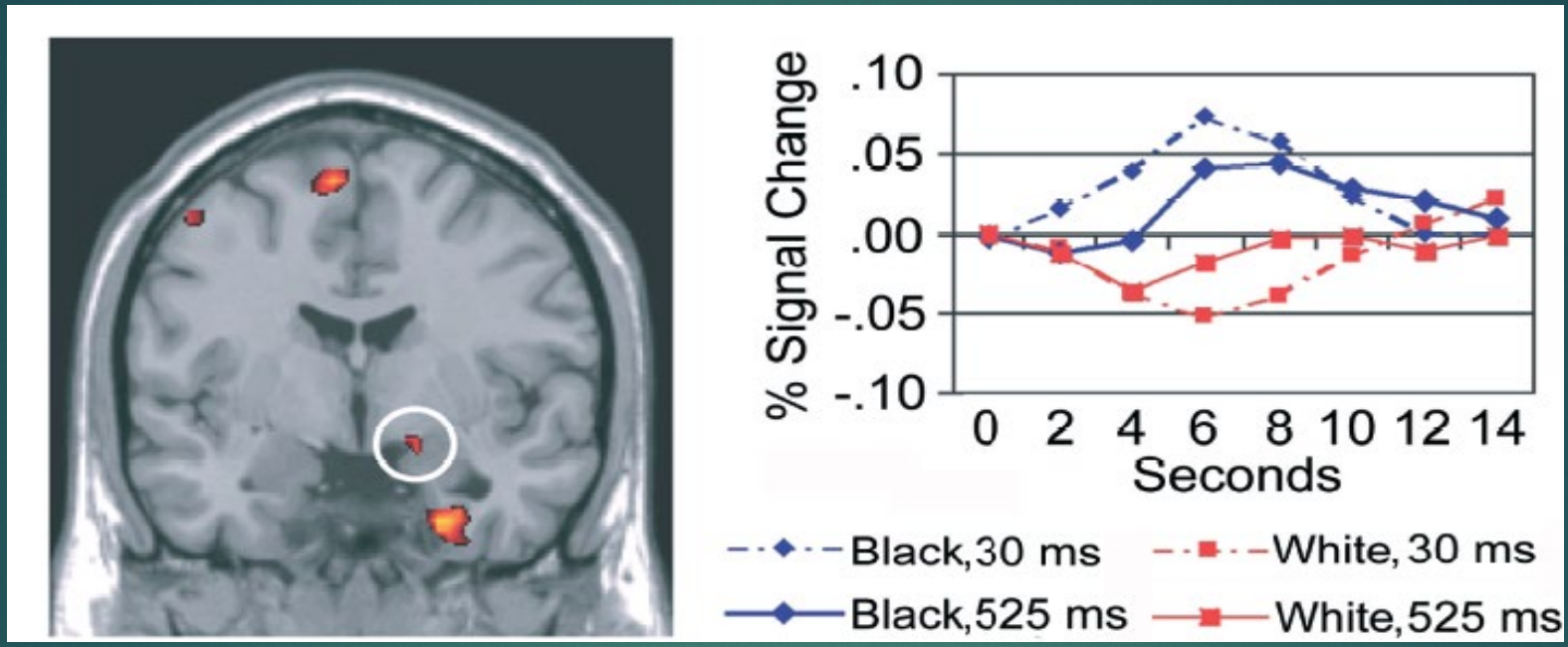
- *All good people agree,*
  And all good people say,
  All nice people, like Us, are We
  And everyone else is They

Rudyard Kipling

Is there a neural basis for racial/group prejudice?

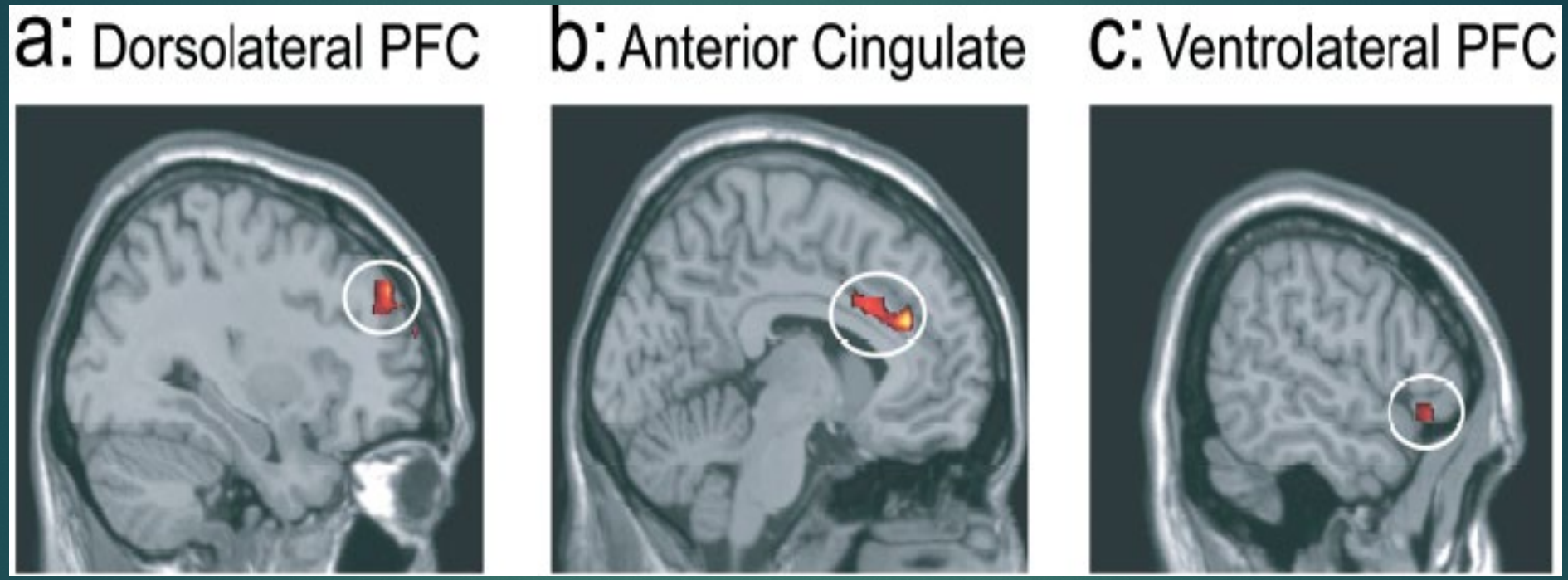


Amygdala: evolutionary stereotyping



Amygdala activation is associated with threat, vigilance, emotional arousal and ambiguity

Stereotyping: Frontal control



The prefrontal cortex and anterior cingulate are associated with inhibition, conflict resolution, and behavioral control.

Strangers and fusiform gyrus and amygdala activation

- When white subjects were shown white faces, there was distinct activation of the fusiform gyrus (facial recognition area)

- When shown non-white face, first activation in amygdala (potential threat analysis; fear response area) and cortisol (stress hormone) release

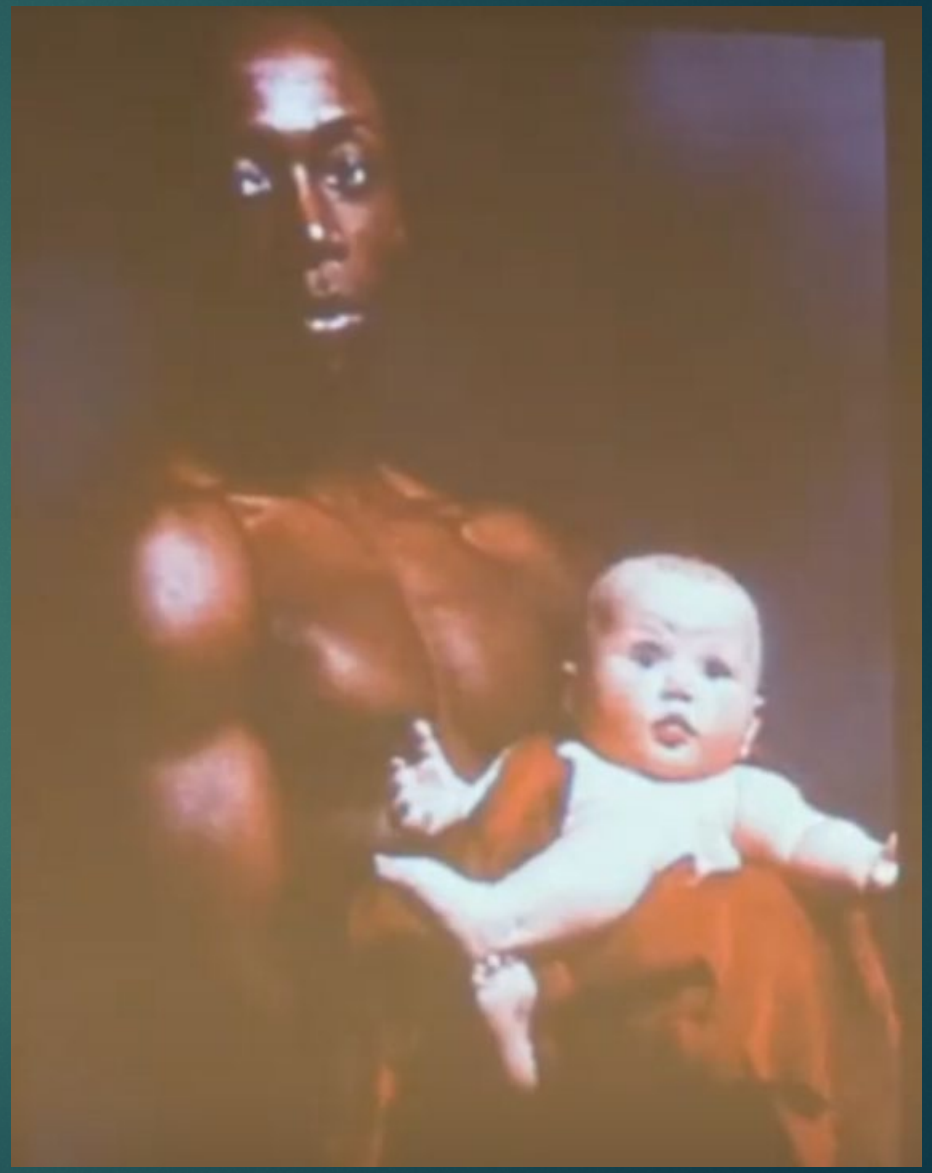
- Frontal cortex evaluates any potential threat and is capable of appropriate response to a “threat”, esp. behavioral inhibition

Amygdala & Insula: Us vs. Them

- Amygdala & insula are strongly activated (in milliseconds):
  - Apparent race
  - Gender
  - Age: older
  - Disabled
  - Homeless
  - Drug addicts
  - Rich businessmen

We are not born to exhibit racial prejudice - we learn it

- Newborn infants demonstrated no spontaneous preference for faces from either their own- or other-ethnic groups
- 3-month-old infants demonstrated a significant preference for faces from their own-ethnic group – scan for longer time
- Parents avoid talking about race when children ask about it
- When presented 2 dolls, both white children and children of color have a white bias as early as age 4



Wired for Bias: Innate Prejudice

- Hominin on African Savannah, 2 Mya: fast identification of stranger/the other fosters survival and is an evolutionary advantage

- Despite this overwhelming evidence that our brains are evolutionarily wired for bias, our society continues to think about prejudice as premeditated behavior.

- Our current laws against discrimination, as well as the majority of diversity training programs, assume that prejudice is overt and intentional.

OFC & Stereotyping

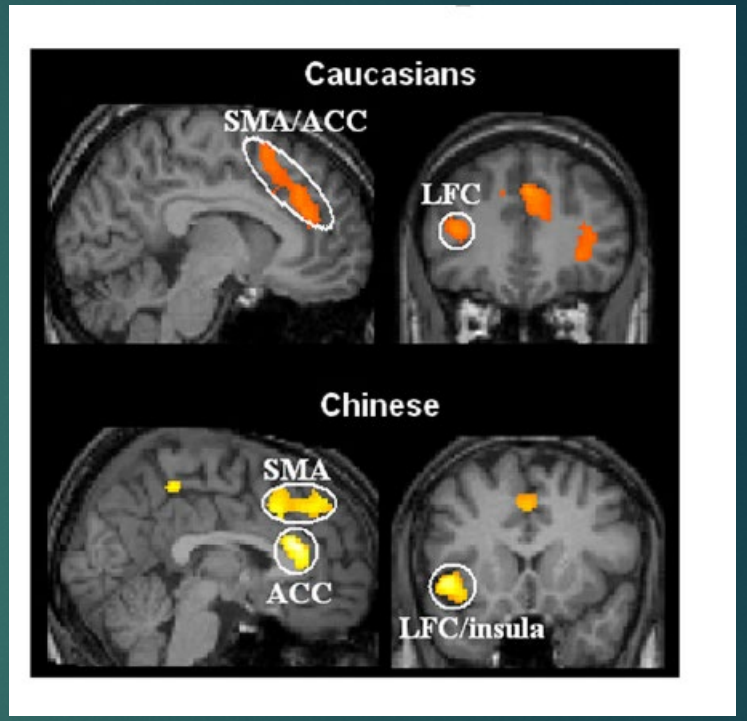
- Evolution favored fast identification of us vs. them, of categories (otherness) vs individuals.
- OFC: rapid evaluation of complex social information based on learned associations
- Neurological Stereotype = cognitive "shorthand" for instantaneously decoding social situation for rapid behavioral response
- Faster reaction time to stereotypes

Amygdala and Prejudice: Out group identification

- Stereotyping and primitive emotional prejudice responses: amygdala has major role in implicit prejudice.
- Greater amygdala activation to unknown black faces in white subjects despite denial of prejudice; but do not activate to famous black faces
- People who exhibit more racial prejudice, show more amygdala response
- Not inevitable: malleable by societal goals and PFC activation.

Loyalty & Empathy & Prejudice in the In Group:
Do You Feel My Pain?

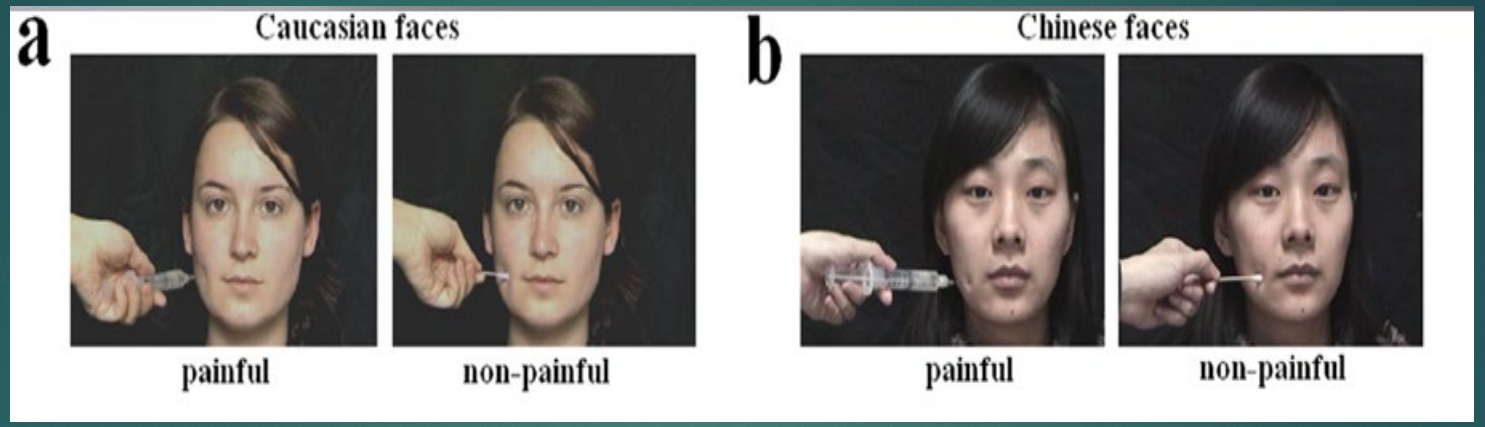
- People show more empathy to own group.
- ACC mainly contributes to the affective component of empathy
- ACC & FI activate when witnessing someone in pain



Do You Feel My Pain?

Own-race bias in ACC activity in empathy for pain

ACC ↑ if white viewer



ACC↓↓ if white viewer

Pain applied to racial in-group faces induced increased activations in the ACC & inf FI in both Caucasians and Chinese when viewing own group.

Empathic neural response in the ACC decreased significantly when subjects viewed faces of other race.

Most empathic to in-group showed stronger empathy to out-group members

Xiaojing Xu et al., 2009

But we have Frontal lobes & evolved for cooperation

- We can rein in our unwanted prejudices:
  - Among whites, longer exposure to black faces reduces Amygdala response (30 ms vs 525 ms)
  - People with positive attitudes toward African Americans show greater left PFC activity in situations were stereotyping was possible
  - Less prejudiced people have ACC (conflict resolution circuit, empathy) activation in above situation
  - Smiling reduces racial categorizaiton

Conclusion

- Our brain's evolution to avoid threat leads to unconscious threat activation in our brain.
- Our basic snap judgments and gut reactions are evolutionarily based subcortical responses for protecting ourselves from potentially threating situations.
- We cannot stop spotting differences and sorting people into stereotypical categories.
- But hominins also developed the frontal lobes to suppress inappropriate social reactions and maintain appropriate social goals.

New perspectives on Amygdala

- Elizabeth Phelps and others have cautioned that the amygdala also responds more generally to the emotional intensity of a stimulus -- not only fear but also ambiguity, vigilance and even some states of uncertainty that can have a positive outcome.

- fMRI activation of the amygdala should not be taken as unequivocal evidence that the fear and anxiety are the primary unconscious responses to racial or ethnic differences; the activation could represent a nonspecific state of heightened emotional arousal.

Biology is Not destiny

- Phelps has repeatedly emphasized that the behavioral studies demonstrating unconscious bias "do not indicate that this behavior is 'hard-wired,' or unchangeable."

- Unconscious biased responses (amygdala activation) can be significantly reduced by experience and familiarity.

- In other words, emergent prejudiced behavior isn't an inescapable aspect of our biology.

- "No one is born hating another person because of the color of his skin, or his background, or his religion. People must learn to hate, and if they can learn to hate, they can be taught to love . .”
  - *Nelson Mandela, Long Walk to Freedom*

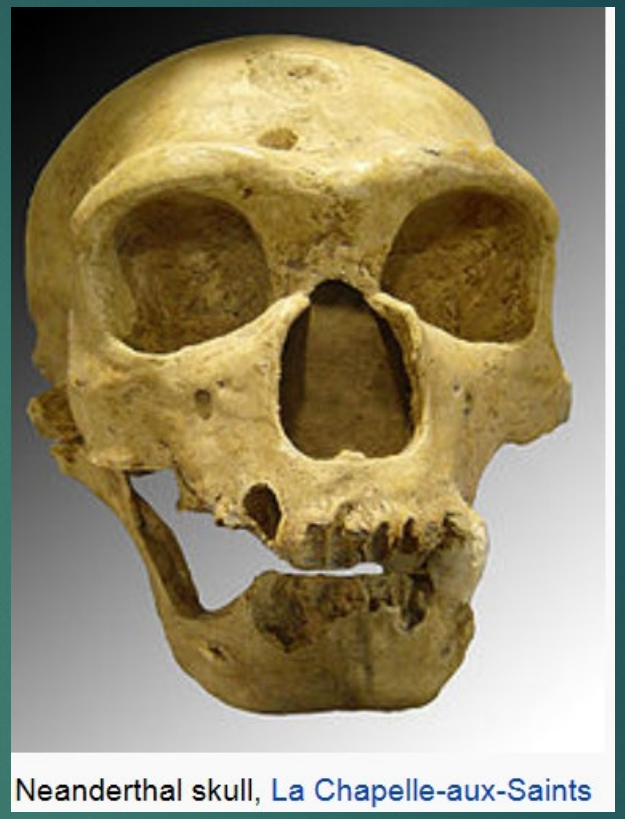
Social Brain Hypothesis

Sociality: Even if you are smart, it is important to have help

Larson

Cooperation/Compassion at 1.8 MYA

Homo erectus:
Dmanisi D3444, ~1.8 MYA



Neanderthal skull, La Chapelle-aux-Saints

Neanderthal, ~50 kya

Reabsorbed teeth bone: lived without teeth for years;
Must have been taken care of by their social groups

Social Animals

- In primates, the size of social circles correlates to the relative size of the neocortex compared with the rest of the brain.
- In humans, Dunbar's number is a suggestion of the maximum amount of relationships a person can maintain.

