A comparative approach to human cognitive evolution

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IAST

Inside the primate mind

Francesca De Petrillo, PhD

Cognitive primatololigst

How animals think about their world and make decisions?

Rhesus macaques

Barbary macaques

Capuchin monkeys

Lemurs

Our place in the nature

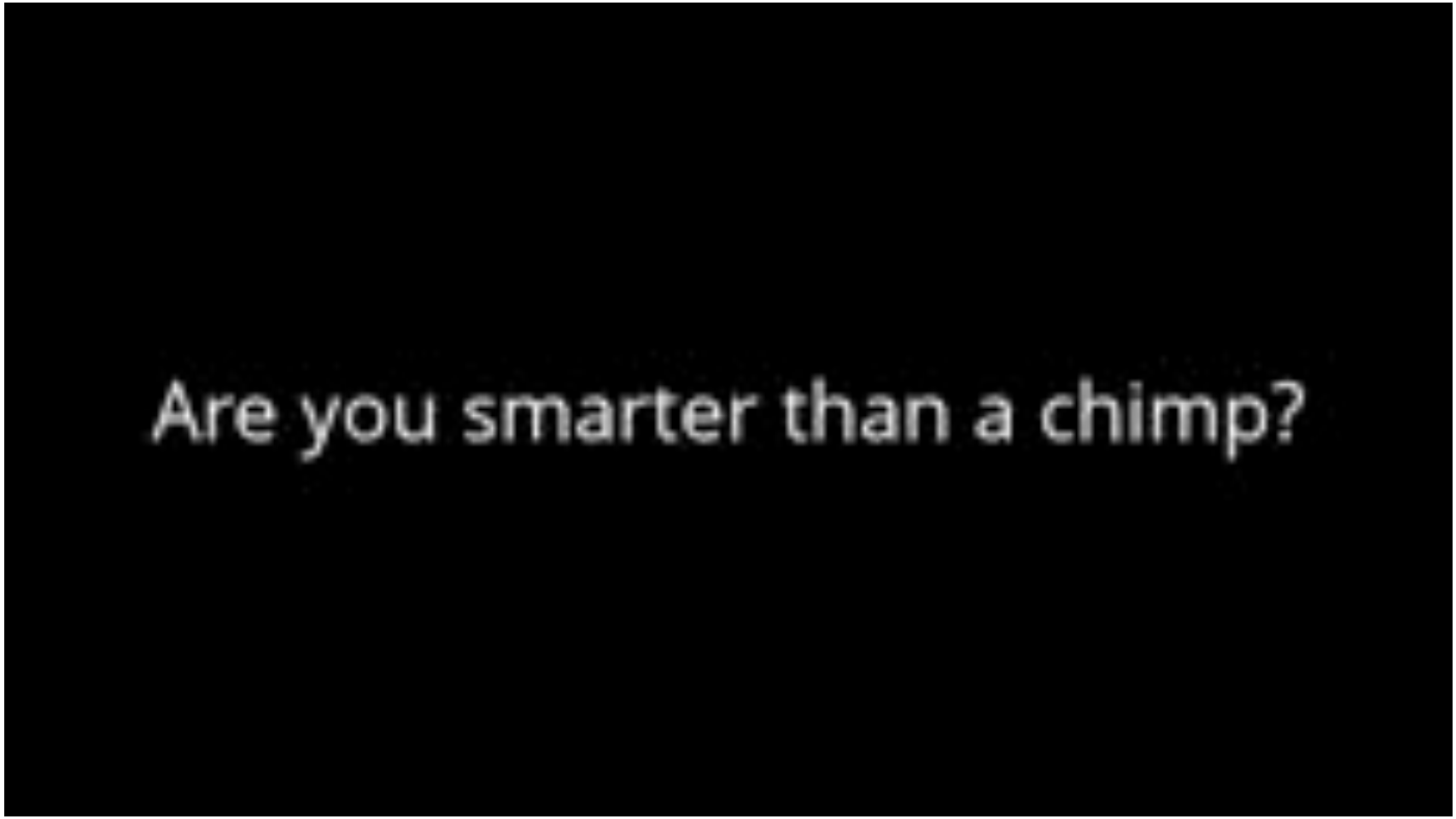
http://www.onezoom.org/life.html/@Hominoidea=386191 - x1022,y1007,w1.4733

Our place in the world

- Humans live in a wide variety of habitat
- Humans have few environment-specific genetic adaptation

Our place in the world

What makes us special?



What makes us special?

Technical intelligence

Language

"Ultrasocial" species
Extensive cooperation between non-kin

Cumulative culture, social learning and teaching

What makes us special?

"the difference in mind between man and the higher animals, great as it is, certainly is one of degree and not of kind."

Charles Darwin, 1871

Technical intelligence ✓



Language X

Cooperation ?

Social learning ✓

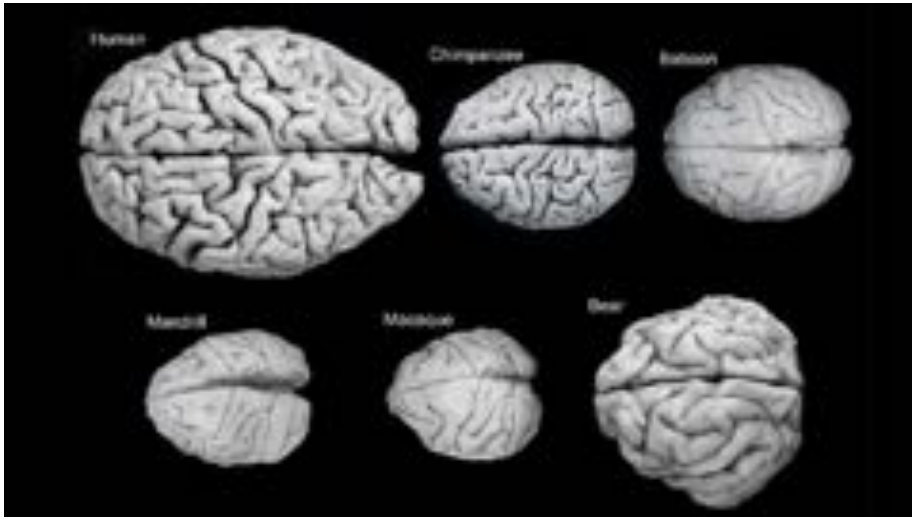
Road map

- How does cognition evolve?
  - Ecological intelligence hypothesis
  - Social intelligence hypothesis
  - Cultural intelligence hypothesis

- The evolution of human cooperation
  - What is cooperation?
  - What are the differences between human and non-human cooperation
  - Cognitive abilities underlying cooperation
  - The coevolution hypothesis

How we measure cognition?