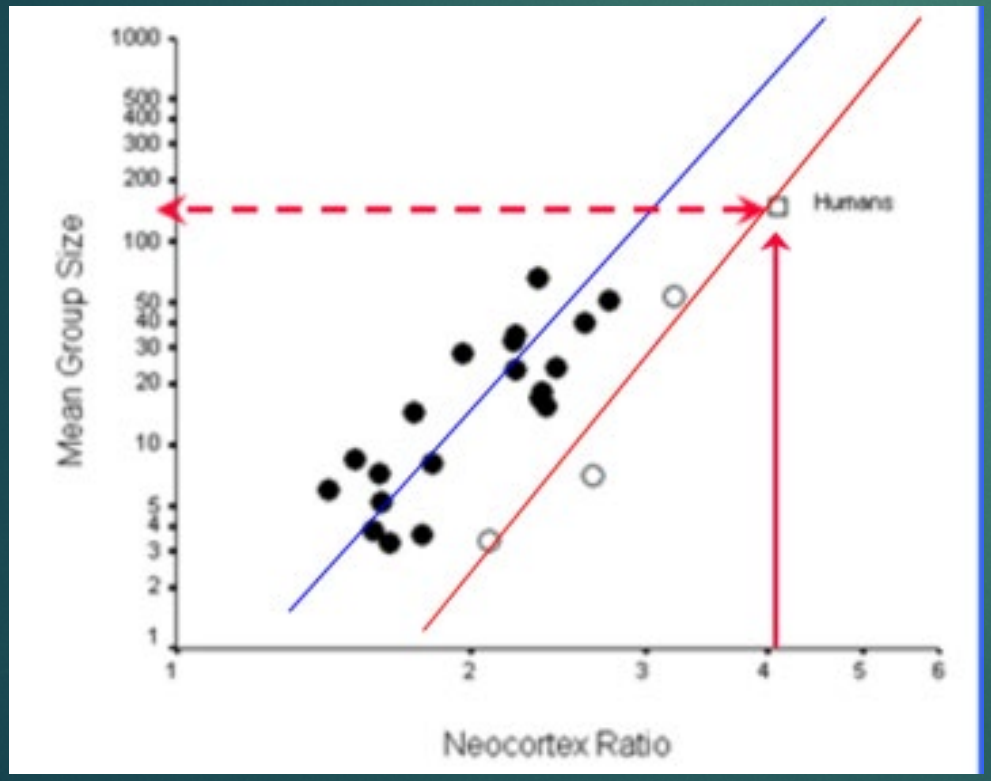
Brain region sizes correlates of social complexity

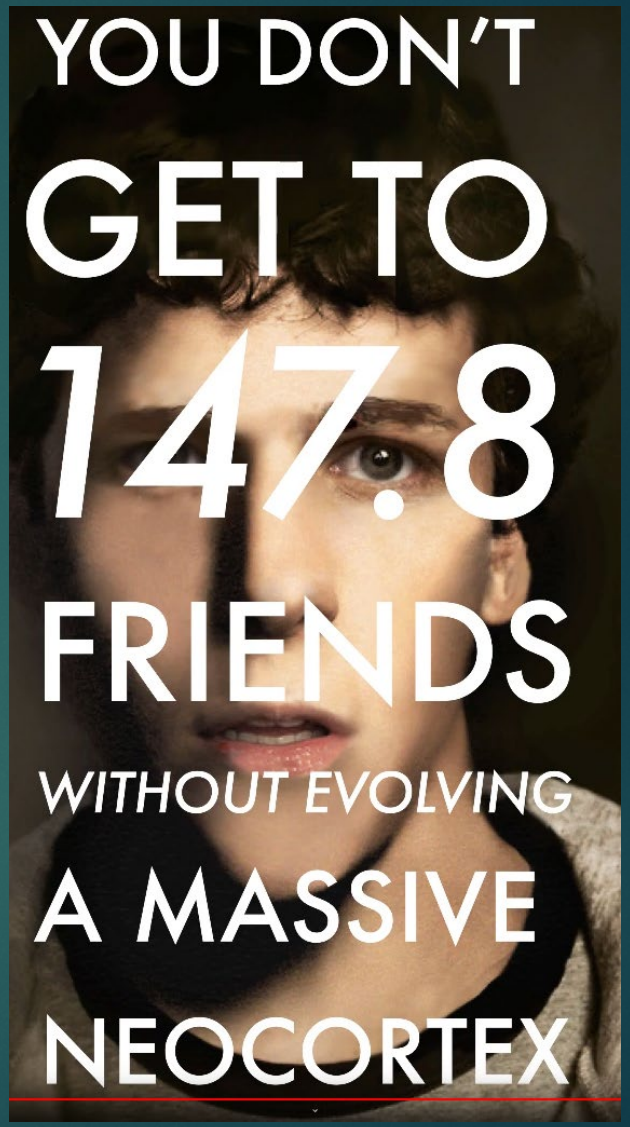
- Correlation between the size of a person's social network and their performance on tests of both memory and 'theory of mind'
- Grey-matter volume of parts of the prefrontal cortex vary with social-network size, as well as with performance on theory-of-mind tasks
- Volume of the amygdala correlates with the size and complexity of a person's social network.

Humans and the Social Brain Hypothesis

Predicted group size max for humans is ~150

"Dunbar's Number"

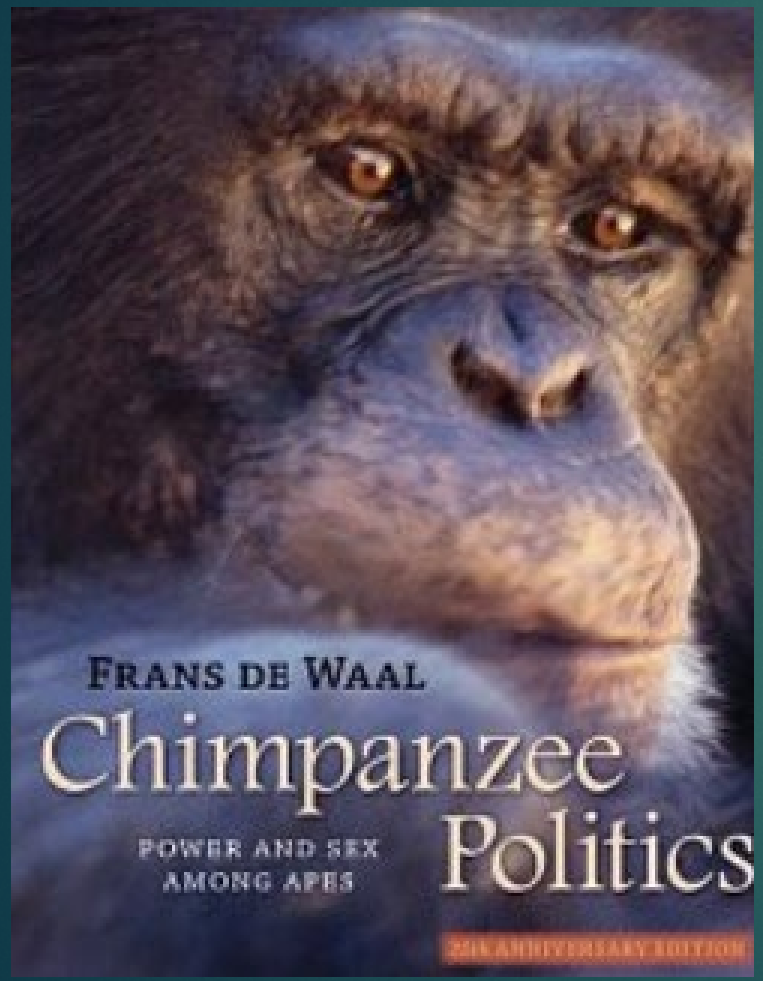




Theorizing about the evolution of social brain

- What types of selection pushed the evolution of the size of the human brain?
- Charles Darwin, in *The Descent of Man*, proposed that evolution of intelligence is linked to living in social groups.
- Increased size of primate groups was response to potential predation.
- But larger groups bring their own problems.

Why did Newt Gingrich recommend this book to all new politicians?



Detailed and thoroughly engrossing account of ape social power struggles, rivalries and coalitions.

Machiavellianism: political behavior is rooted at a level of development that is below the cognitive and is as much instinctive as it is learned.

de Waal 1982

De Waal, Byrne & Whiten: Machiavellian IQ

- Machiavelli's The Prince: Frans de Waal introduced the term 'Machiavellian Intelligence' to describe the social and political behavior of chimpanzees

- Social behaviors: reconciliation, alliance, and sabotage

- Tactical deception in primates:
  - Vervet monkeys use false predator alarm calls to get extra food
  - Chimpanzees use deception to mate with females belonging to alpha male
- Originally theory was “Machiavellian IQ”, too negative in connotation. Now “Social Brain Hypothesis” (SBH)

Robin Dunbar: Social Brain Hypothesis

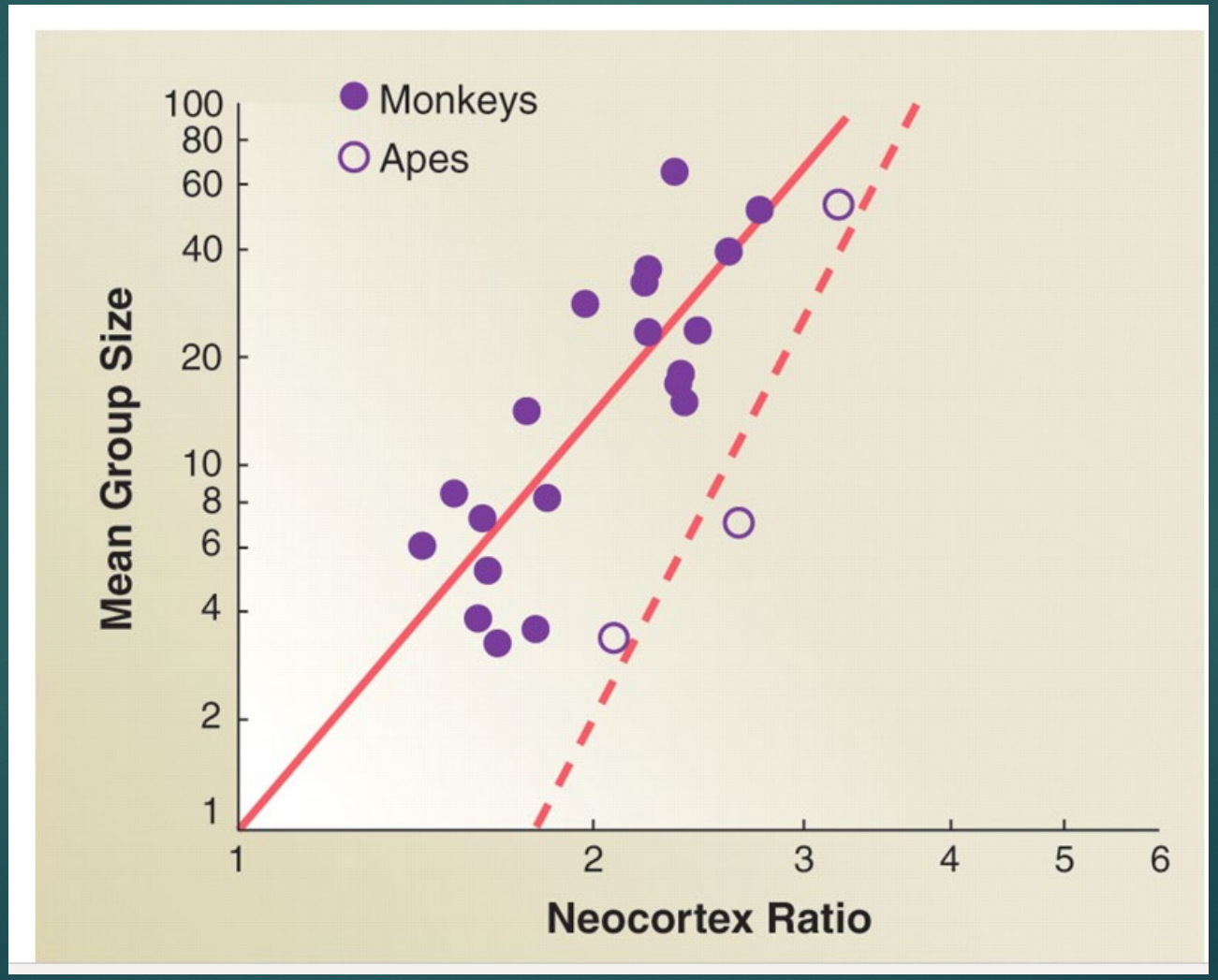
- Primates developed large social group in response to ecological threat
- Primates evolved large brains to manage their unusually complex social systems.
- This hypothesis has found support in numerous comparative studies of group size.

Dunbar, 1998

Social Brain Hypothesis

- SBH = An explanation why primates have such big brains compared to all other species
- Primates live in unusually complex societies, and this is computationally very demanding on the brain
- Group size is an index of social complexity
- Neocortex ratio is an index of overall brain size

In primates, mean social group size increases with relative neocortex volume (indexed as the ratio of neocortex volume to the volume of the rest of the brain).



Language: Invention of friendship

80% of college campus conversations are ‘networking” = gossip

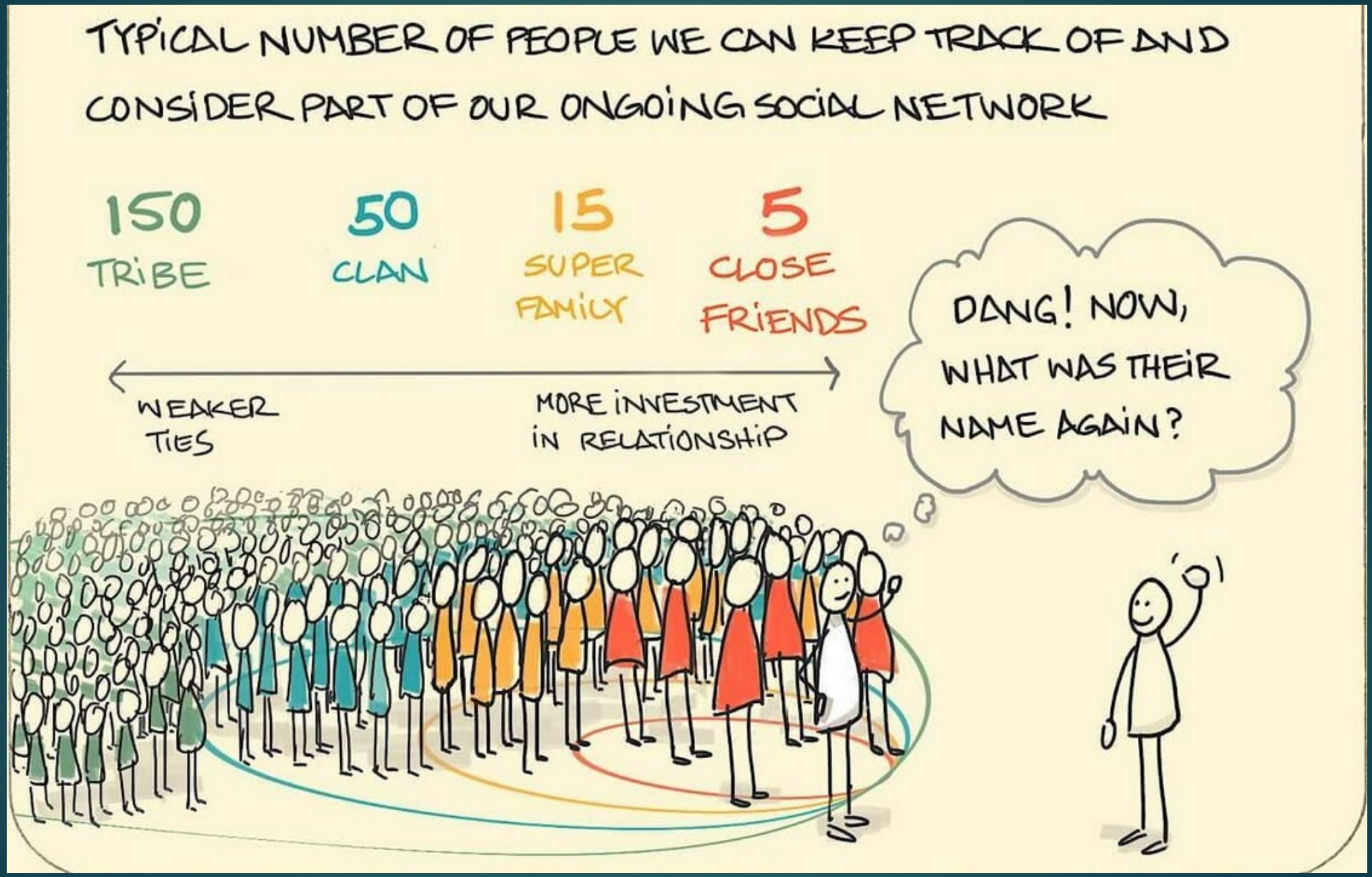
Gossip

- Dunbar: 66% of human talking is dedicated to gossip (affairs, insider trading, food sourcing, trading, who likes who, who is out to get you);
- Impossible to personally monitor the behavior of all group members; way to track our reputations
- Prosocial gossip: Share negative gossip to protect others from antisocial behavior

R. Dunbar, 1996;
M. Feinberga et al., 2012

Evidence for Social Brain Hypothesis (SBH)

- A series of studies demonstrated that, among primates at least, relative brain size [usually indexed as relative size of the neocortex] correlates with many indices of social complexity, including:
  - social group size,
  - number of females in the group,
  - grooming clique size,
  - the frequency of coalitions,
  - male mating strategies,
  - the prevalence of social play,
  - the frequency of tactical deception,
  - and the frequency of social learning.


TYPICAL NUMBER OF PEOPLE WE CAN KEEP TRACK OF AND CONSIDER PART OF OUR ONGOING SOCIAL NETWORK
150
TRIBE
50
CLAN
15
SUPER FAMILY
5
CLOSE FRIENDS
WEAKER TIES
MORE INVESTMENT IN RELATIONSHIP
DANG! NOW, WHAT WAS THEIR NAME AGAIN?

Robin Dunbar: Evolution of social brain

- Primates have big brains to compute social complexity
- Bigger the group size, bigger the brain; bigger the neocortex; esp. frontal volume
- Unique to primates & birds
- Related to monogamy; pairbonding = management of complex relationships
- 150 = Dunbar's number: cognitive limit to the number of people with whom one can maintain stable social relationships—relationships in which an individual knows who each person is and how each person relates to every other person
- We spend 60% of our time on the 15 most important of 150 people

Why Your Network Matters

What best predicts your survival for the next 12 months after a heart attack?

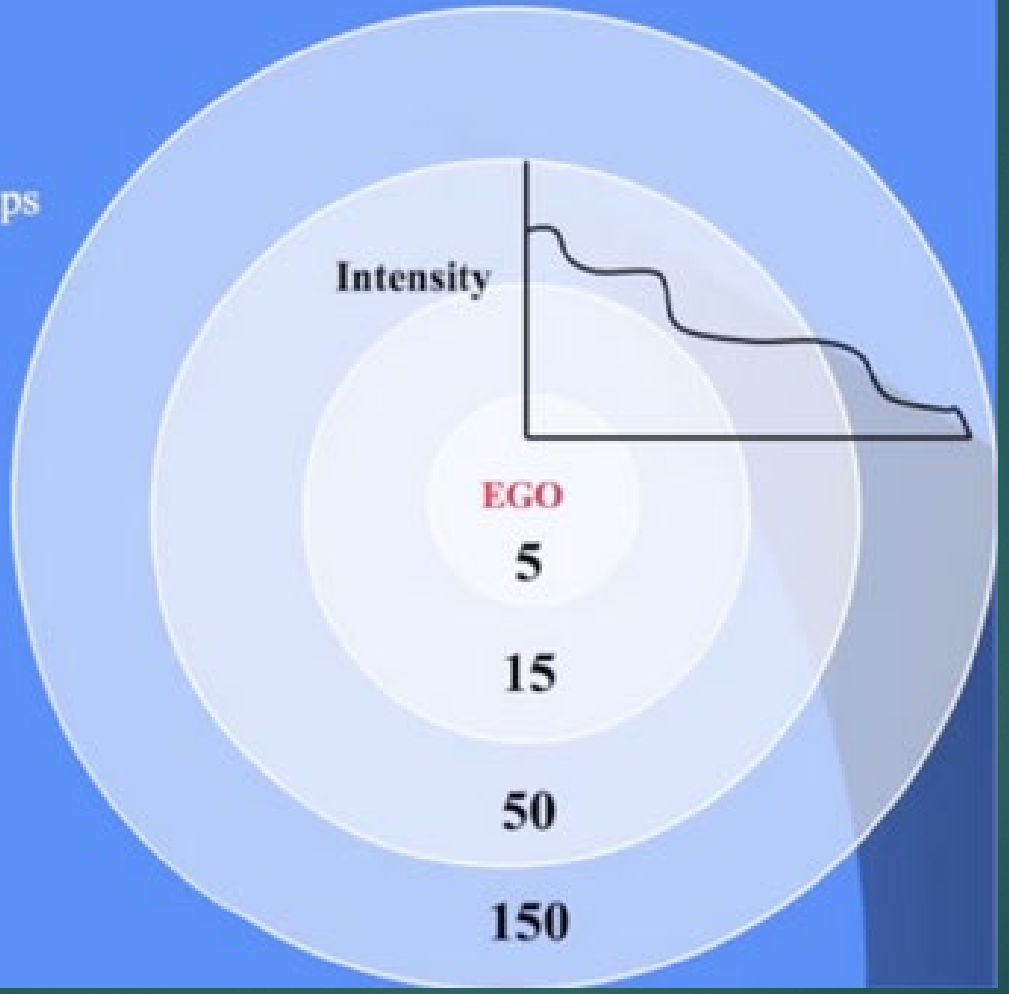
Meta-analysis of 148 studies of heart attack patients

= Social Network Quality

Not: smoking, activity, alcohol, BMI, drug Tx

The Expanding Circles

- Your social world consists of scaled layers of relationships …with 150 as a core number …but extending beyond to 500, 1500, and 5300 (according to Plato, 350BC)…..

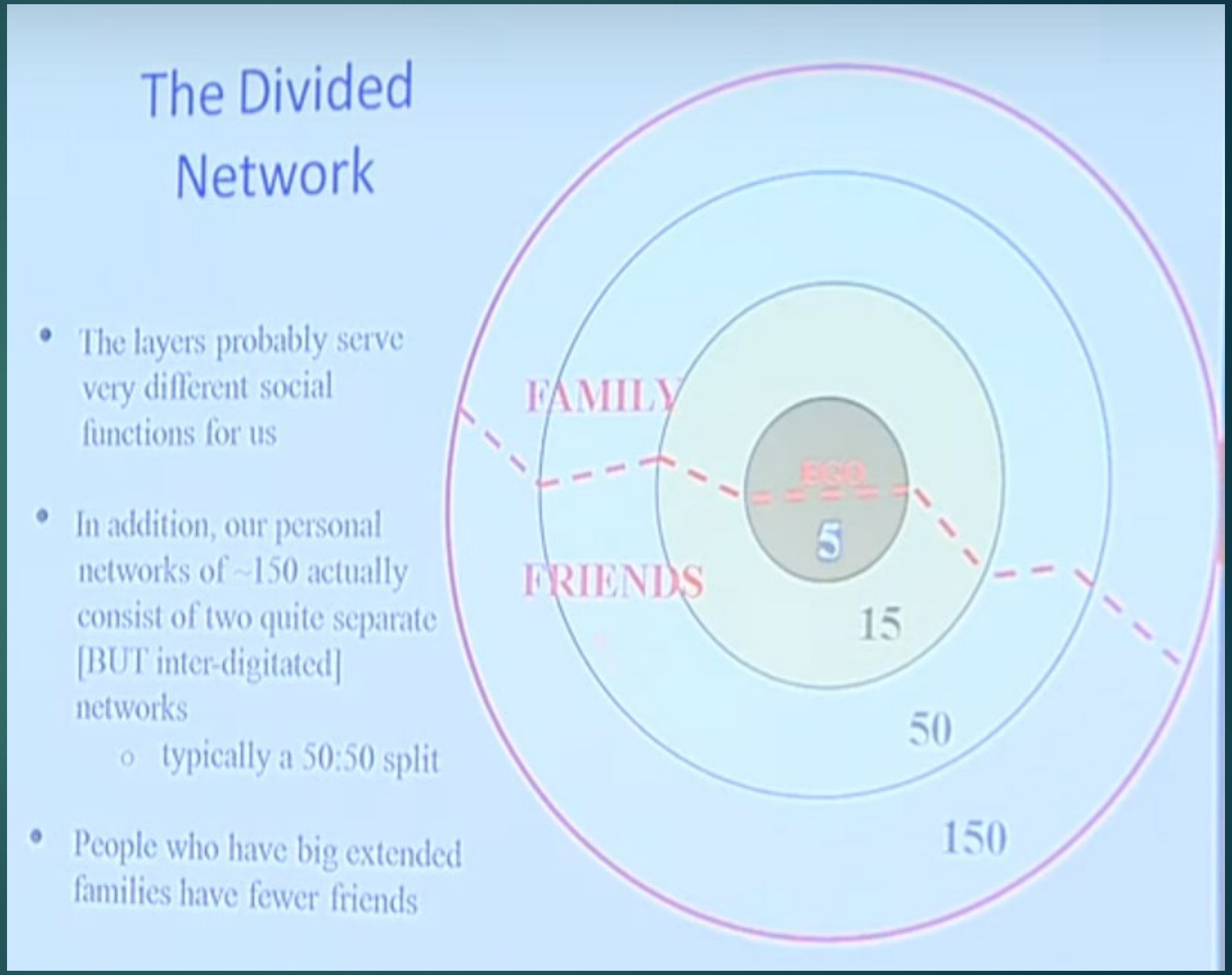


- Closest 5 people = 40% of actual contact time; highest rating of emotional closeness
- Next 15 people= 60 %
- of time
- Less altruism outside of 150

Based on contact data, etc.

Of 150:

- 50% are family,
- 50% are friends
- Those from larger families have fewer friends
- Average emotional closeness is higher for family than friends
- Women high in neuroticism have fewer close female family



Facebook

- Researchers found the average Facebook user:

- Has **155** friends on the platform
- Only consider **4-3** contacts to be genuine friends
- Would only trust 4 of their Facebook friends in a crisis

Human Social Groups with mean sizes of 100-200

- Hunter-Gatherer communities 148
- Xmas card networks 154
- Neolithic villages 6500 BC 150-200
- Modem armies (company) 180
- Hutterite communities 107
- ‘Nebraska’ Amish parishes 113
- Business organization <200
- ideal church congregations <200
- Doomsday Book villages 150
- 18th century English villages 160
- GoreTex Inc’s company structure 150
- Research sub-disciplines 100-200
- Small world experiments 134

Pair bonded monogamy

- Large relative brain size is associated explicitly with pair bonded (i.e., social) monogamy
- Monogamous pairbonding (and especially lifelong pairbonding) is particularly strongly associated with large brain size across three major mammalian orders (primates, carnivores, and ungulates) likewise emphasizes the importance of social complexity
- Total brain size correlates with the level of parental investment (as indexed, for example, by the duration of pregnancy and lactation).
- Neocortex volume correlates best with the period between weaning and puberty (i.e., the main period of socialization before the animal finally joins the adult world).

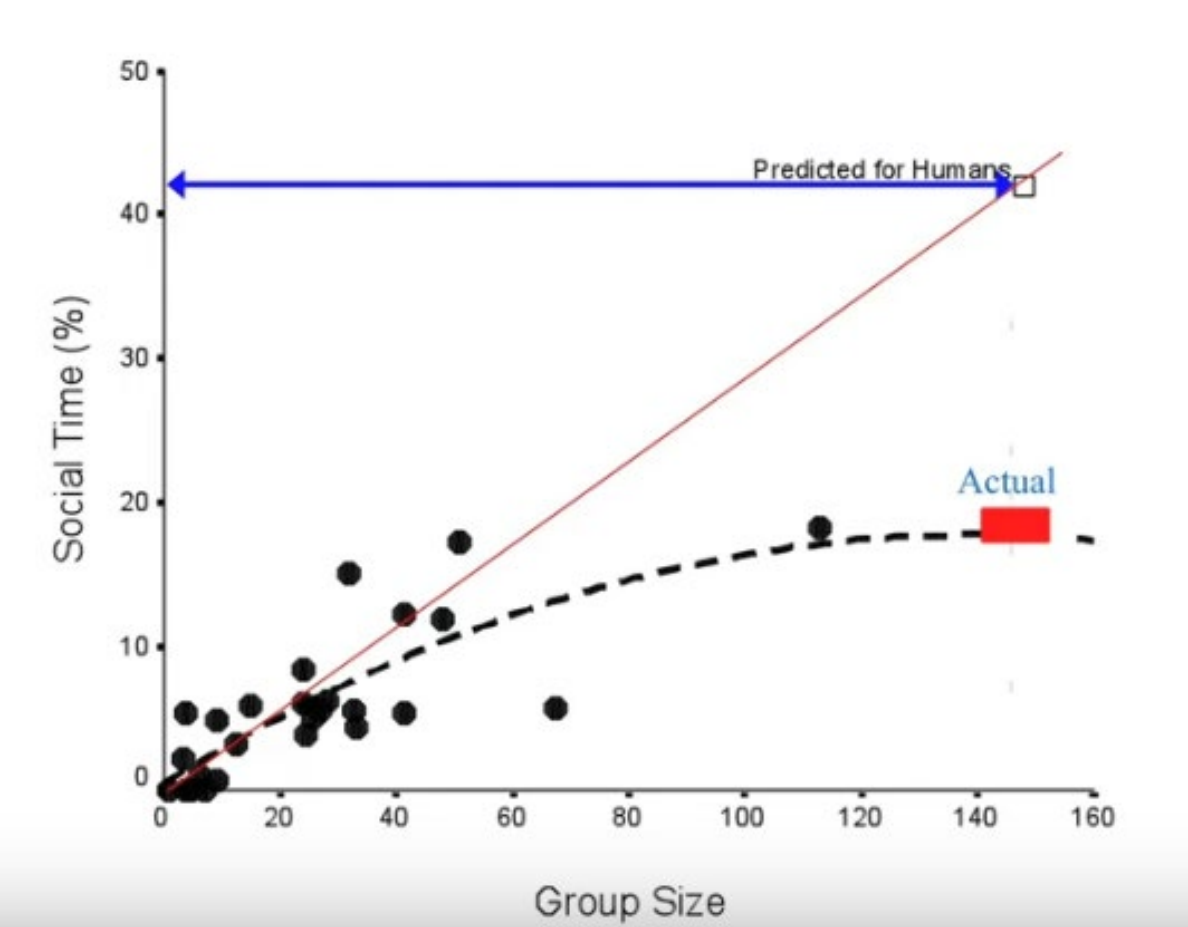
Pair bonded monogamy

- This suggests that growing a big brain depends on how long the mother can afford to invest in direct parental care;

- But having a socially complex brain (and this really means a large neocortex) depends on the time you can afford to invest in socialization (in effect, the equivalent of the software programming of your social neural system).

- In primates, neocortex size also correlates with the proportion of all play that is social (as opposed to instrumental or solitary): most social play takes place during this main period of socialization between weaning and puberty.

Why time is important in social relationships.

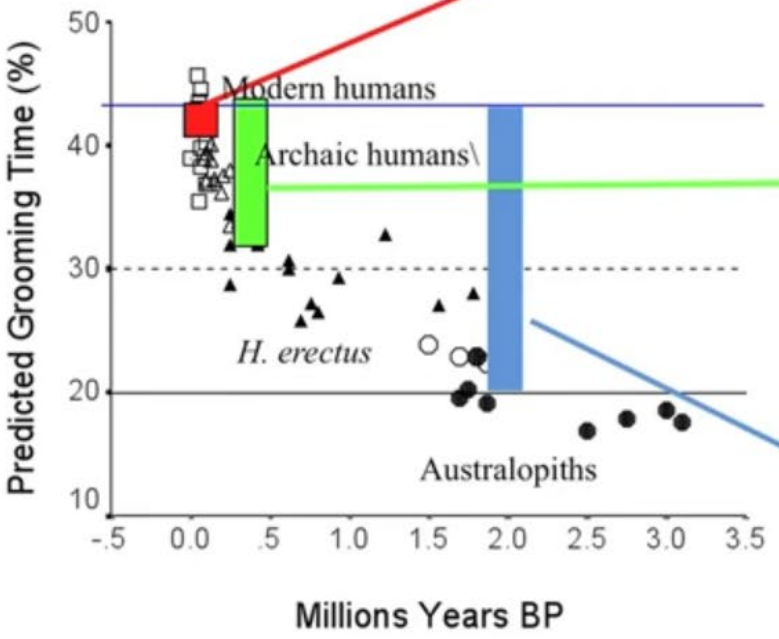


- Grooming is the bonding agent in primates
- Grooming time is determined by group size
- Social grooming time = 20% of day
- Humans would need 43% of their day; but actually do 20%
- Romantic relationship costs loss of another friendship in terms of time commitment

Language and social grooming

- Language may have arisen as a “cheap” means of social grooming
- Social grooming consists of bonding practices, reinforcing social structure, and sometimes reconciliation
- Without language, humans would have to spend nearly half of their time on social grooming

Three Ways We Solved the Problem



Religion and its rituals

Music and dance

Laughter
a cross-cultural trait
shared with chimpanzees

How Social Grooming Works

- Light tactile stroking triggers endorphins In the brain In primates
- Endorphins are relaxing
- They create a psycho-pharmacological environment for building trust
- Density of endorphin cells in OFC correlates with group size

Laughter is best medicine

- 4 is magic number for laughter: 30% more likely to laugh if in a group of 4 people than if alone
- Laughter is one of best triggers of endorphins
- Boosts immunity
- Lowers stress hormones
- Decreases pain; increases pain threshold
- Relaxes your muscles

How to Prevent friendships dying

- Study: change in emotional closeness over 9 months
- Depends on number of contacts among friends
- For women, amount of contact time determines emotional closeness
- For men, depends on number of activities done together.
- Ave. phone call for boys is 7.3 seconds; But activities together is high

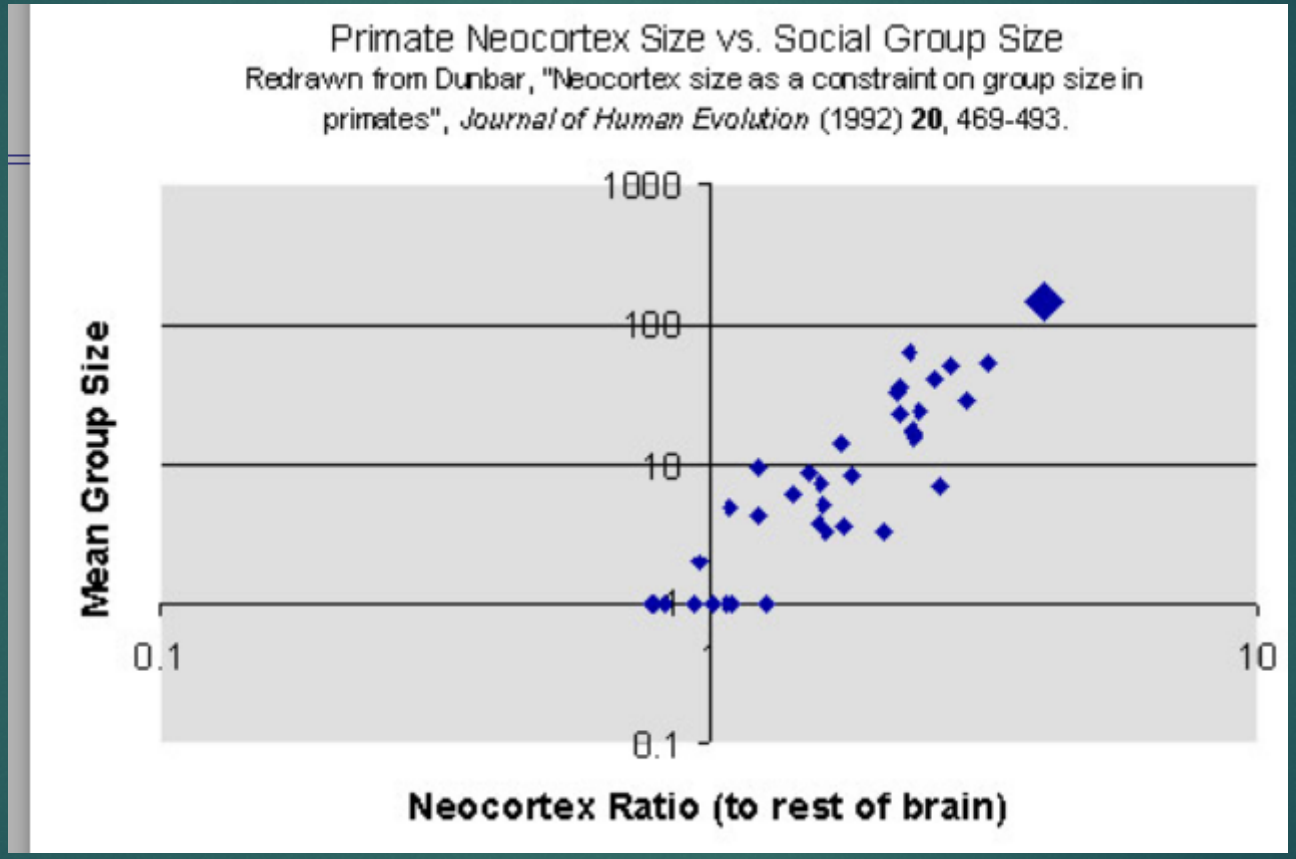
Social correlates of neocortical size:
emphasis on complexity not quantity

- Social group size
- Average group size of free-ranging primates
- Mean number of females
- Frequency of tactical deception
- Length of the juvenile period (intensive social learning period)
- Grooming clique size
- Proportion of play that is social
- Capacity to exploit subtle mating strategies

R. Dunbar, 1998, 2011

Neocortex size limits group size:

Your brain can just deal with about 150 meaningful relationships.



Dunbar's number (150) represents largest number of people with whom they can maintain a social relationship (who each person is & how each person is related)

Group size vs. brain size: chicken or egg?

- Is it the social network that causes the increase in neocortical size or does brain size allow social networks to expand?
- 2011 experiment by Sallet: housing monkeys in different sized groups
- Randomly assigned 34 rhesus macaques to separate social groups ranging in size from 1 to 7 monkeys
- Brain MRI scans of 23 before they were placed into their various groups and again after more than a year had passed.

J. Sallet, *Science*, 2011

Social network size produces GM increases

- Your brain size depends on what it practices:
- A linear relationship between the size of a monkey's social network and an increase of neocortical gray matter
  - Specifically in social cognition regions (mid-STS & IT, right PFC, Amg).

- 3-8% increase for each additional member of their social network.

- Average increase of 20% in the most socially complex group compared to monkeys housed individually.

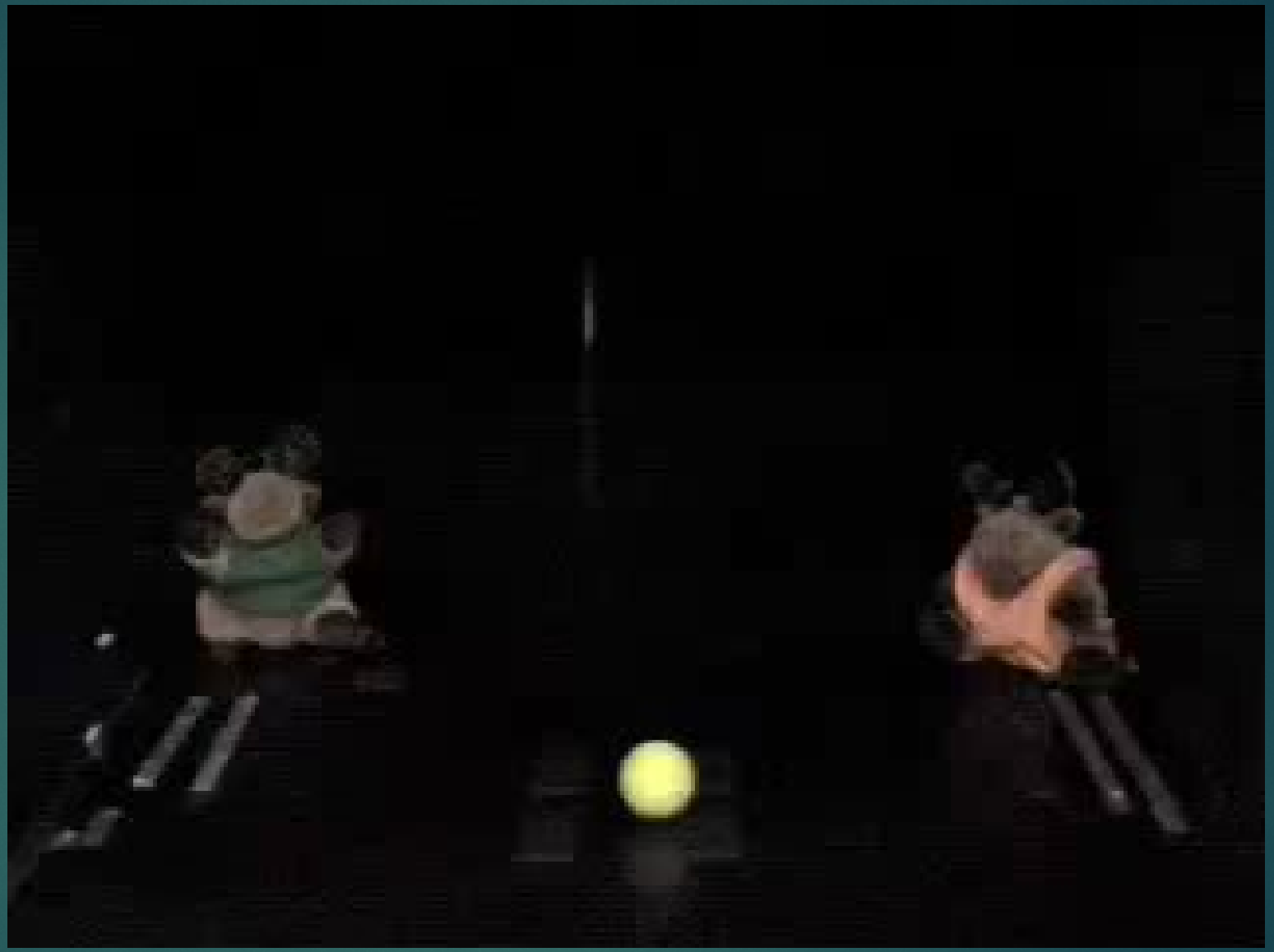
Babies are social…

- Scientists already know that babies expect some social graces in other people:
  - They expect people in a conversation to look at each other
  - talk to other people, not objects
  - are eager to see good guys rewarded and bad guys punished
  - that they want to interact with nice people
  - before they have any friends themselves, young babies are already making predictions about how people get along: babies are also attuned to other people's relationships, even when those relationships have nothing to do with them.