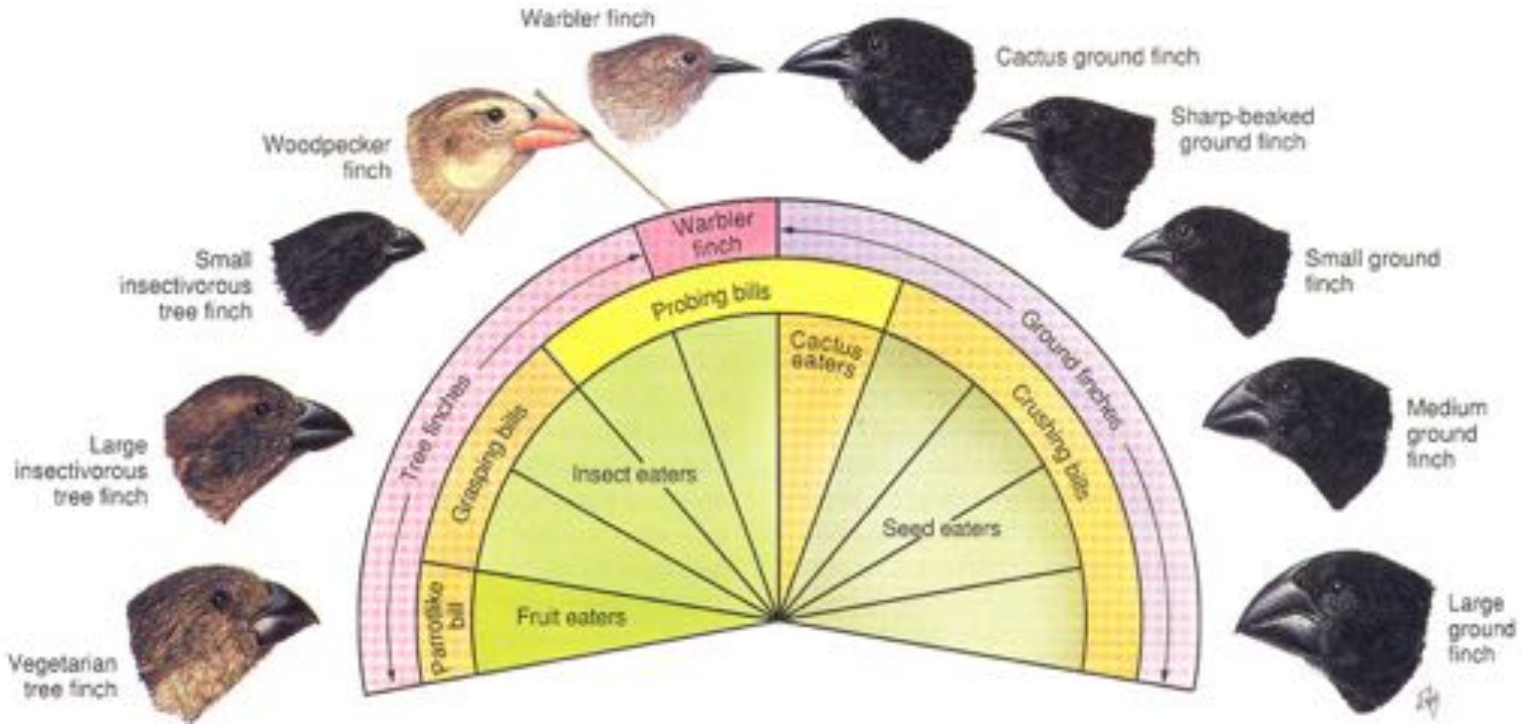
- Measuring cognitive traits poses a special problem: not directly observed, **cognitive processes can be only inferred**



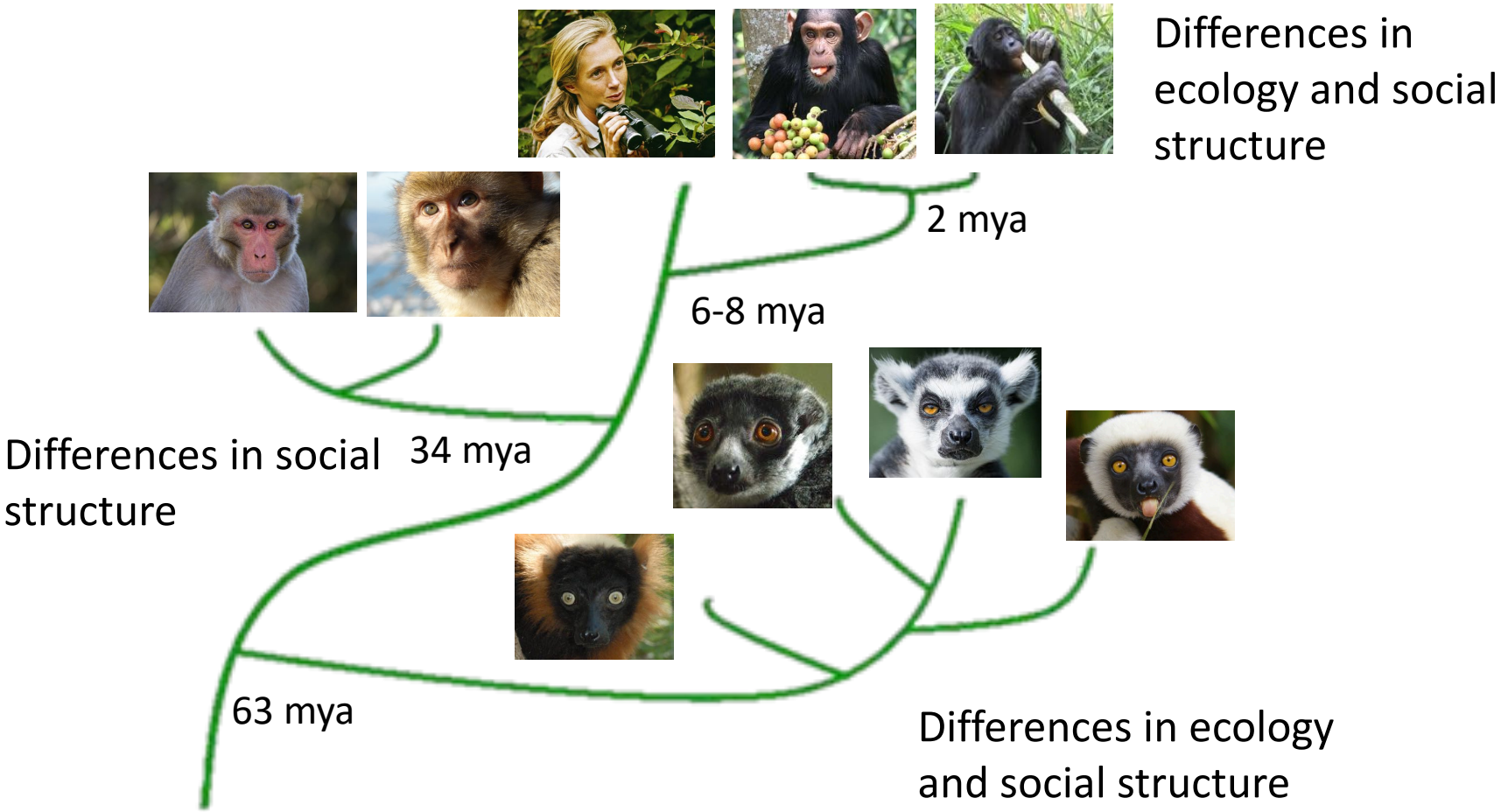
- Much work in primate cognitive evolution has used the whole brain or neocortex size, as a proxy for intelligence (Dunbar, 1998; Dunbar & Shultz, 2007; Sol et al., 2005; MacLean et al., 2009)

The comparative method

The comparative method: relating differences and similarities in a trait across species, or populations, to aspects of those species' environment or socio-ecological characteristics (Harvey, & Pagel, 1991; Nunn, 2011)



The comparative method



The Ecological intelligence hypothesis

- Features of the diet, including the complex spatiotemporal distribution of foods, use of extractive foraging techniques, or responses to a fluctuating environment are the major force for the evolution of cognition (Rosati 2017, MacLean et al., 2009; DeCasien et al., 2017).

- Species living in more complex environments may need more sophisticated cognitive abilities (DeCasien et al., 2017)