Just Babies: The Origins of Good and Evil (2013) by Paul Bloom.

- Testing the theory that we have an innate moral sense, Bloom provides experimental evidence that we are born with:
  - a moral sense—some capacity to distinguish between kind and cruel actions;
  - empathy and compassion—suffering at the pain of others and the wish to make this pain go away;
  - a rudimentary sense of fairness—a tendency to favor equal divisions of resources;
  - a rudimentary sense of justice—a desire to see good actions rewarded and bad actions punished.

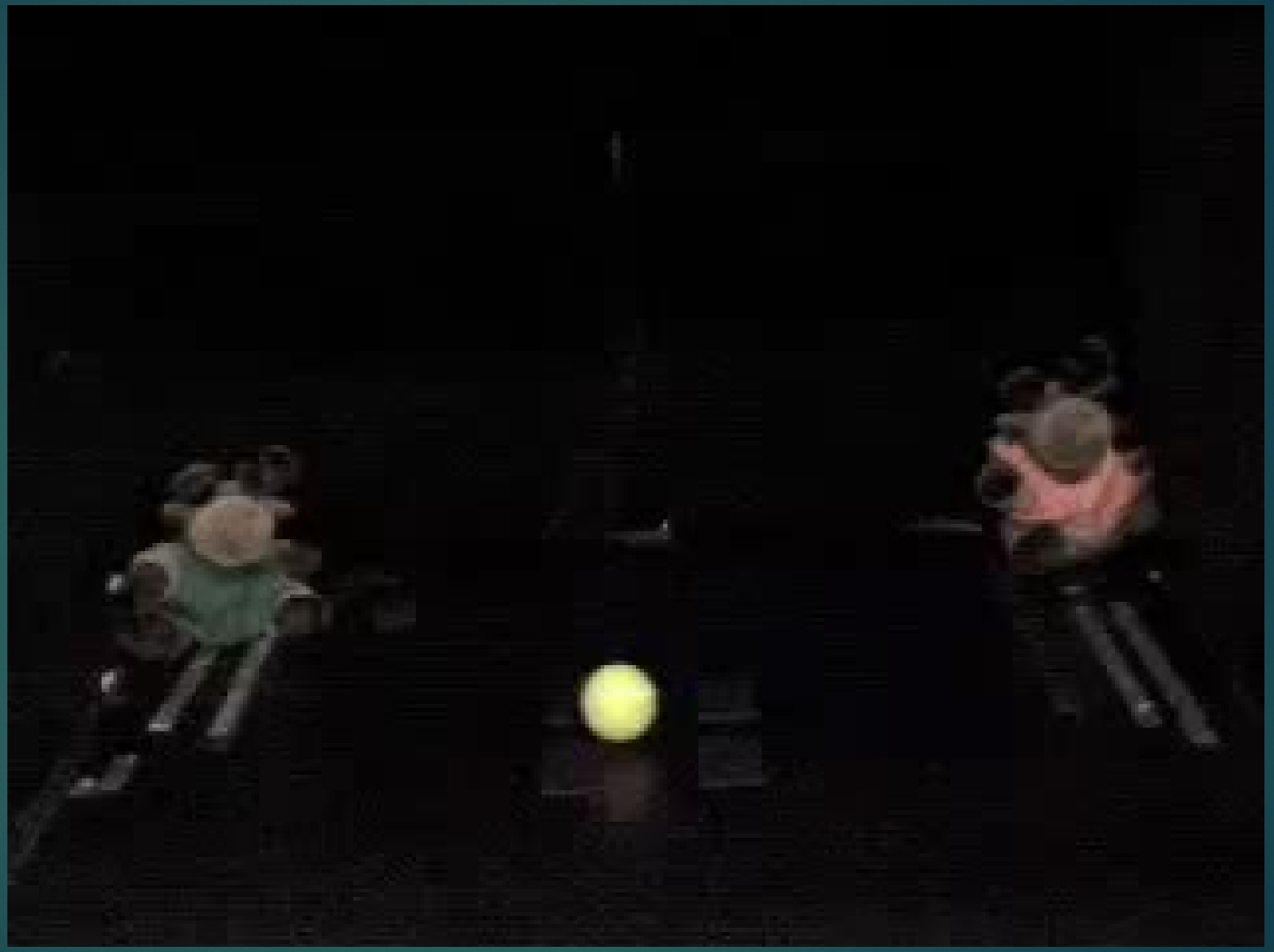
Giving



Notice colors of friendly Moose’s shirts

Hamlin, J.K., & Wynn, K. (2011).

Taking

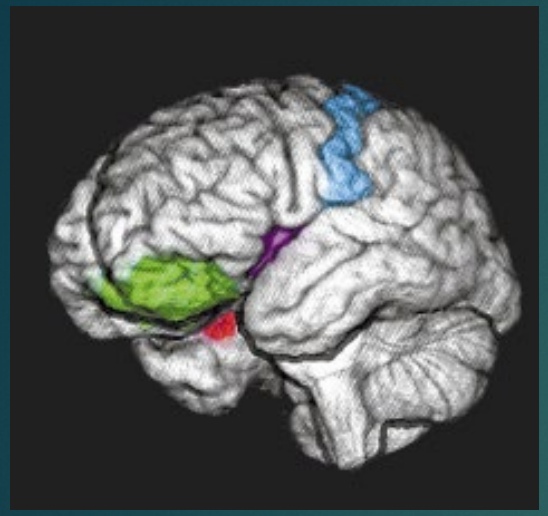


Bloom

- Time and again, the moral sense of right (preferring helping puppets) and wrong (rejecting hurting puppets) emerges in people between three and 10 months of age, far too early to attribute to learning and culture.
- The baby was next given a choice between taking a treat away from the “nice” puppet or the “naughty” one.
- As Bloom predicted, the infant removed the treat from the naughty puppet—which is what most babies do in this experiment.
- But for this little moralist, removing a positive reinforcement (the treat) was not enough. “The boy then leaned over and smacked this puppet on the head,”

- Start here CAS here

The social brain: the usual anatomical suspects



Bottom line:
It's a fronto-temporal world

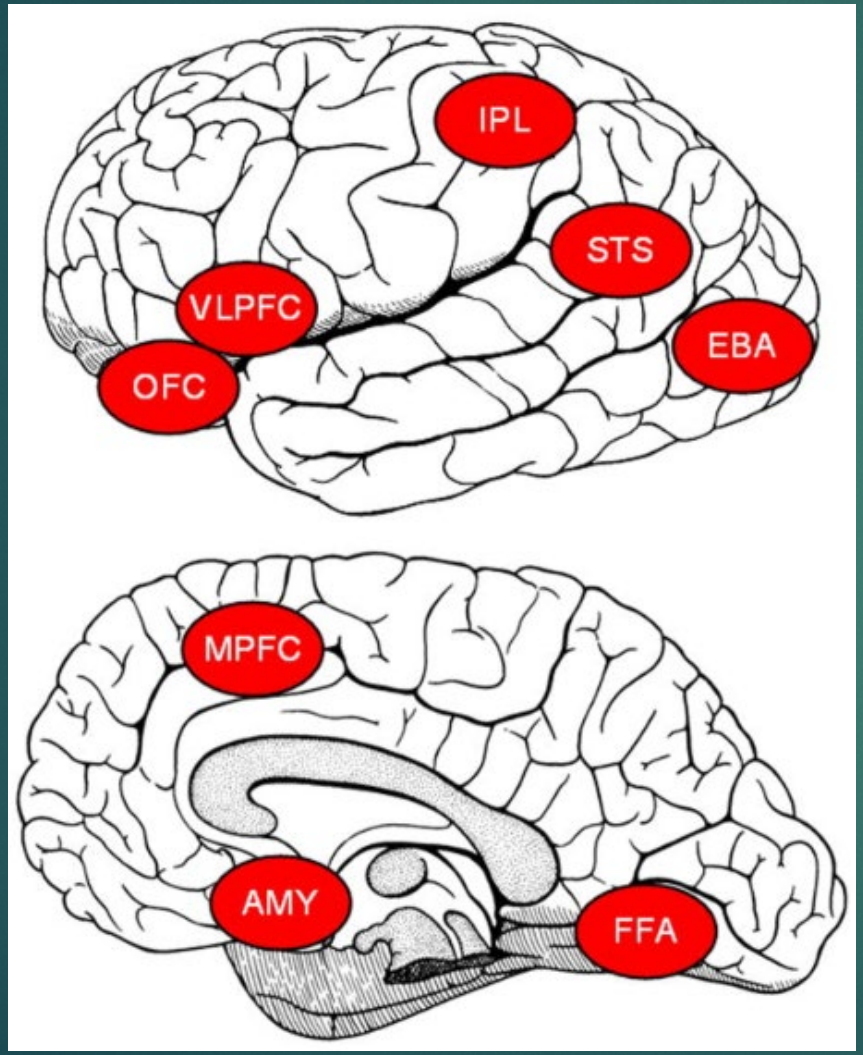
- Ventromedial prefrontal cortex (green): social decision-making, planning, inhibition
- Amygdala (red): fear conditioning, processing emotionally-relevant stimuli including social stimuli; social "judgments"; approach/avoid "decisions"
- Right somatosensory cortex (blue): decoding complex emotional expressions via "simulation", empathy
- Insula (purple): processing bodily signals, self-regulation;
- Fusiform face area (green): face processing

- Fusiform face area: inferotemporal cortex (facial identity, emotional expression, social status)
- Visual cells in temporal cortex responsive to gaze direction and face view
- Amygdala involved in judgments of faces as trustworthy or not

The social brain: the usual anatomical suspects

- Cingulate (yellow): error monitoring, reward, autonomic responses
- Mirror neurons: imitation, simulation, empathy
- Plus: Visual association cortices, hypothalamus, thalamus, brainstem
- Generate or represent somatic states that correspond to anticipated future outcomes of decisions (somatic marker hypothesis)

Social Cognition:
Brain nodes in social brain



Some of the brain regions involved in various aspects of social cognition and social perception.
VLPFC = ventral lateral prefrontal cortex,
OFC = orbital frontal cortex,
IPL = inferior parietal lobule,
STS = superior temporal sulcus,
MPFC = medial prefrontal cortex,
EBA = extrastriate body area,
AMY = amygdala,
FFA = fusiform face area.

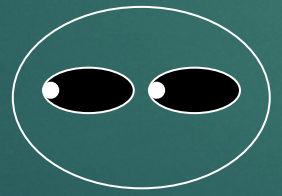
K. Pelphrey & E. Carter, 2008

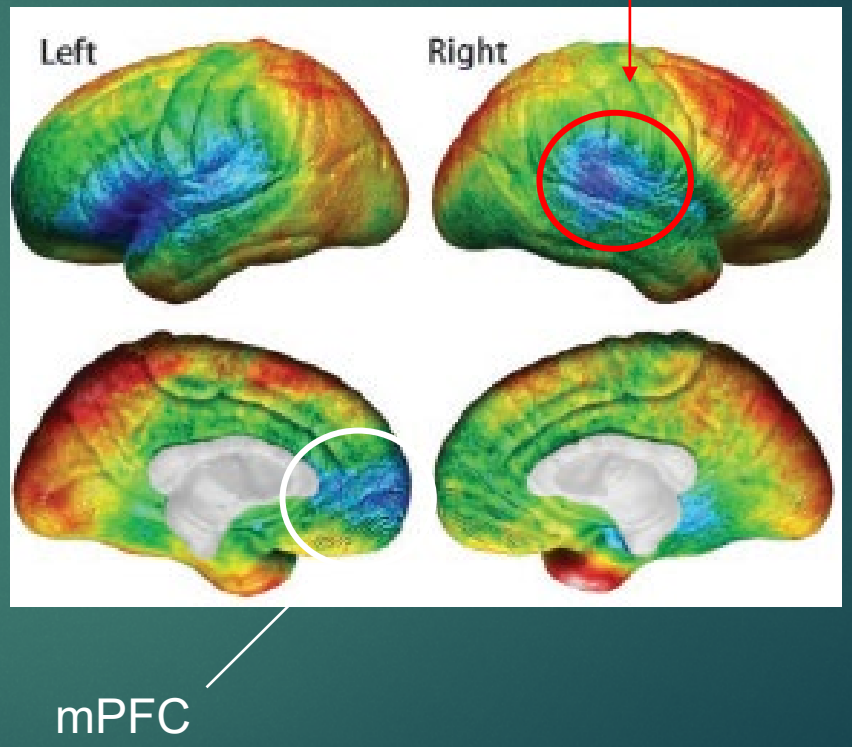
Amygdala and threat detection

- Monkeys with amygdala damage are severely impaired in their social behavior
- Response to stimuli that signal danger or threat.
  - Recognition of emotions from facial expressions, especially certain negatively valenced emotions such as fear.
  - Subjects with bilateral damage to the amygdala judge people to look more trustworthy and more approachable than normal subjects do
- A role in processing the direction of gaze of others.
- The amygdala appears most critical for recognition, rather than for expression

The social brain: Anatomy

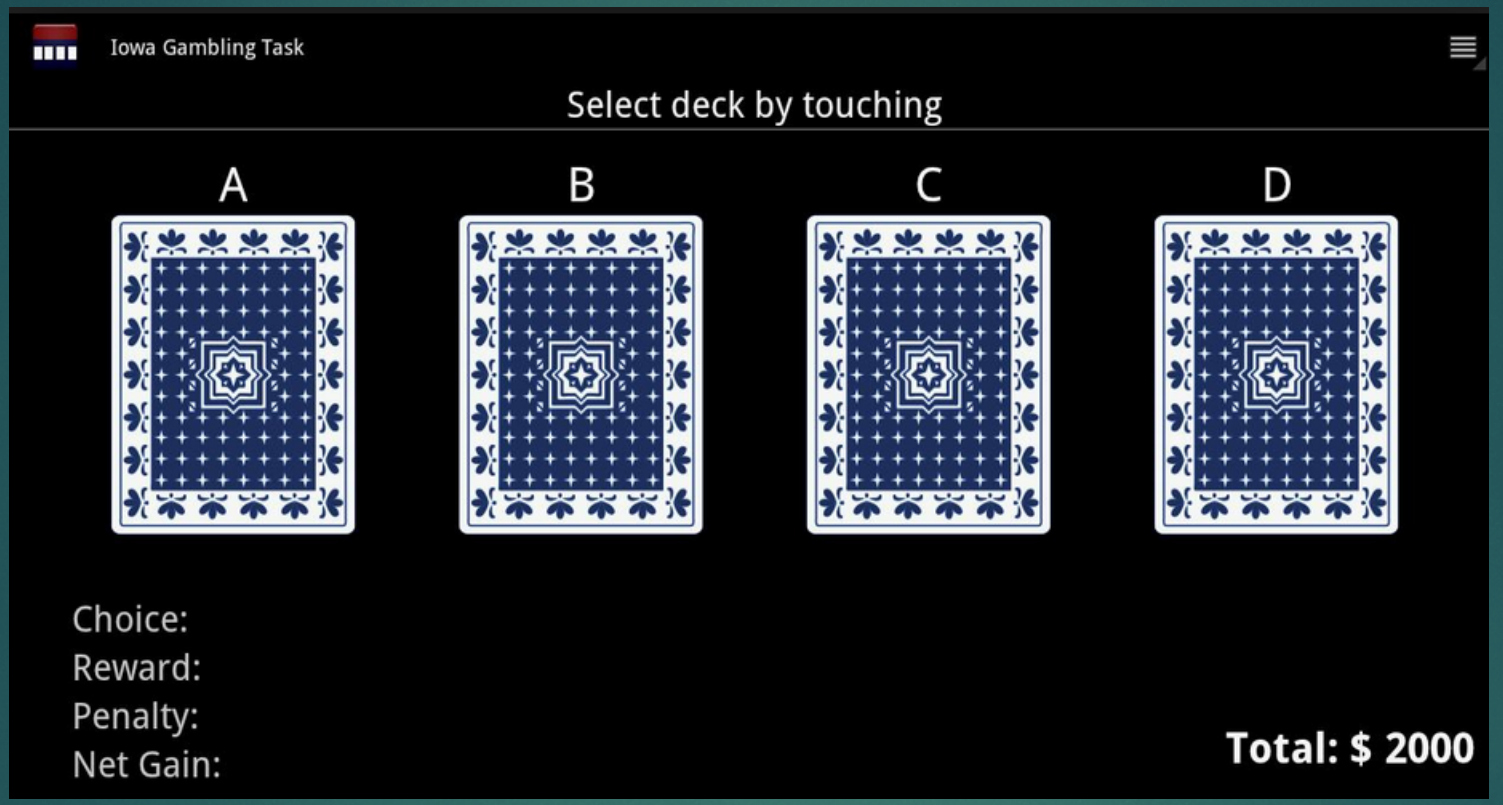
- pSTS/TPJ
  - Social prediction and perspective-taking
    - E.g. Eye gaze – what can they see? What do they want?





Pelphrey et al., 2004a,b; Kawawaki et al., 2006 (review); Mitchell 2007

Iowa Gambling Task: 2 decks lose consistently



Normals stop using bad decks quickly;
vmPFC damaged never learn negative consequence

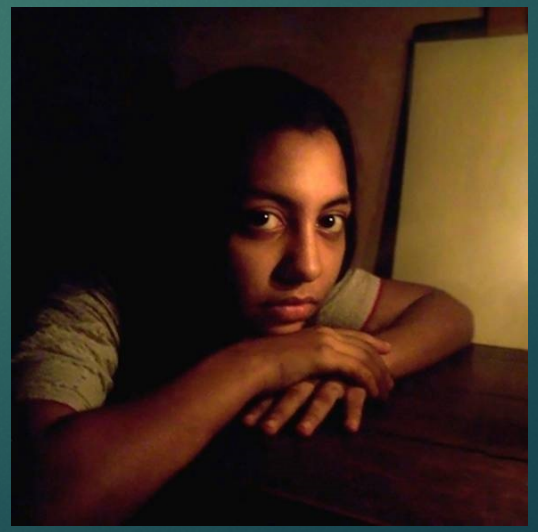
What is a neuronal commonality in social animals with large brains?

Elephants

Smithsonian.com

Cetaceans: Whales & Dolphins

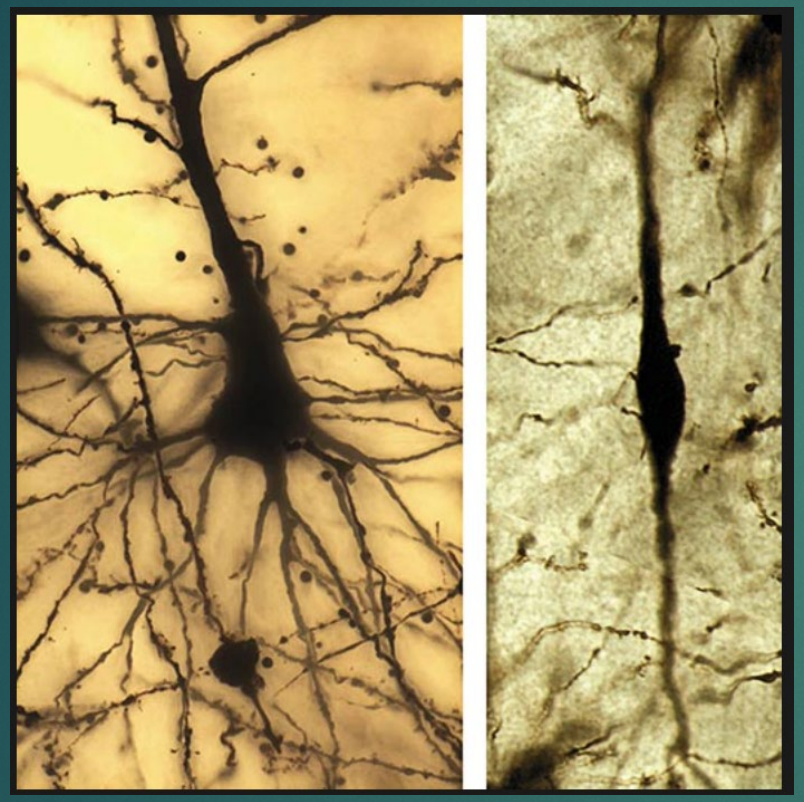
Primates



Von Economo Neurons (VENs)

- These are the 3 species with the largest brains on the planet.
- They are also the most social species.
- They also have the most Von Economo Neurons (VENs).
- P. Hof: "They [VENS] are like the express trains' of the nervous system" that bypass unnecessary connections, enabling us to instantly process and act on emotional cues during complex social interactions.
-

Brain Cells for Socializing?