PNAS

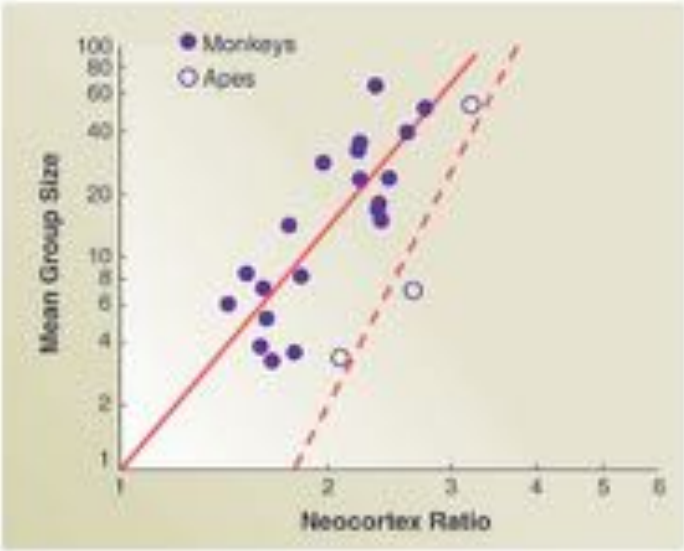
The evolution of self-control

Evan L. MacLean[a,1], Brian Hare[a,b], Charles L. Nunn[a], Elsa Addessi[c], Federica Amici[d], Rindy C. Anderson[e], Filippo Aureli[f,g], Joseph M. Baker[h,i], Amanda E. Bania[j], Allison M. Barnard[k], Neeltje J. Boogert[l], Elizabeth M. Brannon[h,m], Emily E. Bray[n], Joel Bray[a], Lauren J. N. Brent[h,o], Judith M. Burkart[p], Josep Call[d], Jessica F. Cantlon[k], Lucy G. Cheke[q], Nicola S. Clayton[q], Mikel M. Delgado[r], Louis J. DiVincenti[s], Kazuo Fujita[t], Esther Herrmann[d], Chihiro Hiramatsu[t], Lucia F. Jacobs[r,u], Kerry E. Jordan[v], Jennifer R. Laude[w], Kristin L. Leimgruber[x], Emily J. E. Messer[j], Antonio C. de A. Moura[y], Ljerka Ostojić[z], Alejandra Picard[r], Michael L. Platt[a,b,o,aa], Joshua M. Plotnik[q,bb], Friederike Range[cc,dd], Simon M. Reader[ee], Rachna B. Reddy[ff], Aaron A. Sandel[f], Laurie R. Santos[x], Katrin Schumann[d], Amanda M. Seed[l], Kendra B. Sewall[n], Rachael C. Shaw[q], Katie E. Slocombe[r], Yanjie Su[gg], Ayaka Takimoto[t], Jingzhi Tan[a], Ruoting Tao[l], Carel P. van Schaik[p], Zsófia Virányi[cc], Elisabetta Visalberghi[c], Jordan C. Wade[w], Arii Watanabe[q], Jane Widness[x], Julie K. Young[hh], Thomas R. Zentall[w], and Yini Zhao[gg]

36 species tested in a self-control paradigm

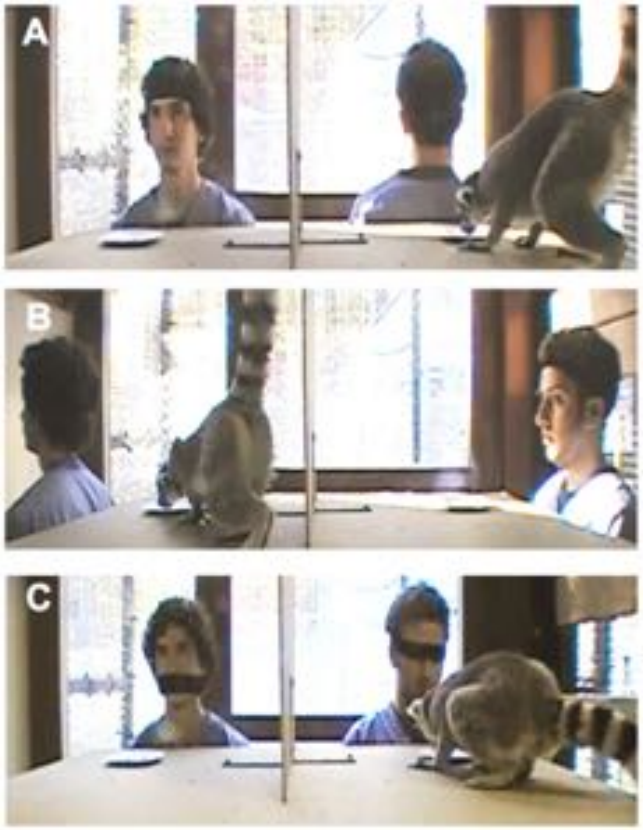
The Social intelligence hypothesis

- Social life –living in large groups, the need for political or 'Machiavellian' maneuvering, cooperative breeding, or social learning – has been the primary force shaping intelligent behavior (Dunbar, 1998; Dunbar & Shultz, 2007, Byrne & Whiten, 1988)
- Primate sociality is based on relationships of a kind that are found only in pair bonds in other taxa



Dunbar & Shultz, 2007, *Science*

The Social intelligence hypothesis



MacLean EL, Sandel AA, Bray J, Oldenkamp RE, Reddy RB, et al. (2013) Group Size Predicts Social but Not Nonsocial Cognition in Lemurs. PLOS ONE 8(6): e66359. https://doi.org/10.1371/journal.pone.0066359
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0066359

- Group size predicts social skills (MacLean et al., 2013, *Plos One*)

The Cultural intelligence hypothesis

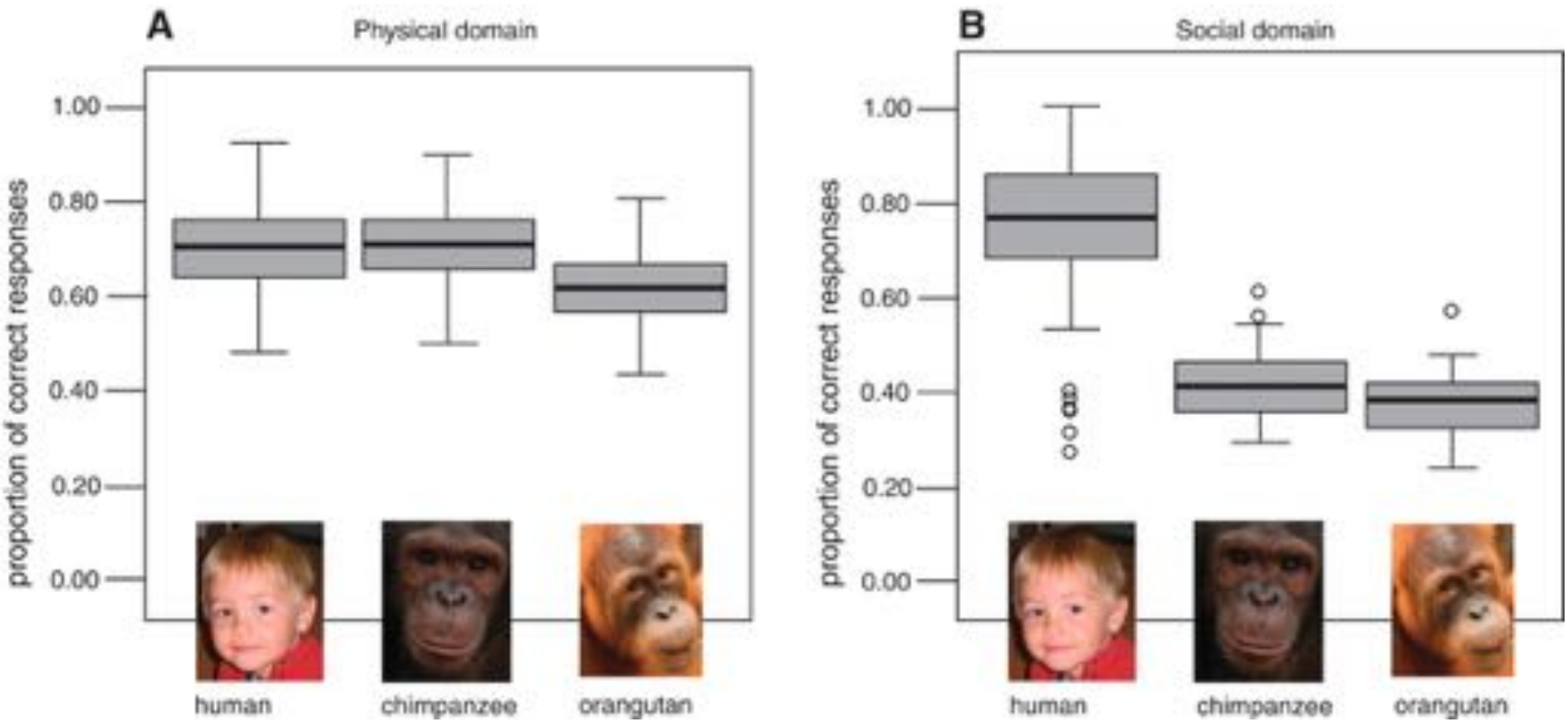
It has been proposed the big differences between human and non-human primates:

- humans have also evolved skills that enable them to create different cultural groups, symbols, and social practices and institutions.

- Humans rely consistently on social learning and on participation in cultural interactions

→ children's early emerging, of specialized skills for absorbing the accumulated skillful practices and knowledge of their social group

The Cultural intelligence hypothesis



(Herrmann et al., 2007, *Science*)

The Cultural intelligence hypothesis

So which hypotheses is correct?