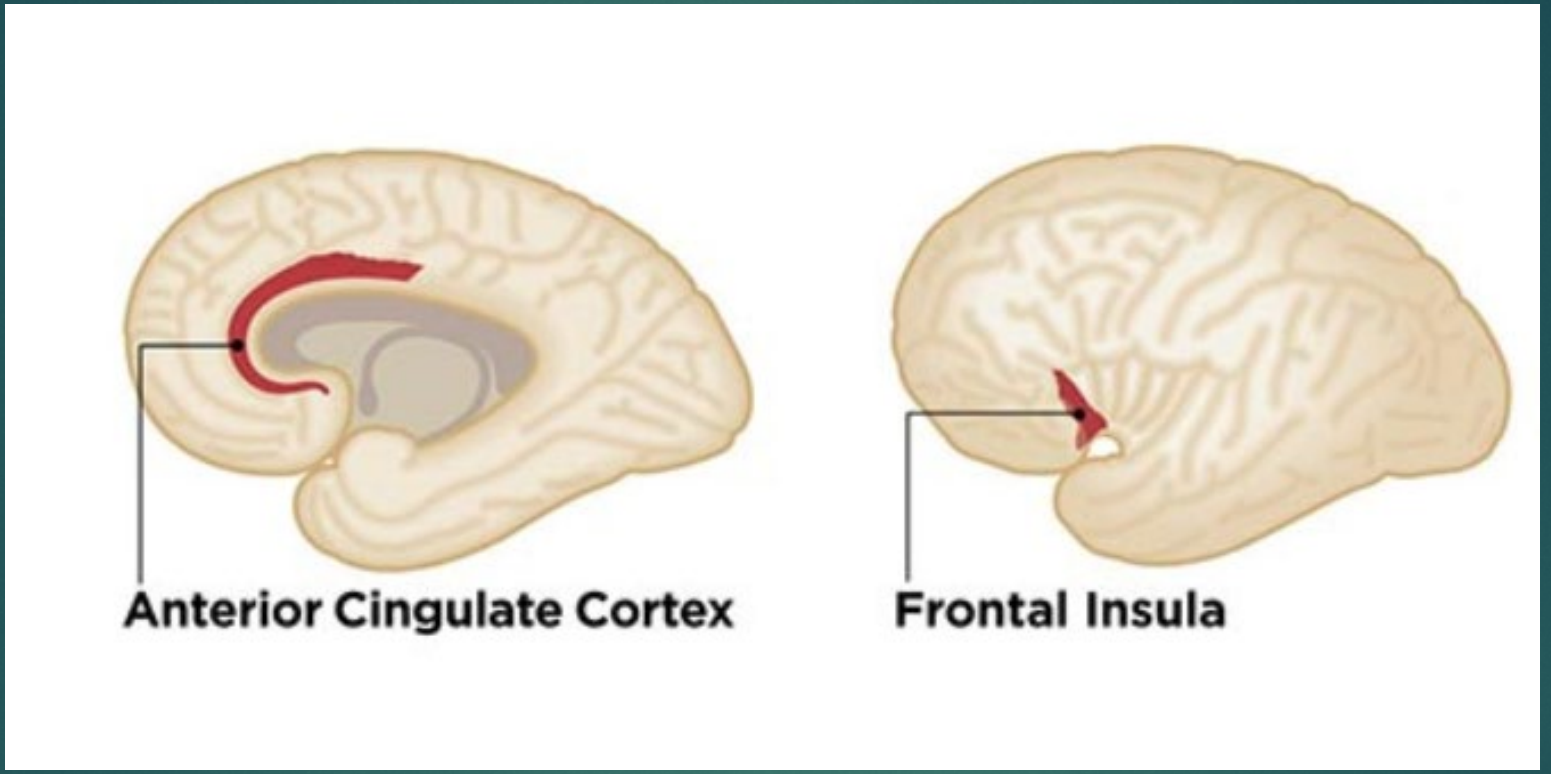
A focal concentration of VENs in ACC and FI distinguishes large-brained, highly social mammals from other mammalian species.

(Allman et al., 2010; Hakeem et al., 2009; Hof and Van der Gucht 2007; Nimchinsky et al., 1999; Rose 1928)

Von Economo Cells

- Fastest and largest neurons located primarily in the anterior cingulate and insula (layer Vb)
- Only 3 groups with significant VENs: primates/humans, certain cetacians, elephants; largest brains and most social species
- Evolved to speed information around a big brain for social analysis

Location of VENS: ACC & FI



The FI features the other layer 5 neuron, the fork cell, which is scarcely seen in ACC.

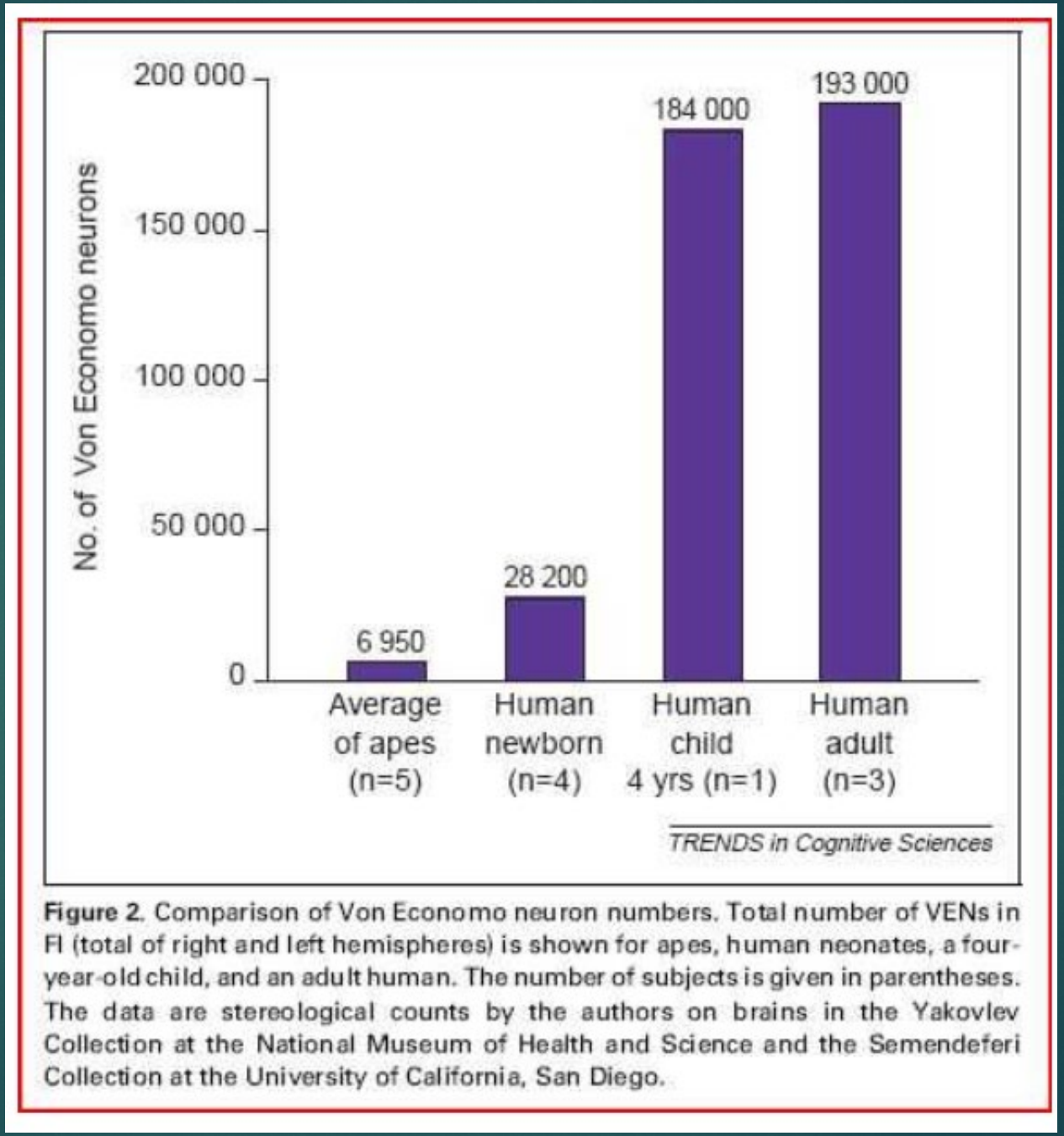
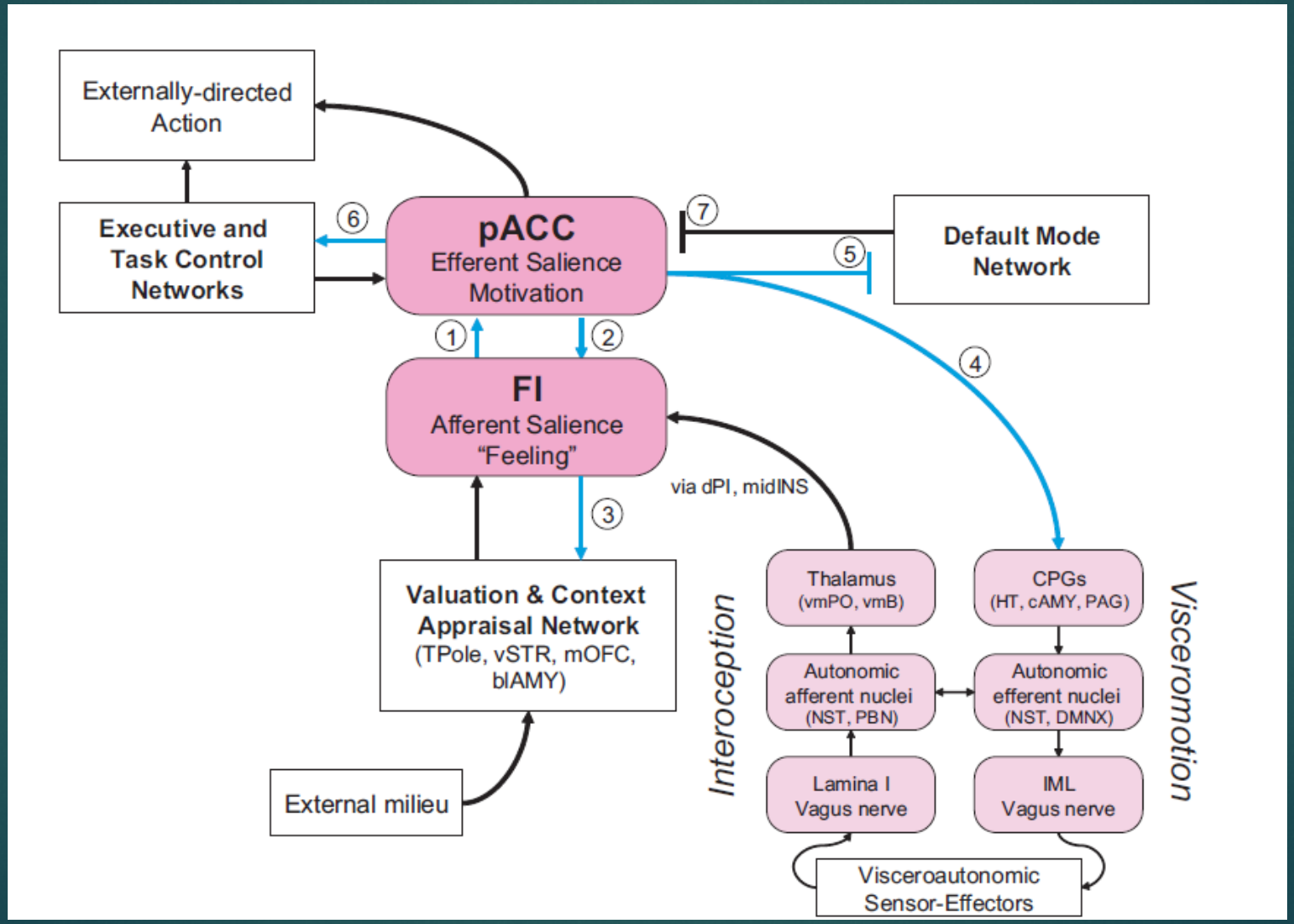


Figure 2. Comparison of Von Economo neuron numbers. Total number of VENs in FI (total of right and left hemispheres) is shown for apes, human neonates, a four-year-old child, and an adult human. The number of subjects is given in parentheses. The data are stereological counts by the authors on brains in the Yakovlev Collection at the National Museum of Health and Science and the Semendeferi Collection at the University of California, San Diego.

Social Salience Network Central:
pACC & FI, VENS: alertness to social cues



W. Seeley, et al., 2011

VENs: Involvement in neuropsychiatric disorders

- If you alter VENS, you produce deficits in social ability
- Frontal Temporal Dementia: destruction of Salience Network
  - 70% reduction VENs in ACC & FI; not in Alzheimer's
  - Correlates with social behavioral severity of bvFTD

Seeley, Allman, and others 2007; Seeley and others 2006; Kim, et al. 2011

.

FTD Social-Emotional Deficits

- Emotional empathy (empathic concern)
- Cognitive empathy (perspective taking)
- Interpersonal warmth
- Emotion recognition of faces (negative emotion↓)
- Emotion recognition of music
- Emotional moral judgment
- Prosocial sentiments (guilt, pity, embarrassment ↓)
- Other critical sentiments (anger, disgust ↓)
- Mutual gaze during dyadic interactions

Rankin et al., 2006, Eslinger et al, 2011; Omar et al., 2011, Sturm et al, 2006, 2008, 2011

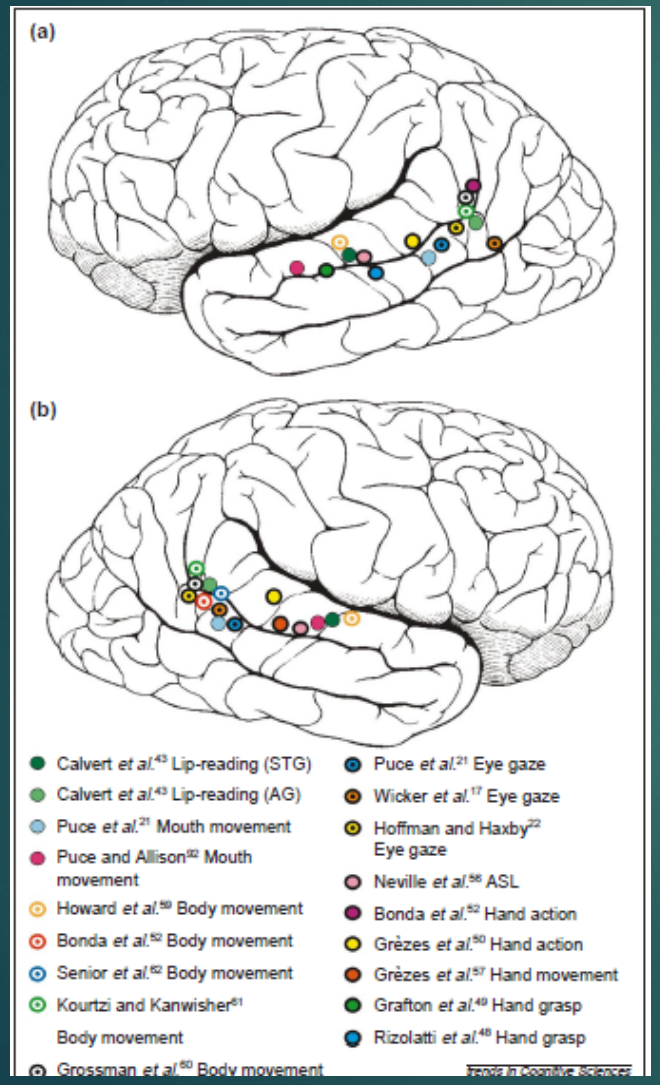
Eye Gaze:
One key to social interactions

Human & Dog Eye Gaze

- Preverbal infants: Must first talk to them, then turn your head and they will follow your gaze
- Dogs too: Vocally address them “Hi dog”, then look them in eye; then they will follow your gaze
- Dogs: left gaze bias only for human faces; right side of the human face is better at expressing emotional state.
- Dog's gaze at its owner increases owner's urinary oxytocin during social interaction

E. Téglás, et al., 2012; Nagasawa, et al., 2008

STS: Superior Temporal Sulcus – biological movement perception



Activated:

- Lip reading
- Mouth movement
- Body movement
- Eye gaze
- ASL
- Hand movement
- Hand grasp

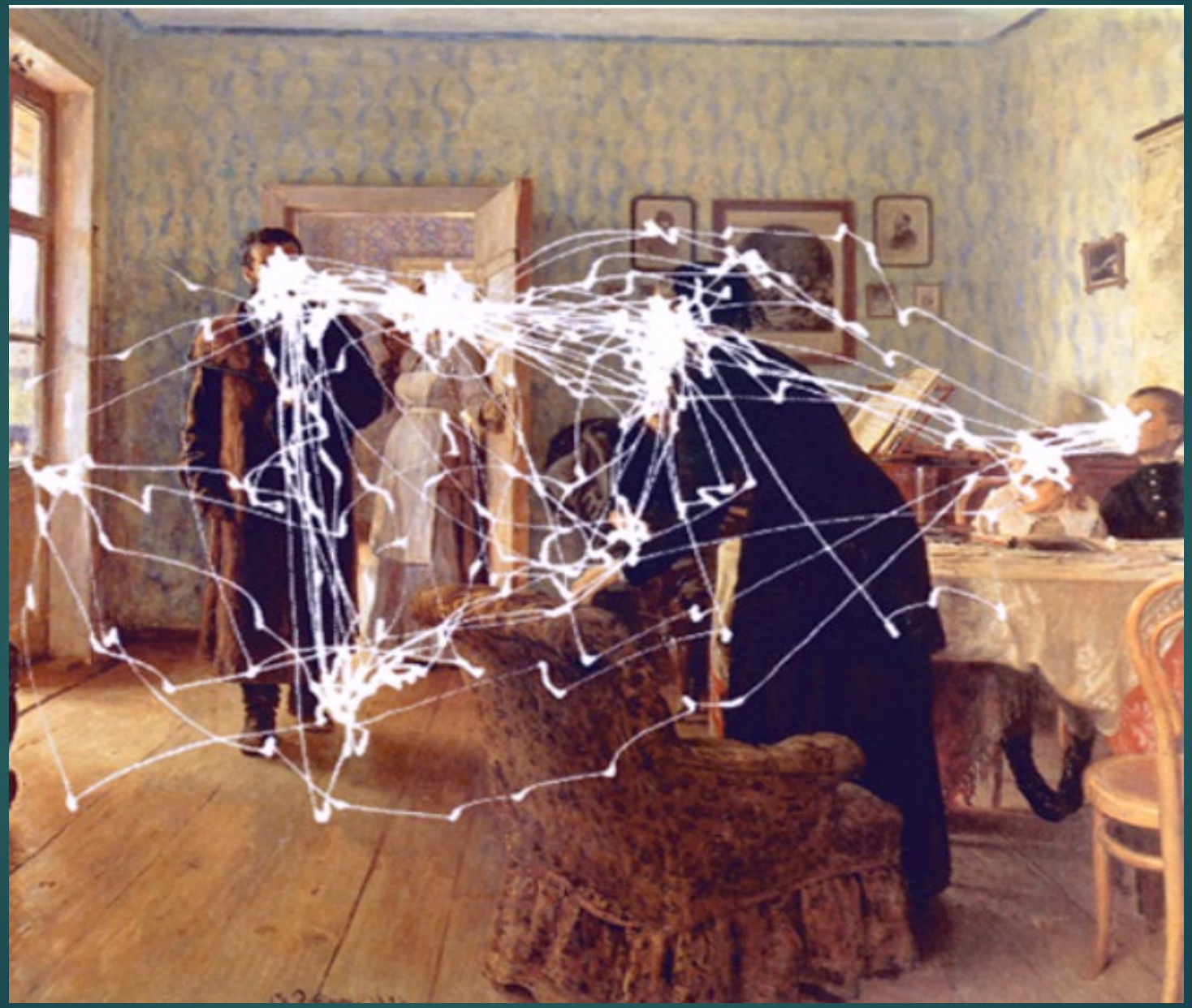
T. Allison, et al., 2000

STS: Grasping the Intentions of Others

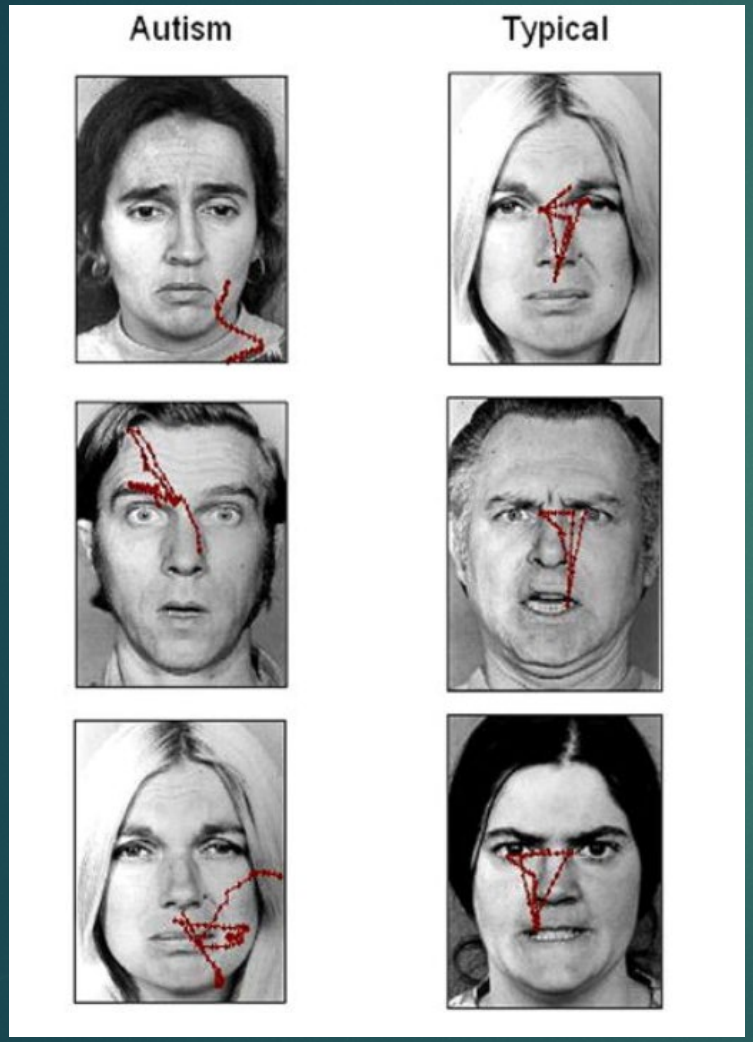
- The posterior STS region:
  - biological motion & intentionality of an action
  - goals of others via gaze shifting or reaching-to-grasp

- In autism, dysfunction in the right STS is strongly and specifically correlated with the level of social impairment exhibited.

Social eye tracking



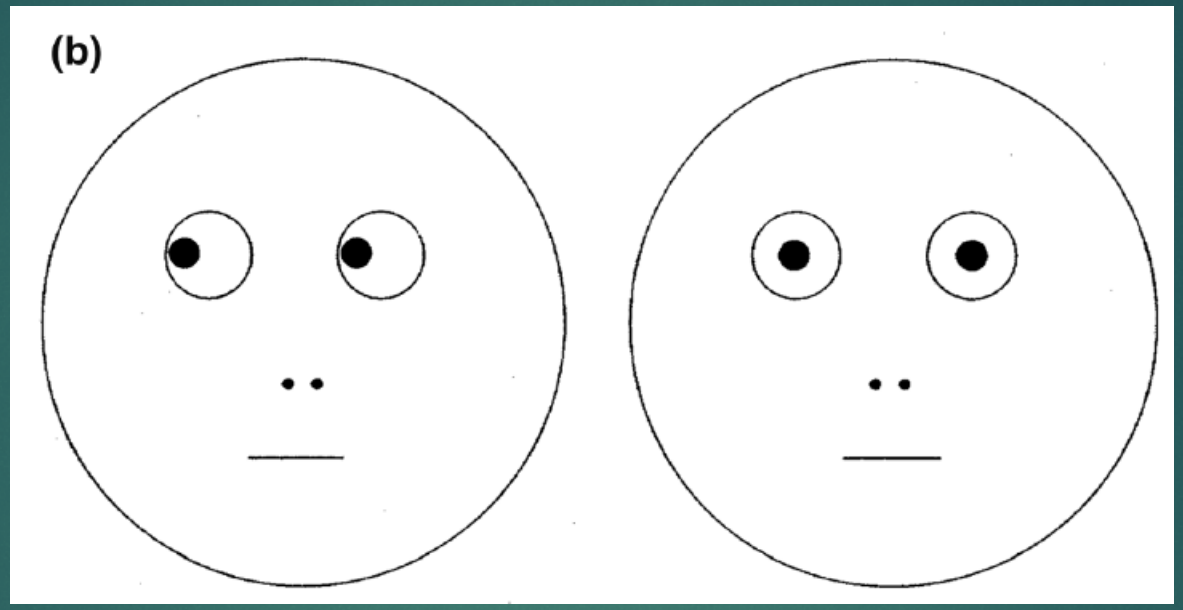
Autism: Deficit in social eye tracking



- Neurotypicals (us): focus on the eyes, nose and mouth
- Individuals with autism do not look at the eyes; more on mouth
- Using gaze information to infer mental states and intentions is consistently impaired even in high-functioning adults with autism

Pelphrey et al. (2002).

Autism:
Able to perceive the direction of gaze



- When asked ‘which one is looking at you?’, autistic children score as well as normal children.

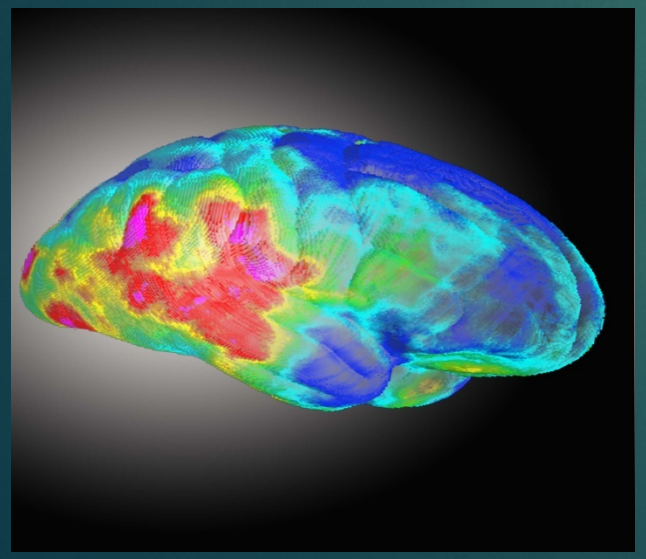
Autism: Can do gaze following, but not it's meaning

When asked which candy 'Charlie' prefers, most normal children point to the Polo Mints, but autistic children are less likely to do so.

Social Deficits in Autism

- Right STS & rTPJ deficits correlate with behavioral severity
- Lack social meaning of eye gaze tracking
- Developmental difficulties with VENs
- Structural deficits in ACC & FI (Social Salience network)
- MNS delayed
- Lack of ToM

William's Syndrome: Social ++



- Neurodevelopmental disorder
- Mental retardation coupled with:
- Excessive sociality: Unusually cheerful demeanor and ease with strangers
- Severe VS deficits

Williams Syndrome: No Social Fear

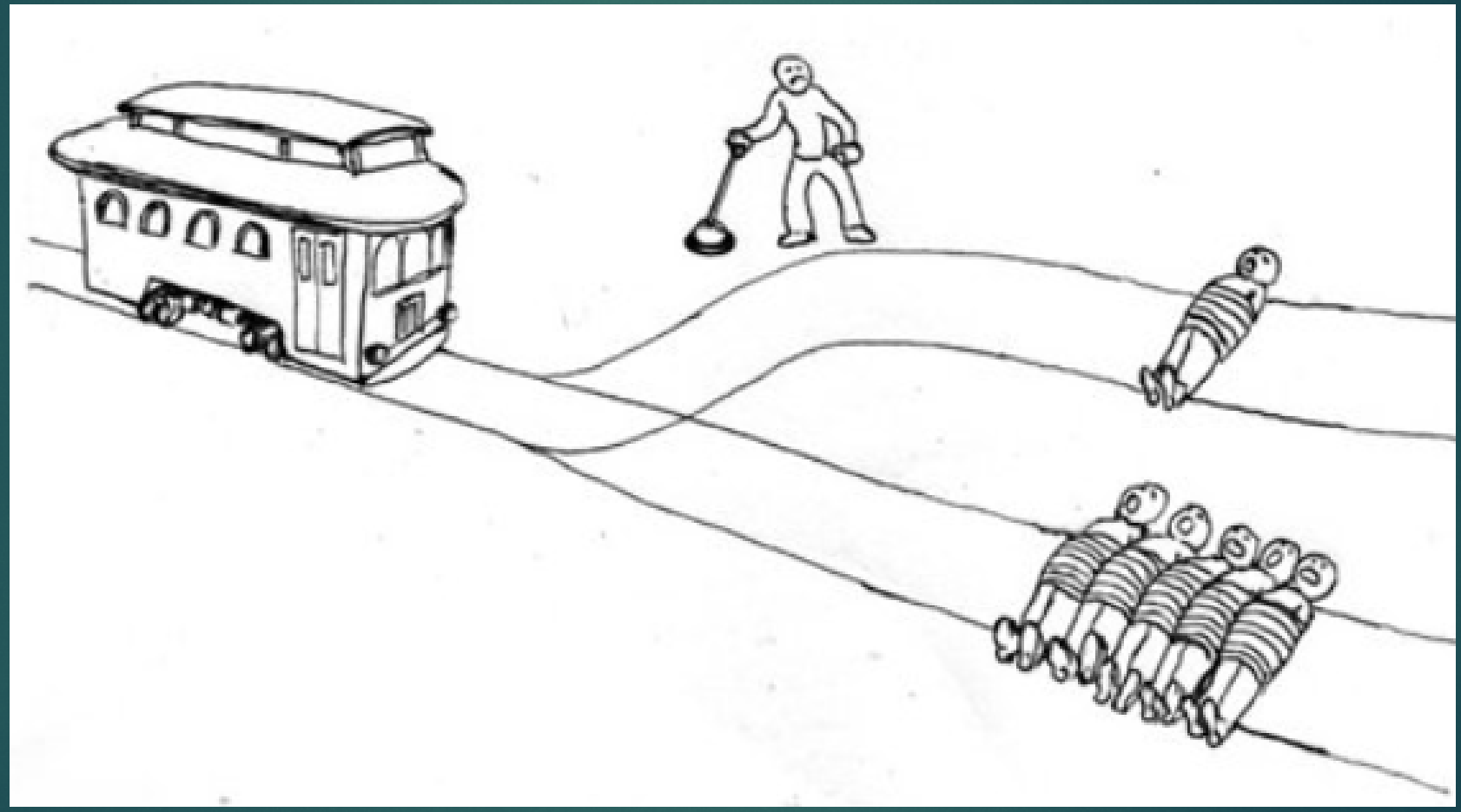
- Gregarious, Increased empathy, no social fear
- Positive interpersonal facial perceptual bias
- Inability to detect social danger
- Reduced Amygdala activation to social danger cues (faces)
- Increased activation in the Mirror Neuron System (Inf PFC, bilateral IPL, and right STS)

(Hoeft et al, 2007);

Damage to OFC:
Alters interpersonal behavior

- Abnormal social behavior and violations of social norms
- Cannot see how behavior might be viewed negatively by others & be socially punished
- Bilateral damage: impaired identification of self conscious emotions (no embarrassment, shame)
- Unilateral right damage: impaired recognition of anger & disgust

Trolley Problem 1: DL PFC is normal



9 of 10 people confronted with this scenario say it's O.K. to hit the switch.

Trolley Problem 2: vmPFC is damaged

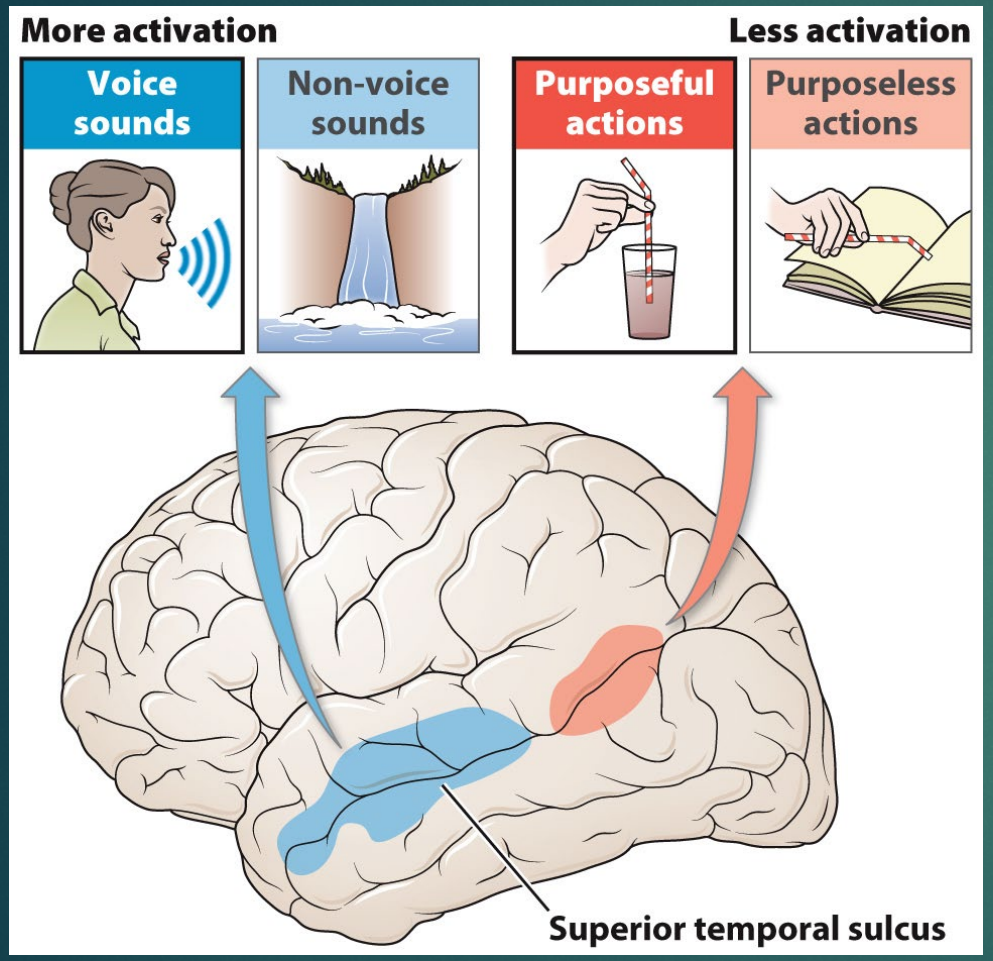
9 of 10 people say it's not O.K. to kill one person to save five;
Individuals with vmPFC damage 3x more likely to push the person off.

vmPFC Damage

- VMPFC damage: strongest predictor of empathic deficits
- 3 x more likely to advocate throwing a person to certain death in front of a runaway train to keep it from killing five other people.
- 5 x more likely to advocate smothering one's baby to save others

Damasio, 2007; Amitai Shenhav and Joshua D. Greene, 2010

Social Signals and the Superior Temporal Sulcus



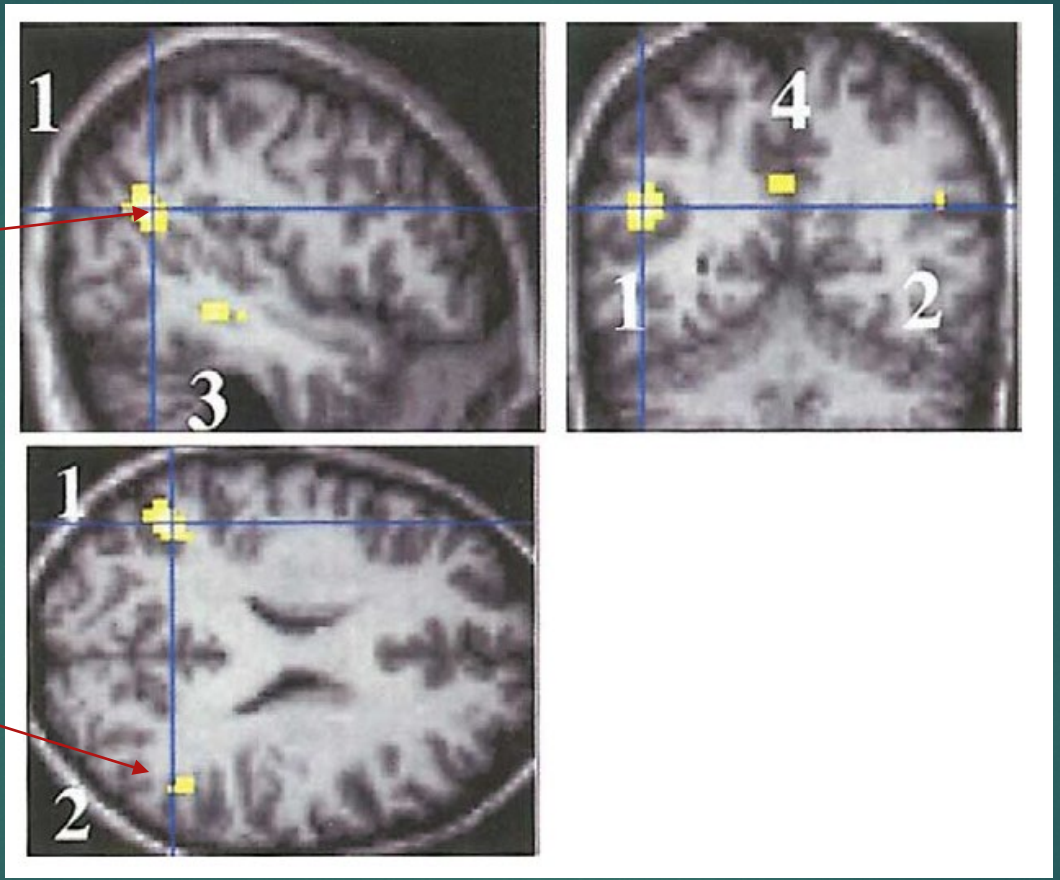
Intentionality is represented in the superior temporal sulcus.

Areas in the superior temporal sulcus activate more for voice than for nonvoice sounds, and more for witnessing purposeful rather than purposeless actions.

rTPJ: Source of Reading Thoughts, Theory of Mind, Intention

left TPJ
verbal

rTPJ
pictures



Reading stories that describe or imply a character's goals and beliefs

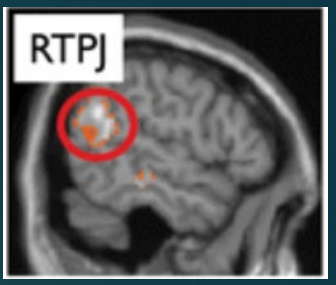
Theory of mind vs. mechanical inference stories. Crosshair marks the most significant voxel in the left TPJ (1). Also visible are activations in right TPJ (2), left aSTS (3), and precuneus (4). TPJ, temporo-parietal junction; aSTS, anterior superior temporal sulcus.

Saxe & Kanwisher, 2003

TPJ: Mind reading of intention

- Right Superior temporal sulcus (STS):
  - active when people try to understand the minds of other people, as well as when people redirect their attention.
  - ability to follow people's gaze and determine where another's attention is directed; movement intention from visual context
- If TPJ damaged: poor ability to interpret other people's actions and emotions, and ability to judge intention of another

rTPJ: Judge and jury



- rTPJ is critical for representing mental state information, irrespective of whether it is about oneself or others.
  - As RTPJ activates, so does the influence of more lenient belief information on moral judgment

- Higher the activation: take intention into account; less blame/more forgiveness if believe harm was accidental (see it from their perspective)

- Lower the activation: less able to take intent into account; reduces the influence of belief information on moral judgments

L.Young and R. Saxe, 2007, L. Young, et al., 2009

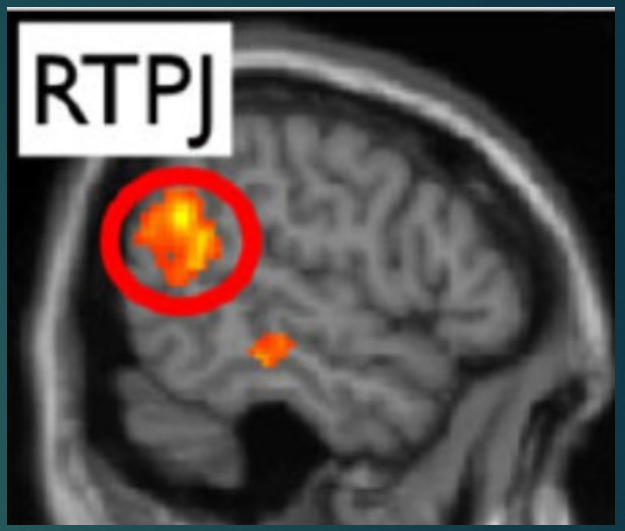
RTPJ: how to blame for behavior: integrating intent with harm.

- rTPJ: codes for intention
  - In normals,
  - rTPJ assess intentionality and
  - amygdala assesses harm
  - calculation of blame based on these two,
  - using intent as main driver and harm only as tiebreaker.