Non-human primates:

✓ Evidence for both ecological and social hypotheses

↓

Debate about general vs. domain-specific intelligence

↑

Human primates: Human have a domain - general intelligence

✓ Evidence for all three hypotheses

Take home message: Importance of using a comparative approach to test hypotheses about the evolution of cognition!!!

Road map

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Cooperation

Cooperation

Definition of “Cooperation” varies

Gilby (2012): “**Joint action for mutual benefit**”
(i.e. among **non-kin**)

Cooperation for today = “Joint action for mutual benefit” + **Altruism**
(i.e. among non-kin and among **kin**)

Cooperation

Why cooperate at all?

Inclusive Fitness Theory (Kin Selection)

Natural selection favors traits that maximize Inclusive Fitness…

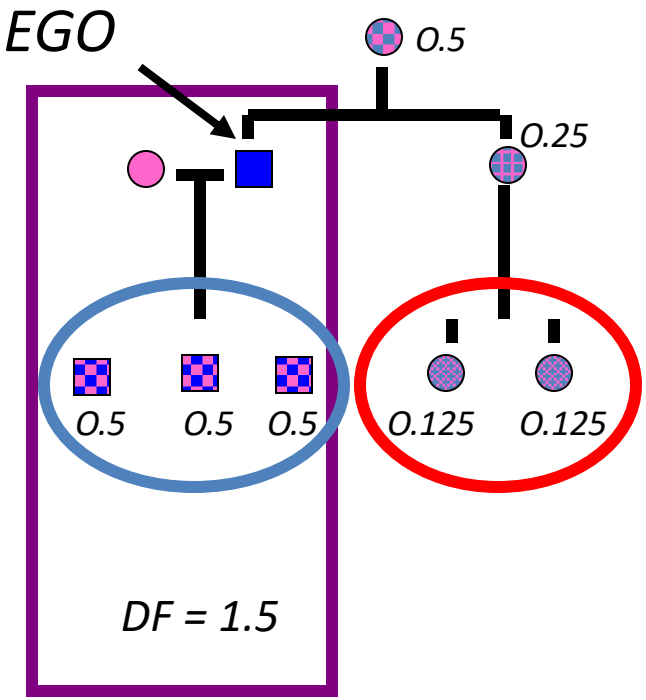
...because the Actor's genes are spread through both direct and indirect fitness

WD Hamilton
1937-2000

Cooperation

Inclusive fitness = Direct Fitness + Indirect Fitness

genome copies passed *in total* to next generation



Indirect fitness
= 1.5 + .25 =
1.75

Cooperation among kin

Evidence for cooperative behavior among kin

Grooming

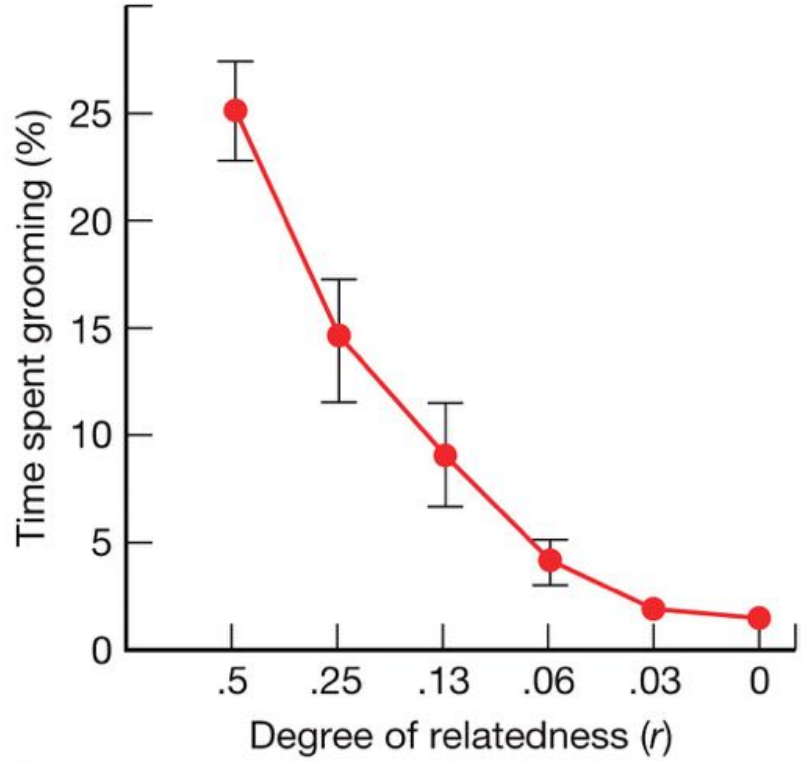
Coalition

Cooperative breeding

Cooperation among kin

Cayo Santiago Field Station

- **Grooming**
  - Most instances between mother and infant
  - Occurs more often between kin than distant kin or nonkin



Kin-recognition

- How primates recognize their kin?