- Normals – intent based judgments: we blame intentional killing most, attempted killing next, accidental killing least

- rTPJ impaired – harm based: using intention to break the ties: blame intentional killing most, accidental killing next, attempted killing least

RTPJ:
It's the thought/intent that counts



- Evil twin tries to poison twin brother but fails
- In judging people, usually bad intention more important than the outcome: people call foul if act is intentional

- Premeditation: When rTPJ was turned off, rely on outcome & less on the actor's intentions; judge attempted harms as less morally forbidden and more morally permissible; Moral judgments shift toward a "if no harm, no foul"

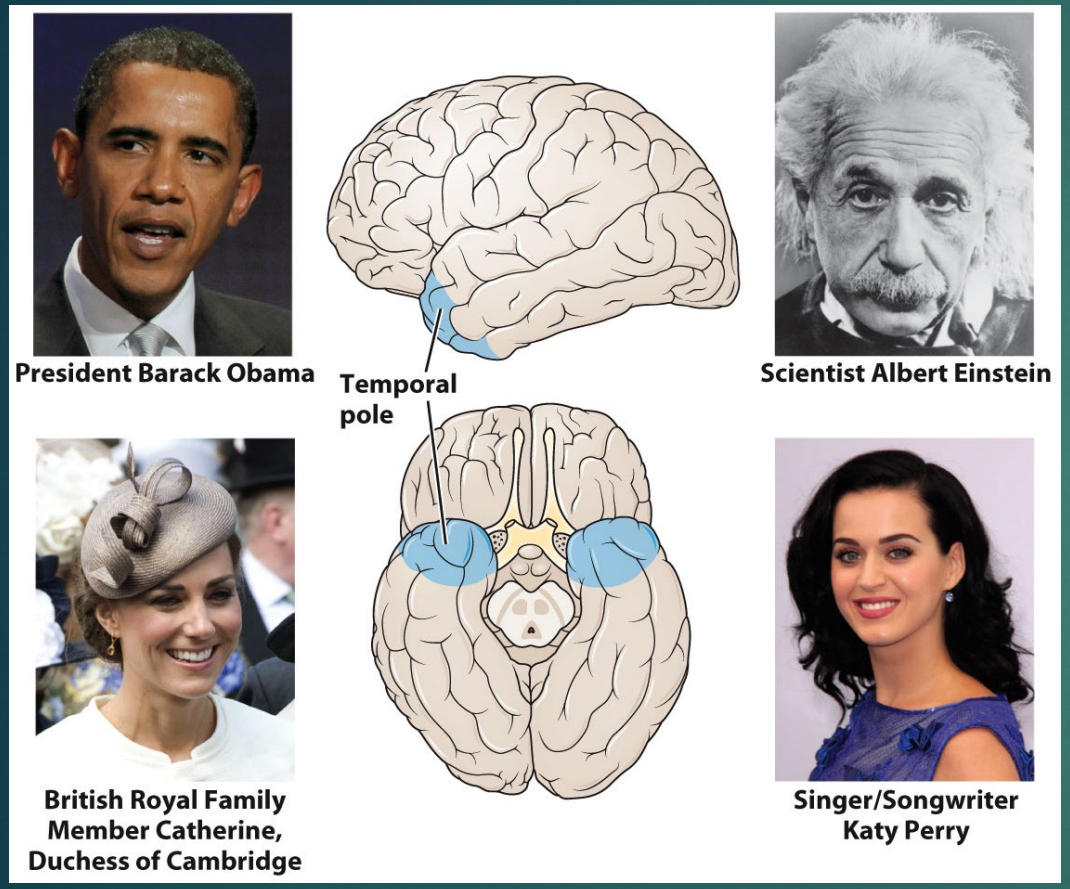
, L. Young, et al., 2009

Temporal Parietal Junction: Intention detector

- Used TMs to disrupt RTPJ function:
  - Lower RTPJ activation: harsh, outcome-based judgments of accidents; (e.g., she *poisoned* her friend; deliberate intention)
  - Higher RTPJ activation: more lenient intent-based judgments; (e.g., she *thought* it was sugar; accident)

- ASD: lower rTPJ; only outcome-based moral judgments, blame even for accidental outcome
- Psychopaths: more likely to "forgive" accidental harms; blunted response to harmful outcome

Social Knowledge and the Temporal Pole



The temporal pole.

Located at the anterior end of the temporal lobe, and lesions to this area are associated with forgetting information about famous people, such as those pictured here.

ToM: Theory of Mind

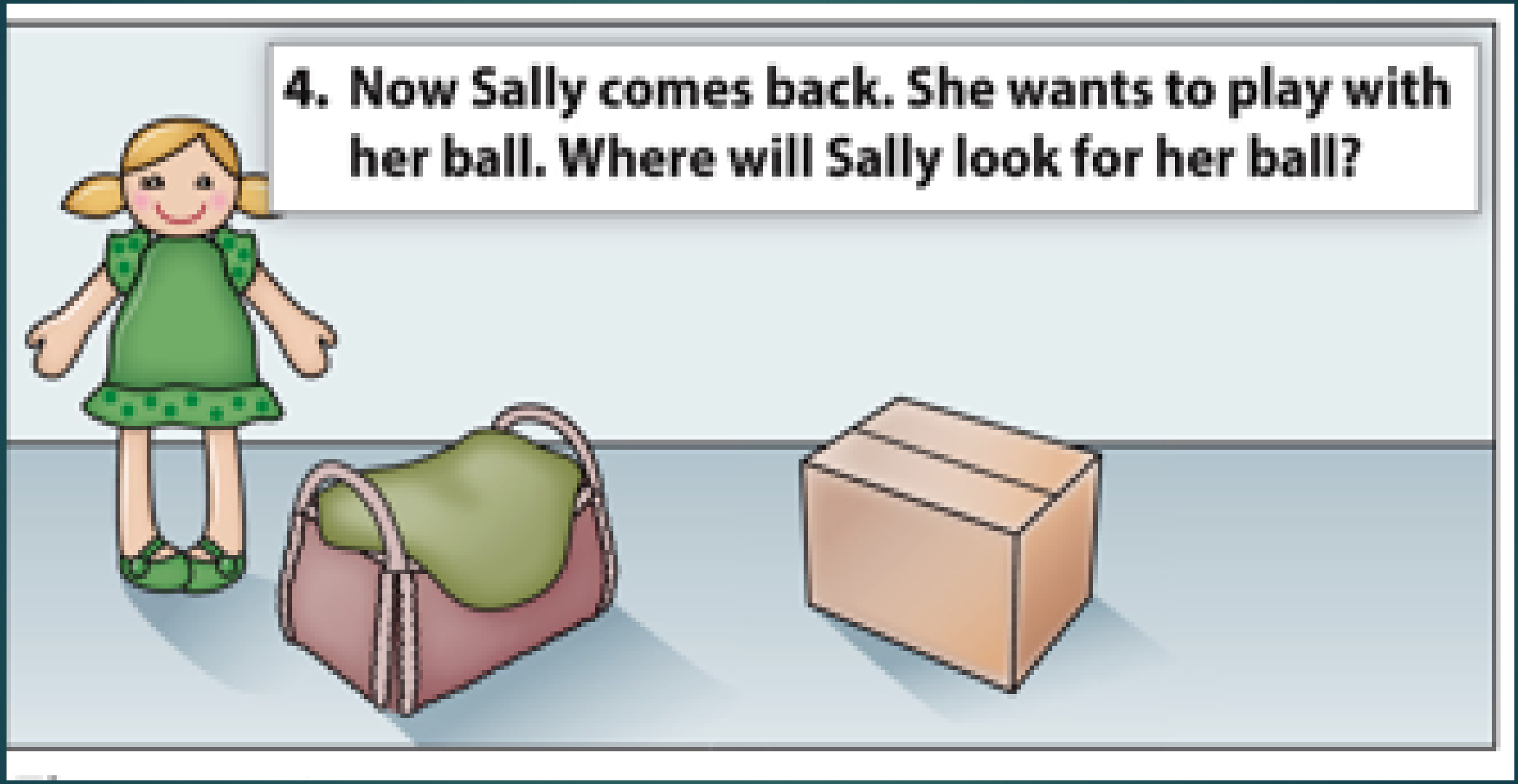
What is Theory of Mind?

- The ability to attribute (unobservable) mental states -- such as beliefs, desires, feelings, and knowledge -- to oneself and to others.
- With the understanding that others can have mental states that are different from your own.
- Can explain behavior in others; see them eating chocolate; they like it;
  or John leaves house with an umbrella
- Make predictions about their behaviors: will choose chocolate next time

False Beliefs

- Highest level of ToM includes ability to attribute *false belief*.
- Ability to recognize that others can have beliefs about the world that are wrong and we can predict their behavior based on this fact
- 3-4 year olds not capable, 6-7 year olds do

The Sally–Anne task



The Sally–Anne task

After viewing the picture story of Sally and Anne, subjects are asked where Sally should look for the hidden toy.

Those who lack a theory of mind think that Sally will look in the box, where Anne hid it. They do not understand that Sally holds the false belief that the toy is still in the basket.

After about age 5, children demonstrate theory of mind by correctly predicting she will look in the basket.

New research, 2021: If you add third box, response is at chance level at age 4-5. Only at age 6-7 is ToM achieved.

80% of children diagnosed with autism are *unable* to understand false belief.

Simon Baron-Cohen: ToM theory

- 4 independent skills:

- Ability to detect Intentionality (purposeful action)
- Ability to detect eyes & gaze direction
- Ability to share attention: gaze shifting & pointing are ways to direct attention In humans by age 1; also by dogs
- Higher order ToM: rules of social cognition: others have mental states; can deceive & be deceived; others can have false beliefs

Box of Cookies?

Jerome, with a physics PhD & autism is shown a cookie box filled with pencils. Box then closed. Joe walks into room.
Jerome is asked “What would Joe guess is in this closed cookie box?“
He consistently answered “pencils”

Some rudimentary traits of social intelligence exist in chimps:

- Deception
- Understanding perception and intention
- Social learning
- Trading and roles
- Cooperation
- Altruism

Understanding intentions of others


World
Science

Complexity of human evolution

“I know you think you understand
what you thought I said,
but I don’t think you realise that what you heard
was not what I meant.”

~ Daniel Greenspan

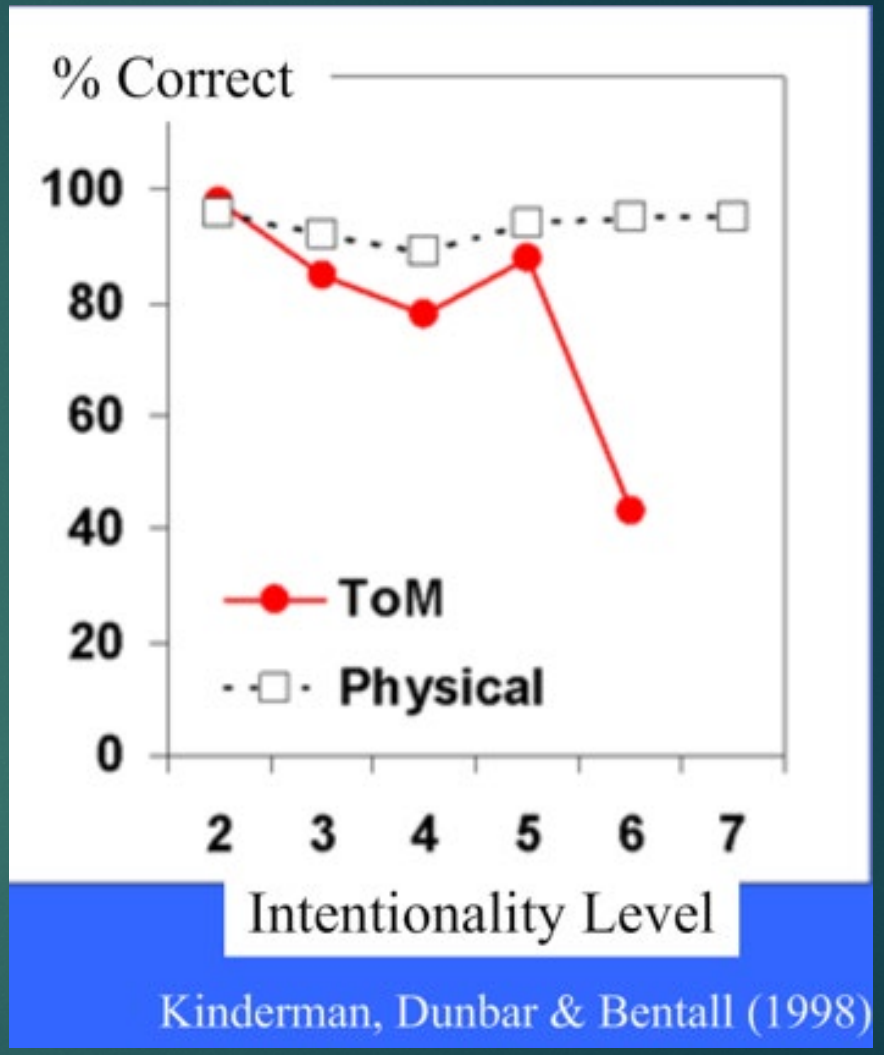
What level?

"Of course I care about how you imagined I thought you perceived I wanted you to feel."

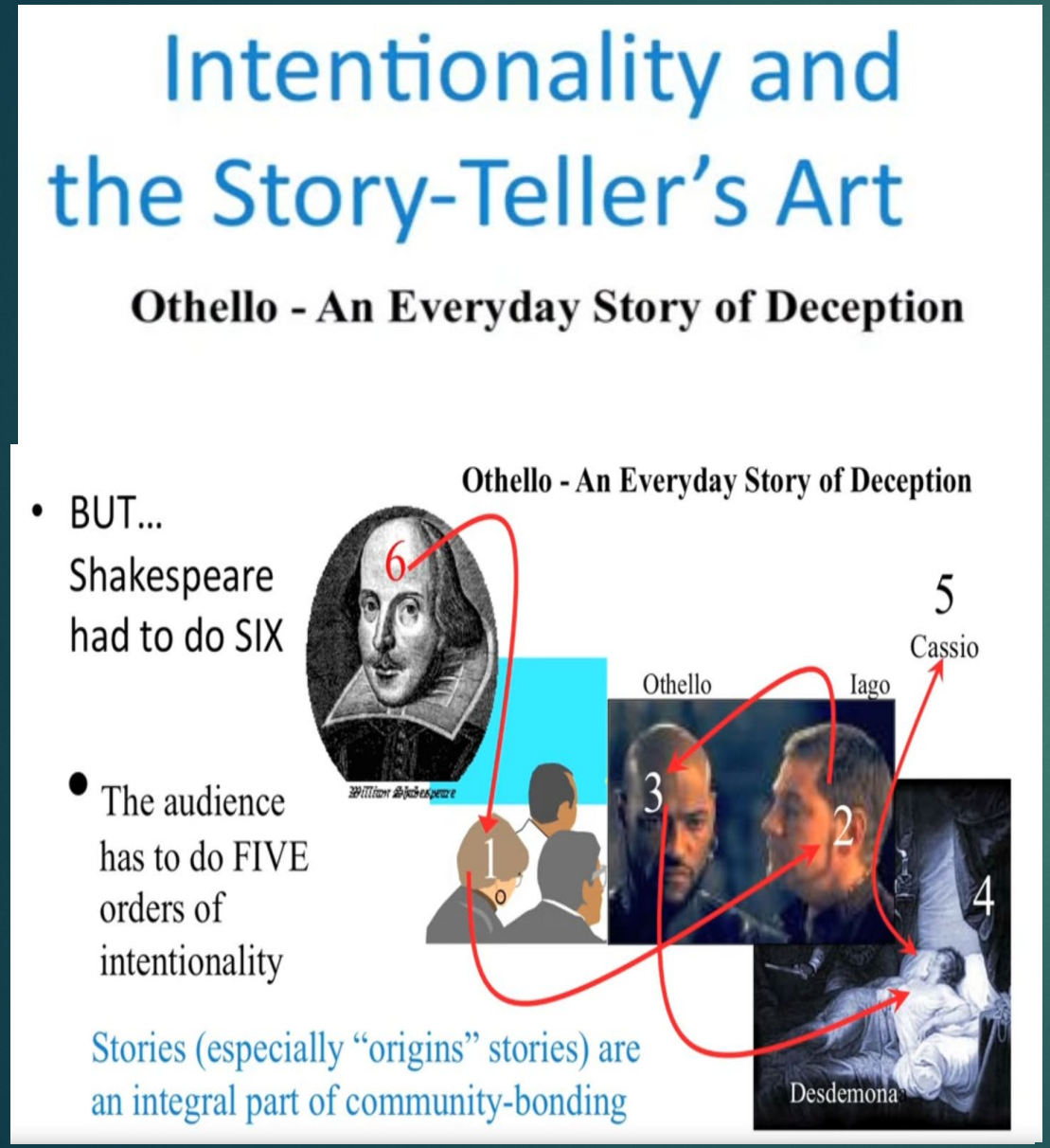
Limits of Intentionality

A natural limit at 5th level of intentionality

"I intend that you believe that Fred understands that we want him to be willing to do something…"
[level 5]



Shakespeare as great manipulator of intentionality

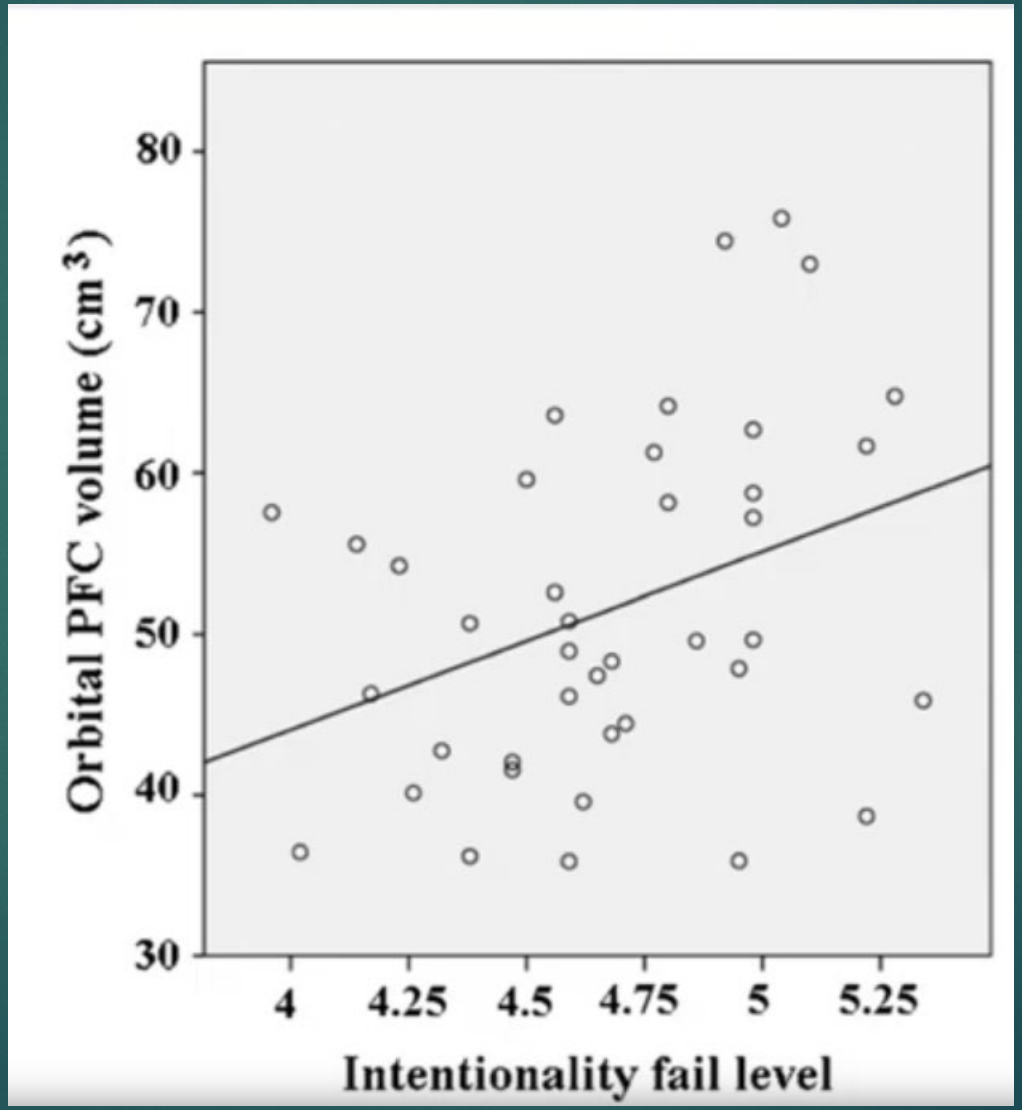


- 1 - Audience believes that
- 2 – Iago intends that
- 3 – Othello believes that
- 4 – Desdemona is in love with someone else
- 5 – Cassio enters interactions
- 6 – Shakespeare working at 6th level of intentionality