Antebrachial gland

A. Phenotype matching

1. Odor
2. Sight

B. Familiarity

Via maternal relationship

*In captivity, mothers who are given non-kin neonates rear them as their own

Langergraber 2012, Ch. 21 in *EPS*

Kin-recognition

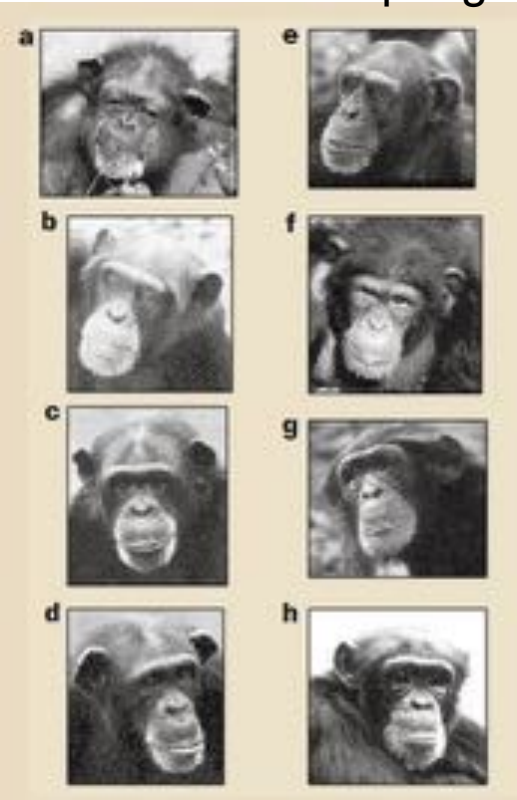
nature
International journal of science

Scientific Correspondence | Published: 17 June 1999

Visual kin recognition in chimpanzees

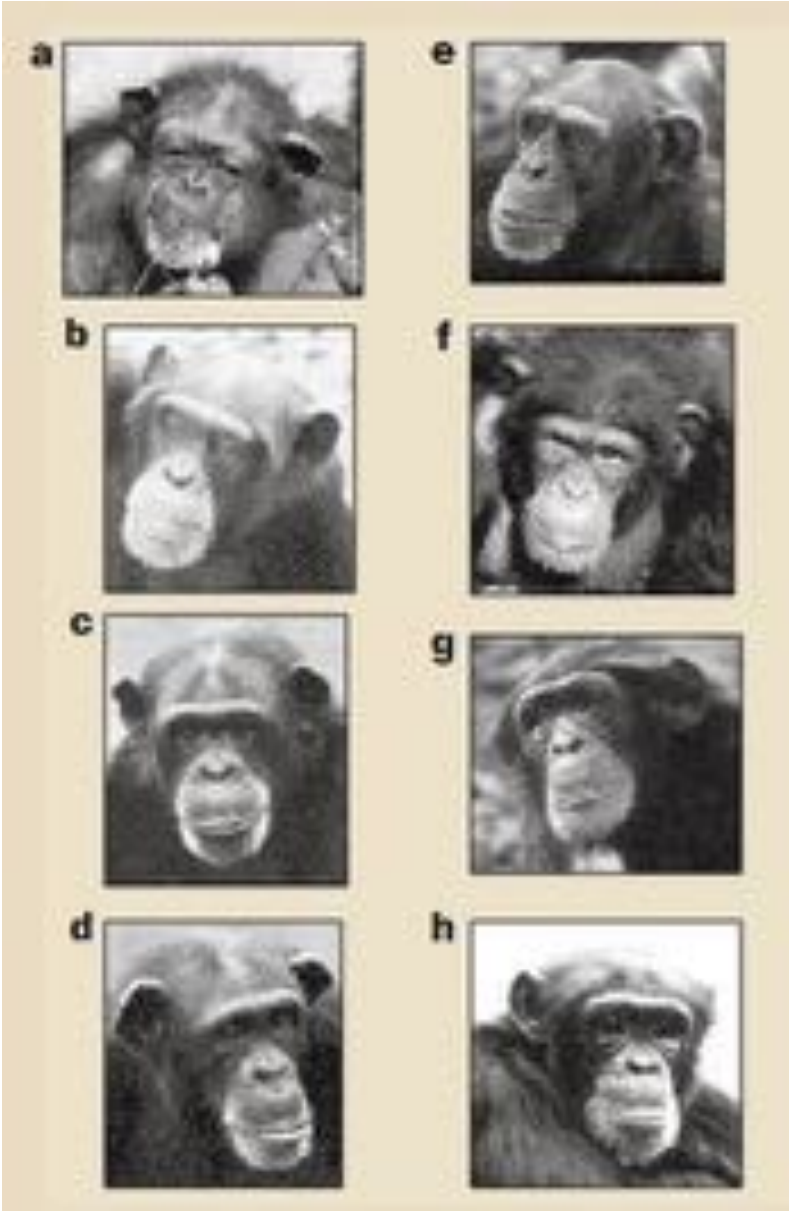
Lisa A. Parr & Frans B. M. de Waal

Mothers Offspring



Kin-recognition

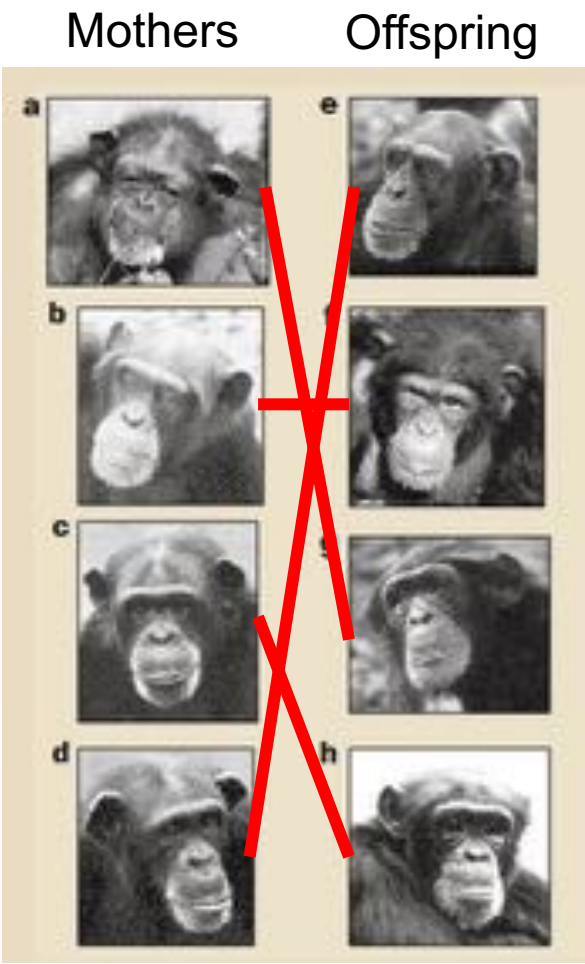
Can you guess right?



Kin-recognition

- Humans can often match close relatives in other species

- Chimpanzees initially recognize only in mother-son pairs – but the non-recognition of mother-daughter seems to have been a false result (an artefact of poor photos)



Cooperation among non-kin

- Cooperation among non-kin creates challenges for evolutionary biology

- Does cooperation among non-kin exist in other species?

Cooperation among non-kin

Gilby's classification of cooperation among non-kin.

A. Cooperation pays [Gilby: "mutualism"]

(1) By-product mutualism

"An individual's selfish actions incidentally benefit others"

Chimpanzee hunting

(2) Manipulative mutualism

"Individual B affects the payoff structure such that cooperation is immediately beneficial to individual A."

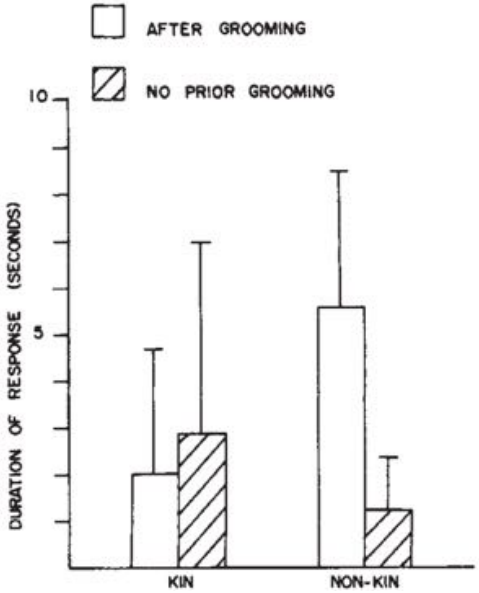
e.g. chimpanzee meat-sharing (by A) following harassment (by B)

Cooperation among non-kin

B. Defection pays – but even so, cooperation evolves.

(1) Contingent reciprocity

"Helping pays if the beneficiary returns the favor"

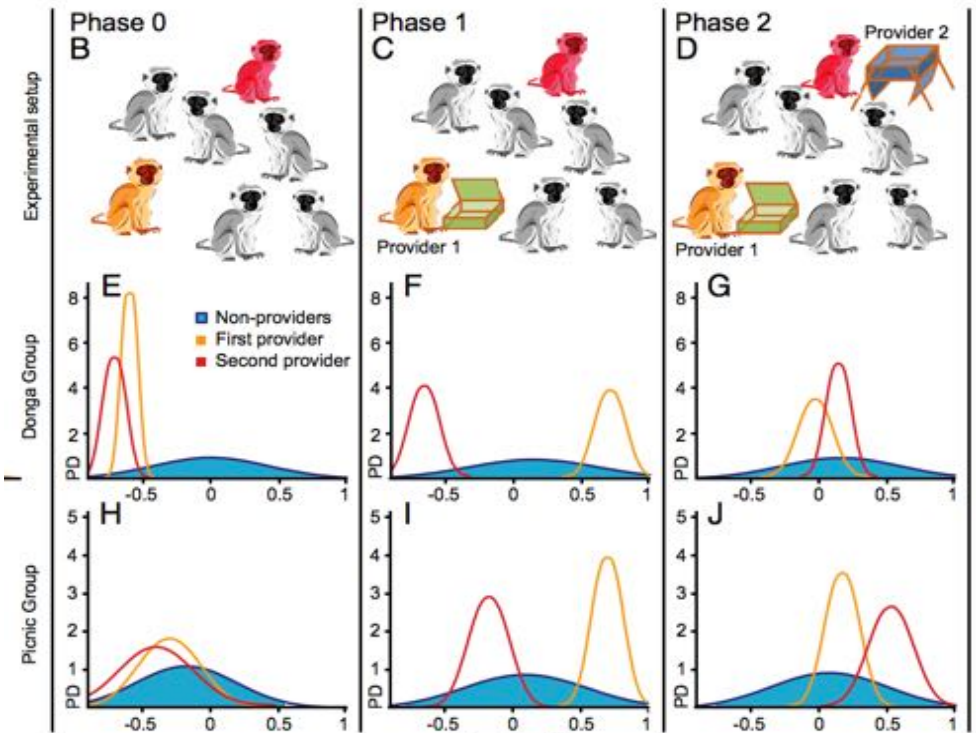


Seyfarth R, Cheney D 1984 *Nature* 308: 541-543

Cooperation among non-kin

(2) Biological market

"Helping pays because it persuades the beneficiary who to return the favor to"



Grooming ratio (grooming received / grooming given)

Food provider gets higher ratio of grooming received to grooming given

Fruteau C, et al 2009 *PNAS* 106: 12007-12012

Cooperation among non-kin

- However, human are hyper-cooperative, how is that possible?

- ***The Altruism hypothesis***: human altruistic tendencies evolved when humans lived in small group, comprised mostly by kin

  - kin selection & reciprocity

- ***The Cultural Group Selection hypothesis***: social group with more altruistic will outcompete other group

  - modern human have specific cognitive abilities (imitation, social learning, conformity) that favor cultural transmission

  - Social norm and institution

Cooperation among non-kin

- Are non-human primates altruistic?

https://www.youtube.com/watch?v=Z-eU5xZW7cU

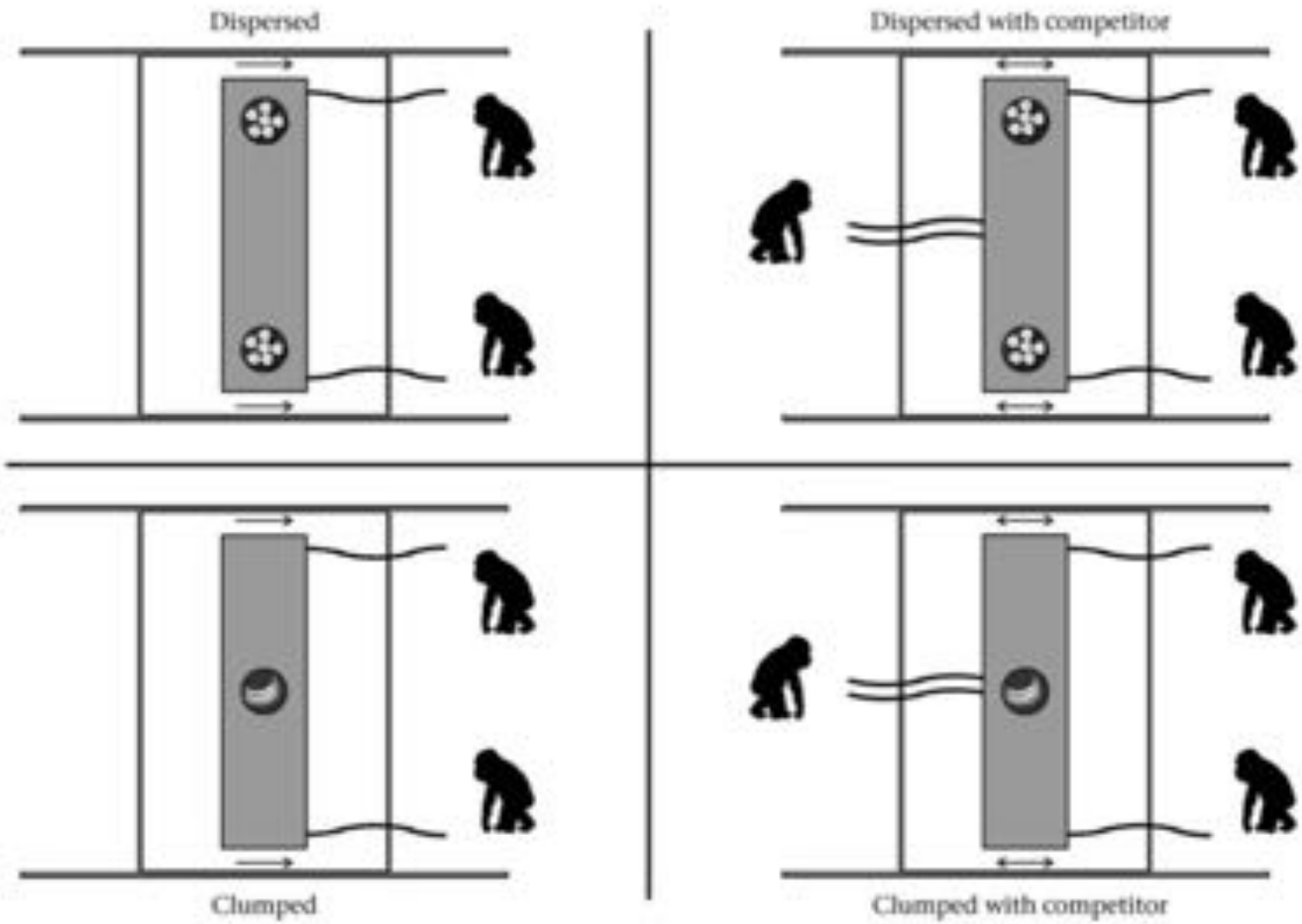
Human vs. NHP Cooperation

What are the ingredients for cooperation to emerge?

Are they present in non-human primates?

- Sharing of the spoils
- Coordination
- Temptation to free ride

Sharing spoils



- Where resources were clumped chimpanzees cooperation dropped
- Dominant individual in the pair monopolize food

Melis, Hare, Tommasello, (2006), *Animal Behaviour*

Sharing spoils

In an ultimatum game chimpanzees are rational maximizers and are not sensitive to fairness (Jensen et al., 2007; *Science*)

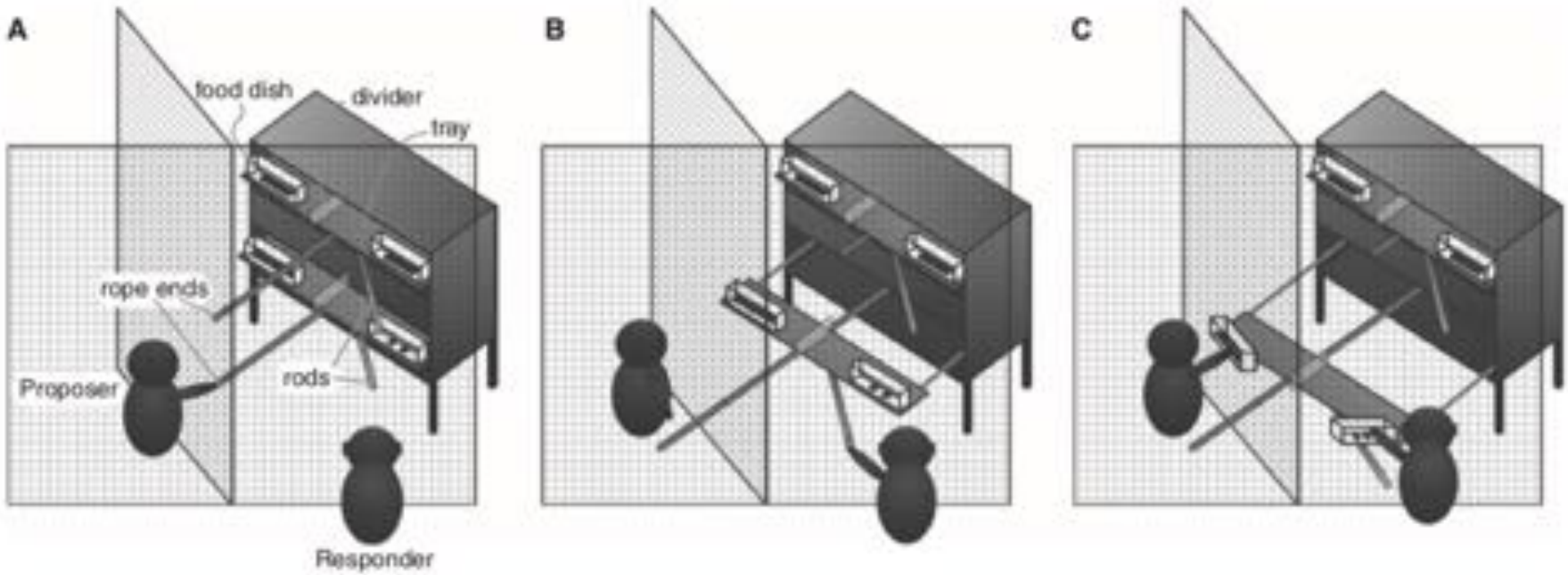
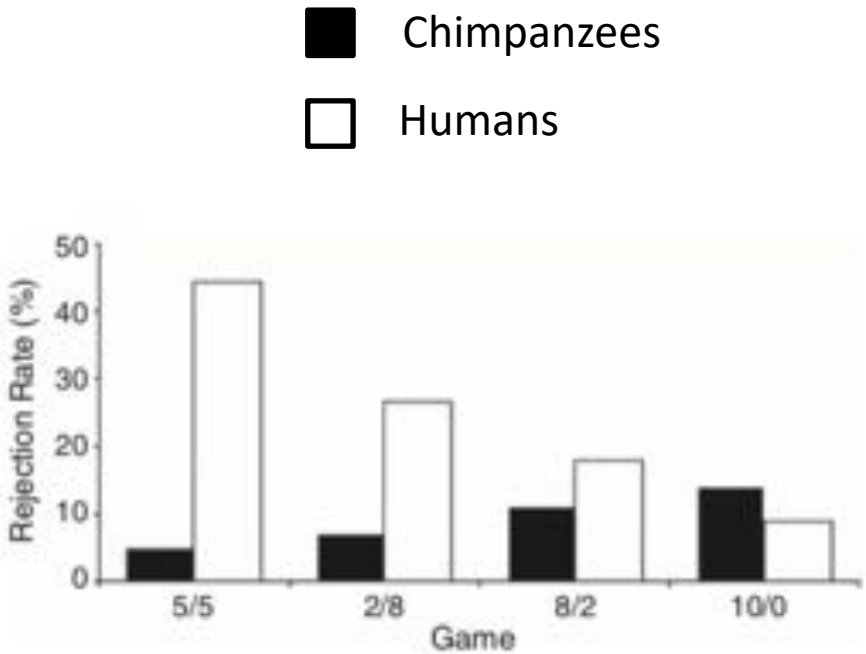