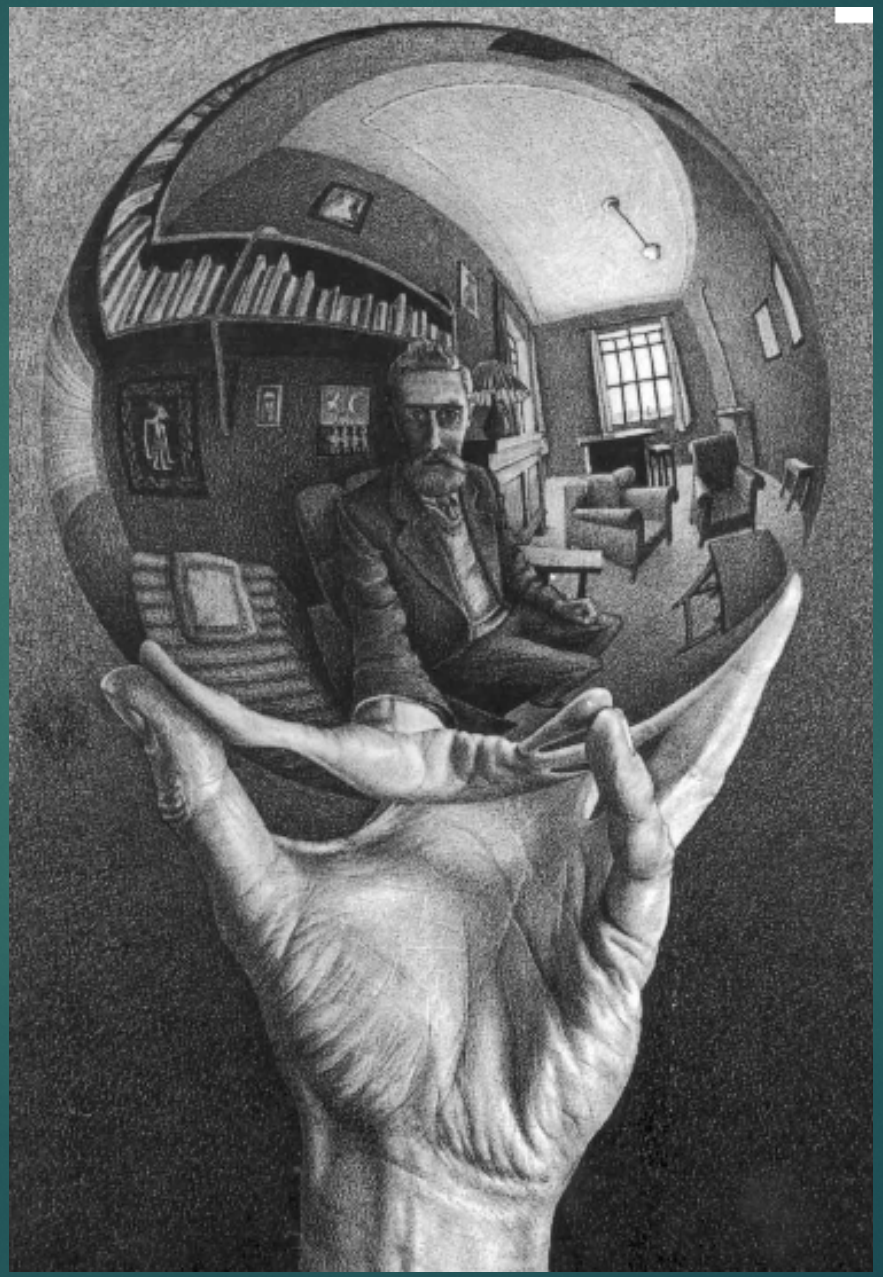
Intentionality

- Dates back to medieval philosophy and adopted by Edmund Husserl
- **Intentionality-** quality of mental states (e.g., thoughts, beliefs, desires, hopes) being directed toward some object or state of affairs
- Dunbar states chimps may aspire to around 1.5 order of intentionality
- Humans in most situations operate around 3rd order of intentionality
- 6th order exceptionally difficult
- No concrete limit to intentionality, simply limited to our cognitive capacity

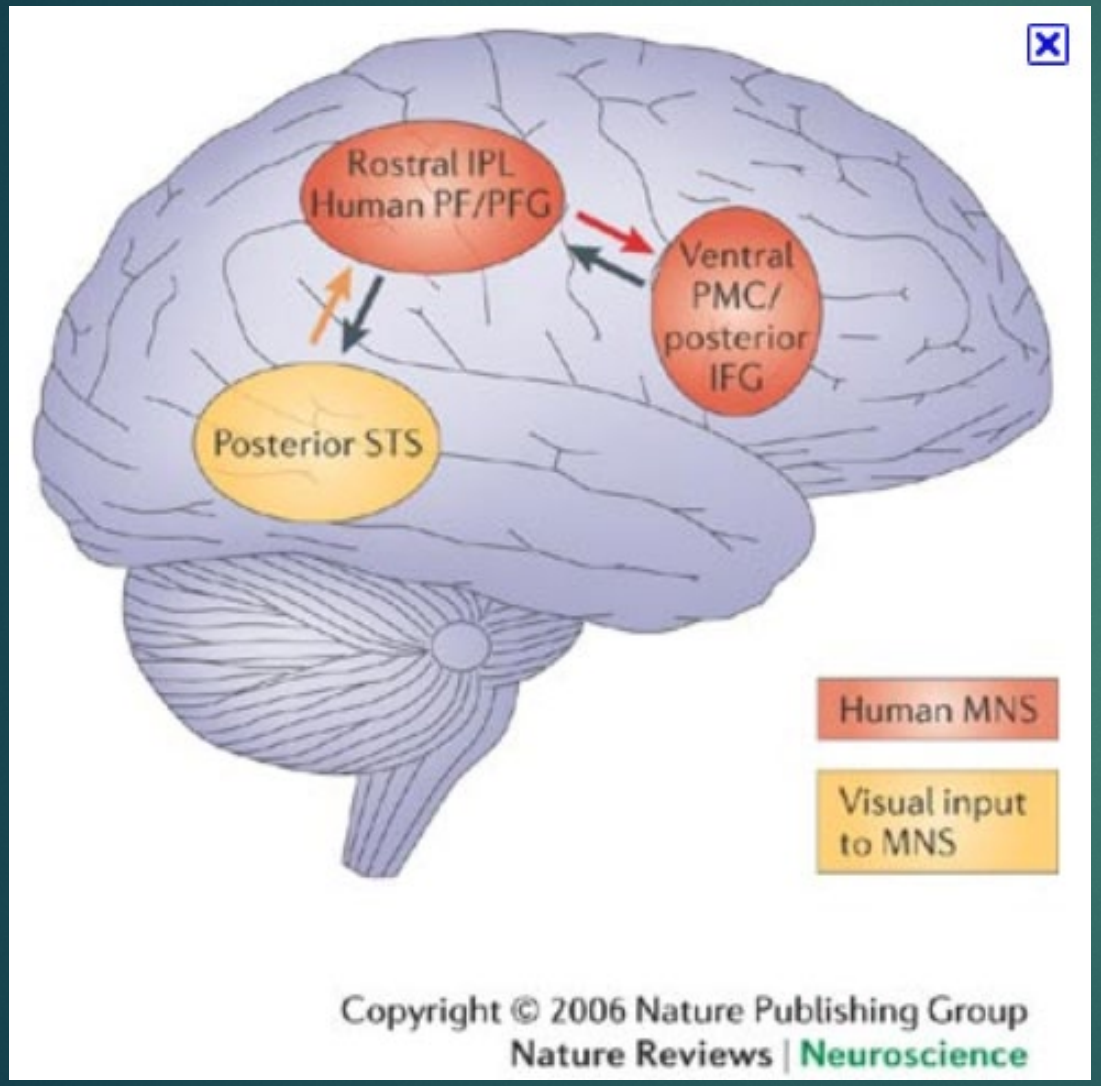
Higher your intentionality comprehension level, larger your OFC



Mirror Neurons



Mirror Neuron System



1 Posterior inferior frontal gyrus (pIFG)

2 Anterior inferior parietal lobule (aIPL)

3 STS: superior temporal sulcus

Gandhi neurons:
dissolve the barrier between you and me

Mirror Neurons

- Mirror neurons are active when
  - performing a particular movement or
  - when observing another perform the same action.

- These have been observed in area F5 in monkeys, which connects with the superior temporal sulcus.

Mirror Neurons:

Understanding of an actor by an observer without any cognitive mediation; direct stimulation of same neurons in both brains

Dr. Rizzolatti:
"Mirror neurons allow us to grasp the minds of others not through conceptual reasoning but through direct simulation.
By feeling, not by thinking."

MNS

- Because of mirror neurons, you can read my intentions. You know what I am going to do next.

- You know how I feel because you literally feel what I am feeling.

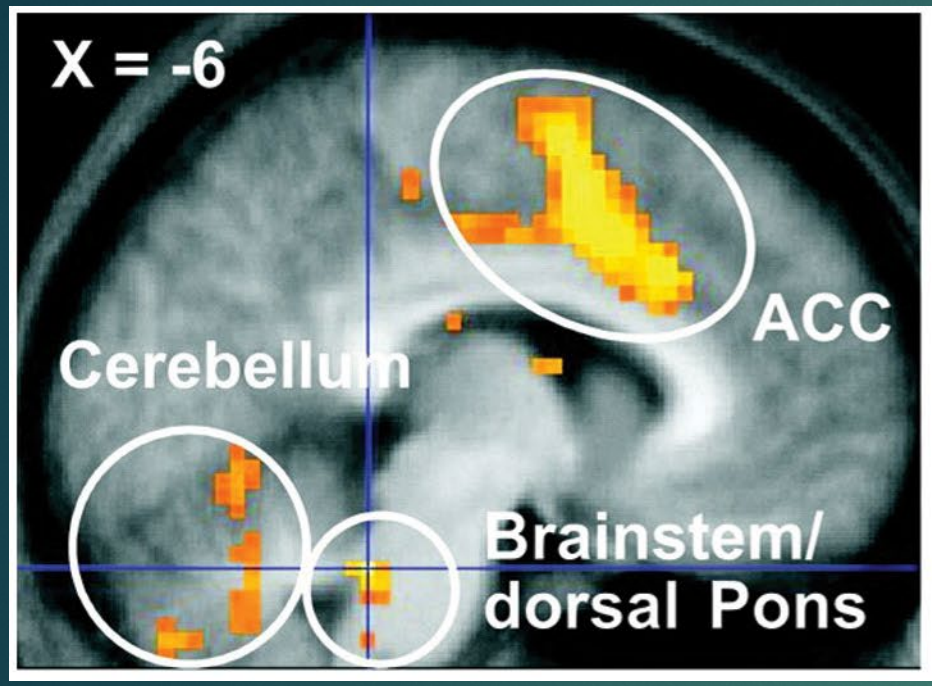
- Mirror neurons seem to analyze scenes and to read minds. If you see someone reach toward a bookshelf and his hand is out of sight, you have little doubt that he is going to pick up a book because your mirror neurons tell you so.

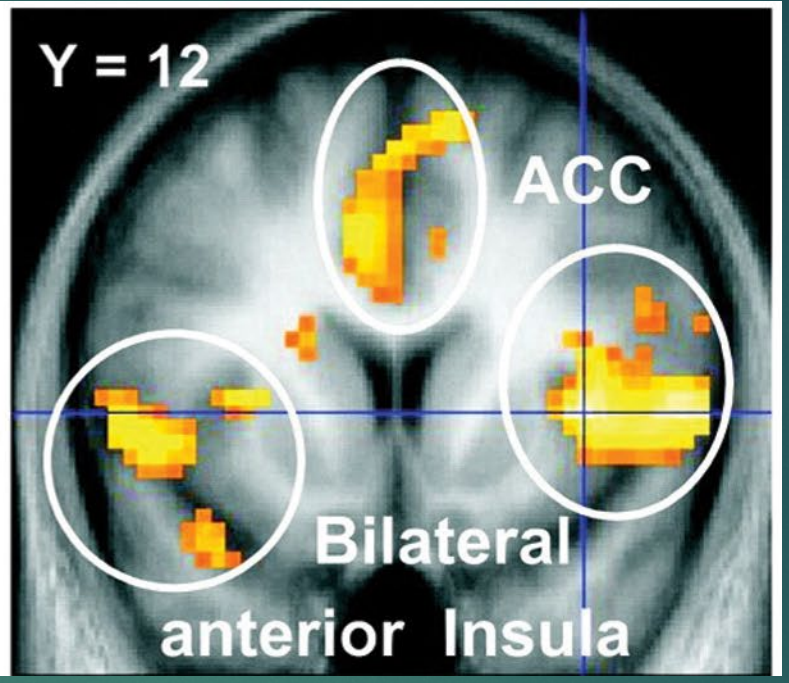
Grasping a teacup in context: Read Intention

MNs discriminate between reaching for a teacup to drink (on a clean table) or to remove it (on a messy table)

Iacoboni, 2005

Neural Mechanisms of Empathy, Sympathy, and Antipathy





Pain networks: Brain regions including the anterior cingulate cortex, the anterior insula, and the cerebellum become more active both when a subject is experiencing pain and when the subject's loved one experiences pain.

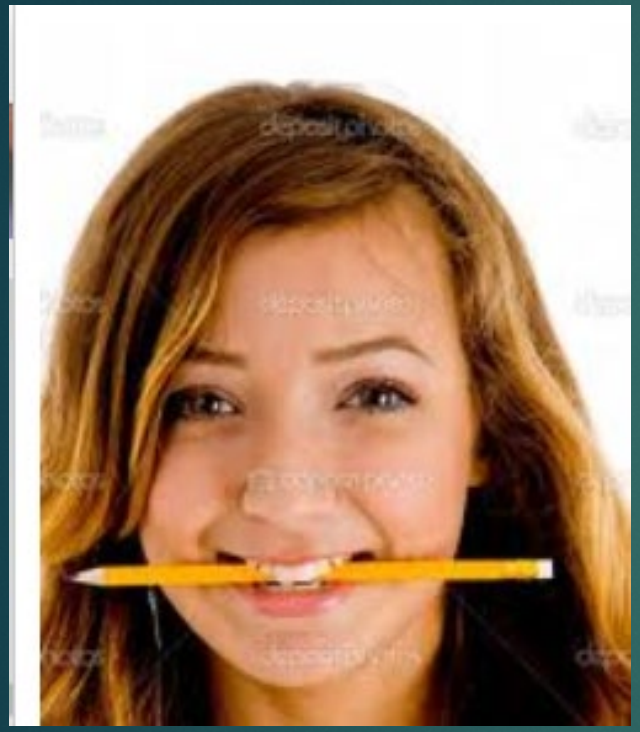
Consequence of MNS

- New knowledge through imitation
- Basis for our capacity to learn by watching.
- Could be evolutionary basis for proliferation of tool use, fire, shelter building, language
- Part of ToM system: Theory of Mind

MNS created by Hebbian classical conditioning

- Learned associations: Neurons that fire together wire together
- You can only mirror what you can do from prior experience
- More experience you have, better ability to predict same activity in another

Congruent facial muscle response:
Seeing the emotions of others



- When we view facial emotion in another, our facial muscles mimic theirs in 100ms.
- Holding a pencil horizontally in your mouth immobilizes facial muscles & decreases your ability to identify a happy emotion on the other's face. (Same with increasing Botox)
- 70% of "neurotypicals" have congruent facial muscle response; Autistics only 35%

Empathy: I feel what you feel

- Mirror neuron system is involved in reading emotions and empathy
- FI, ACC (VENs), & inf PFC are active:
  - Both when people experience an emotion (disgust, happiness, pain, etc.)
  - And when they see another person experiencing an emotion.
  - Our "gut feelings"

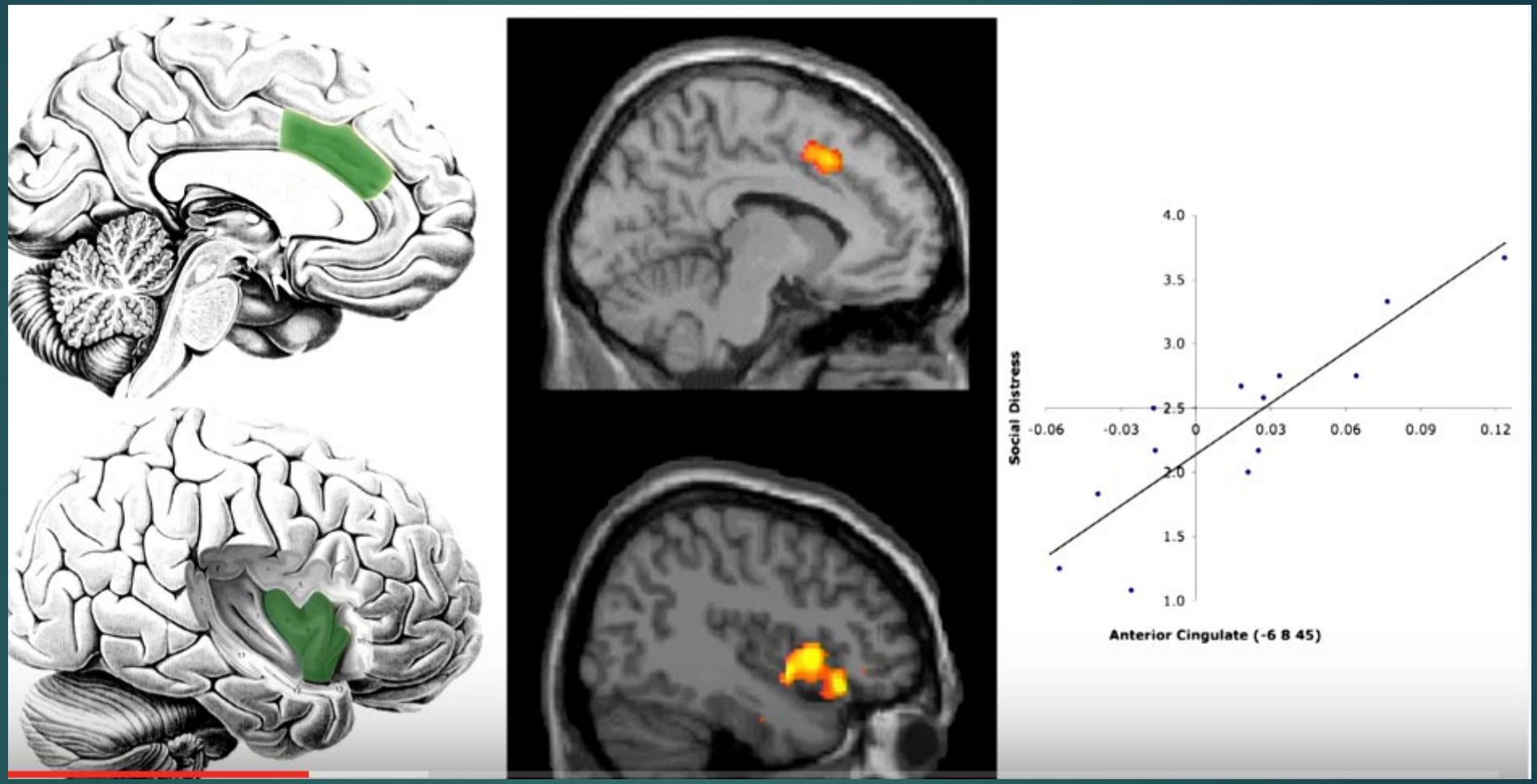
Christian Keysers, 2011

Most painful memory

- When asked what their most painful memory is, most people report the death of a loved one, not a broken leg
- Social pain: based on loss or rejection

Social Game under fMRI: Start with alternatively ball being thrown to you or other person. Then ball is never thrown to you again = MRI registers social rejection as physical pain response

Social pain is real pain = same activation of physical pain sites



Physical pain sites

Social pain sites

More hurt by rejection, stronger ACC activation

Tylenol/pain med makes both kinds of pain go away

Further Reading

Mirroring People – Marco Iacoboni
Empathic Brain – Christian Keysers
The Adolescent Brain – Reyna, Chapman, Dougherty, Confrey
Evolutionary Cognitive Neuroscience – S. Platek, J. Keenan, T. Shackelford
Cognitive Neuroscience of Social Behaviour – ed. A. Easton & N. Emery
The Lives of the Brain – John S. Allen
Social Intelligence – N. Emery, N. Clayton, C. Frith
The Human Brain Evolving: Paleoneurological Studies in Honor of Ralph L. Holloway by D. Broadfield, K. Schick, N. Toth & M. Yuan

Dunbar, R. I. M. (1998), The social brain hypothesis. *Evolutionary Anthropology: Issues, News, and Reviews,* 6: 178–190.
Butti C, et al., Von Economo neurons: Clinical and evolutionary perspectives, *Cortex* (2011), 30: 1-15

www.charlesjvellaphd.com

- All of my lectures in PDF files
- Go to “Neuropsychology Seminar Talks”
- charlesvella@comcast.net