Fig. 1. Illustration of the testing environment. The proposer, who makes the first choice, sits to the responder's left. The apparatus, which has two sliding trays connected by a single rope, is outside of the cages. (**A**) By first sliding a Plexiglas panel (not shown) to access one rope end and by then pulling it, the proposer draws one of the baited trays halfway toward the two subjects. (**B**) The responder can then pull the attached rod, now within reach, to bring the proposed food tray to the cage mesh so that (**C**) both subjects can eat from their respective food dishes (clearly separated by a translucent divider).

www.sciencemag.org SCIENCE VOL 318 5 OCTOBER 2007

Sharing spoils

Game	Proposer Offers	Payoffs Proposer	Payoffs Responder	Responder Rejections
5/5	39 (75%)	8	2	2 (5%)
	13 (25%)	5	5	0 (0%)
2/8	45 (87%)	8	2	3 (7%)
	7 (13%)	2	8	0 (0%)
8/2	53 (100%)	8	2	6 (11%)
		8	2	
10/0	29 (54%)	8	2	4 (14%)
	25 (46%)	10	0	11 (44%)



(Jensen et al., 2007; *Science*)

Sharing spoils

Coordination

- Chimpanzees are able to coordinate and to choose the best collaborator

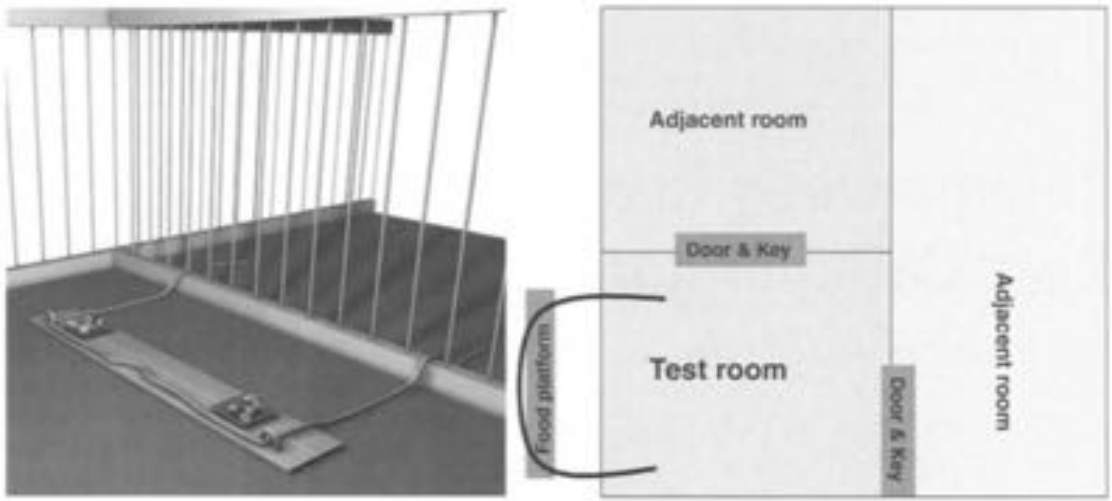


Fig. 1. Experimental setup. The baited food platform, metal loops, threaded rope extended into the test room, room layout used in the two studies, and placement of the food platform. In experiment 1, the subject was released from an adjacent room into the testing room, while the partner was "locked" in another adjacent room that only the subject could open with a key (a wooden peg) from inside the testing room. In experiment 2, the subject was released directly into the test room from a third adjacent room not represented here, while two potential partners were each locked in one of two adjacent rooms that the subject could again open with a key.

- However, chimpanzees collaborated **only when they could not solve the task alone** (Rekesrs et al., 2011)

(Melis et al., 2006; *Science*)

Temptation to free ride

- Humans have evolved extremely sensitive cheater-detection mechanism

  -Reputation
  -Punishment

https://journals.sagepub.com/doi/suppl/10.1177/0956797618800042

- Punishment has been shown in chimpanzees and capuchin monkeys (Rosati et al., 2018, *Psychological Science*; Leimgruber et al., 2016, *Evolution and Human Behaviour*)

Temptation to free ride

PNAS

Third-party punishment increases cooperation in children through (misaligned) expectations and conditional cooperation

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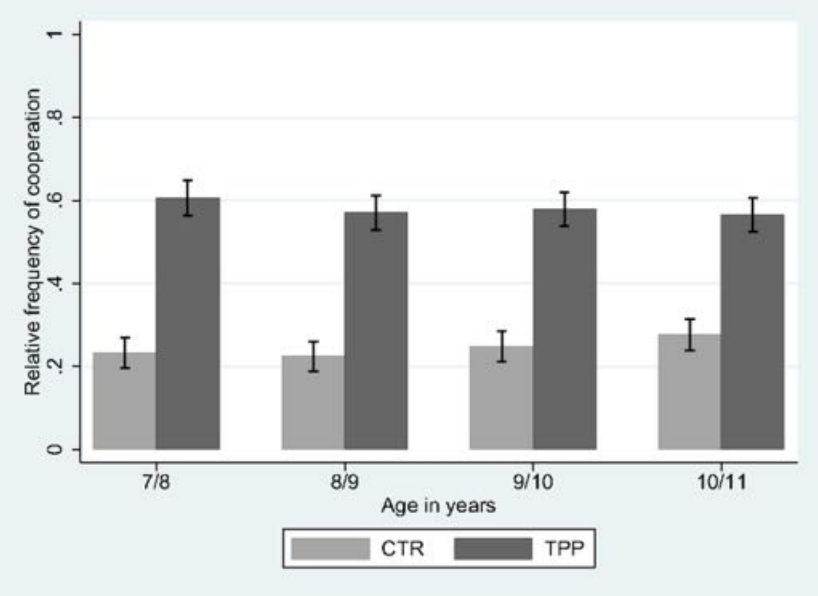
Player 1 \ Player 2	C	D
C	4, 4	0, 6
D	6, 0	2, 2

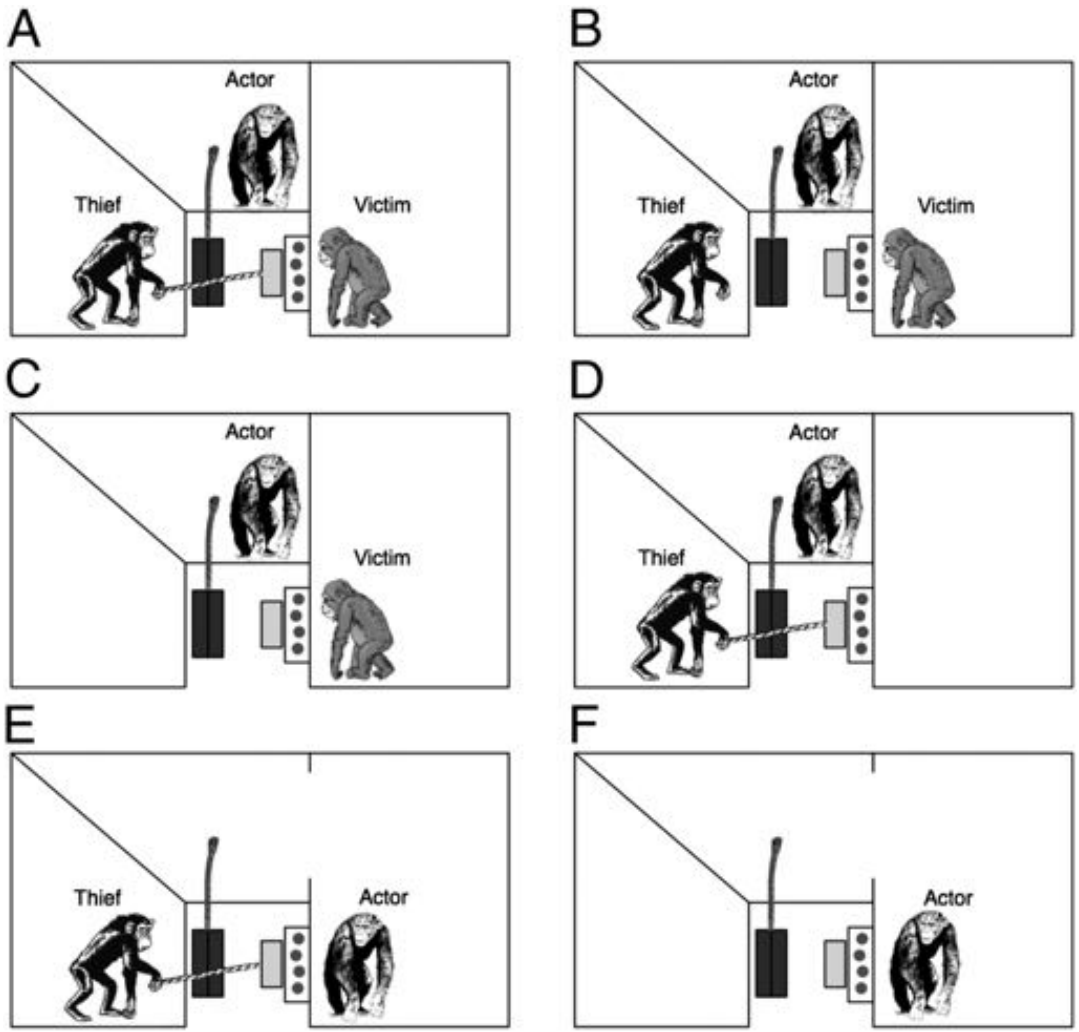


Prisoner dilemma in two condition: with and without third-part observer

Temptation to free ride

No evidence of third-party punishment in chimpanzees

(Riedl et al., 2012, *PNAS*)



Human vs. NHP Cooperation

Self-centred	Other-centred
Some for of altruism	Altruism
Limited sharing of the spoils	Sharing of the spoils
Occasional punishment	Third-party punishmet
Limited communication in cooperative effort	Extensive verbal communication in cooperative effort

Combining Cultural intelligence and cultural group selection: humans have evolved unique cognitive skill to acquire and transmit information socially

Humans Theory of Mind

Cooperation and human cognition: the Vygotskian intelligence hypothesis

Henrike Moll* and Michael Tomasello

Survival of the Friendliest: *Homo sapiens* Evolved via Selection for Prosociality

Brian Hare

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theory of mind to enable cooperation a human-unique ability?

Shared intentionality

Michael Tomasello and Malinda Carpenter

Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

Humans Have Evolved Specialized Skills of Social Cognition: The Cultural Intelligence Hypothesis

Esther Herrmann,[1*] Josep Call,[1] María Victoria Hernández-Lloreda,[2] Brian Hare,[1,3] Michael Tomasello[1]

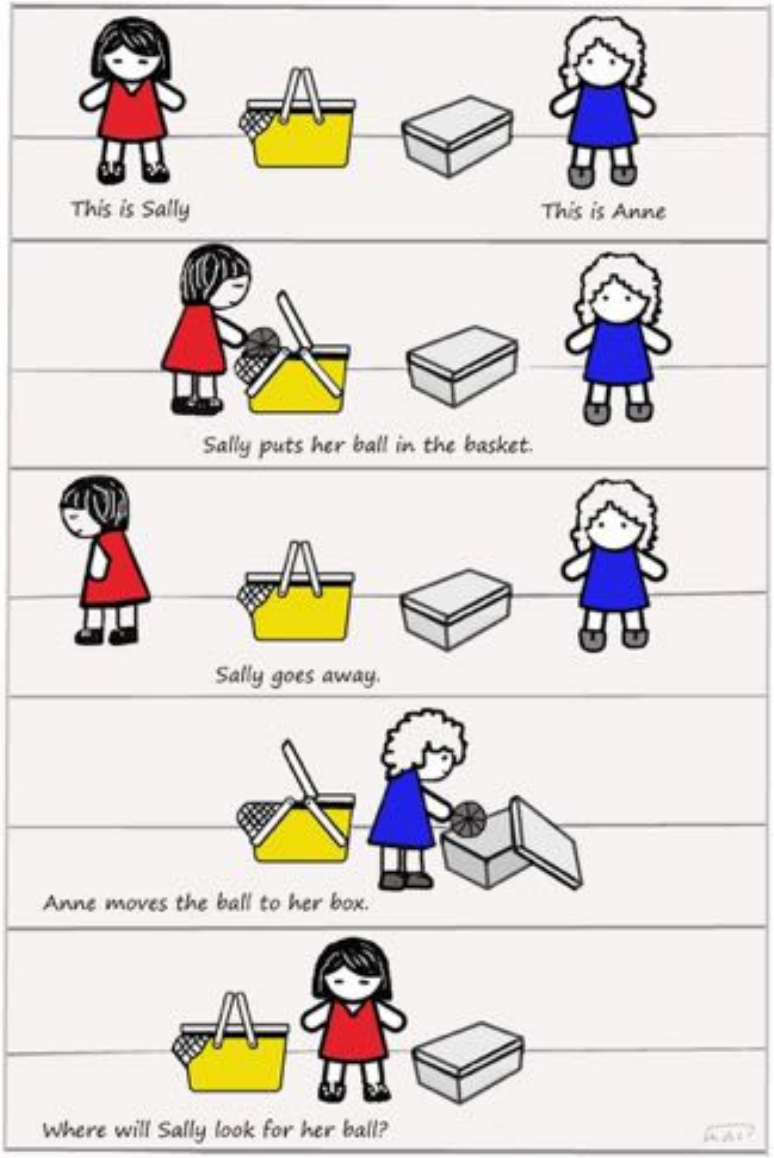
Humans Theory of Mind

Desires	✓		
Taking visual perspective	✓	✓	? Can use cues of visual perspective
Knowledge/ ignorance	✓	✓	
False belief	?	✗	

(Flombaum and Santos, 2005)
(Hare et al. 2000)
(Kaminski et al. 2008)
(Krupenye et al. 2016)
(Marticorena et al. 2011)
(Okamoto Barth et al. 2007)
(Sandel et al. 2011)

Humans Theory of Mind

Understanding false beliefs: the Sally-Ann task



Children around 4 year of age start to understand that people can have false belief

Humans Theory of Mind

REPORT

Great apes anticipate that other individuals will act according to false beliefs

Christopher Krupenye[1,*,†], Fumihiro Kano[2,3,*,†], Satoshi Hirata[2], Josep Call[4,5], Michael Tomasello[5,6]
• See all authors and affiliations

Science 07 Oct 2016:
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DOI: 10.1126/science.aaf8110

Humans Theory of Mind

Million Dollar Question!

So why human cooperate so much and non-human primates do not?

- Non-human primates social skills are shown mostly in competitive situation

The coevolution hypothesis: Critical aspect of human social cognition (theory of mind) and social motivation (tolerance and gregariousness) evolved in parallel (Evan MacLean, 2016, *PNAS*)

Humans Theory of Mind

Systemizing—empathizing hypotheses: High level of androgen exposure during prenatal development lead to a bias toward systemizing (Baron-Cohen et al., 2005, *Science*)

Trait	Species Difference	Trait	Species Difference
Gaze Following	B > C	Tool Use	C > B
Food Sharing	B > C	Causal Reasoning	C > B
Cooperation	B > C	Spatial Memory	C > B
Social Play	B > C	Aggression	C > B

Thanks

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