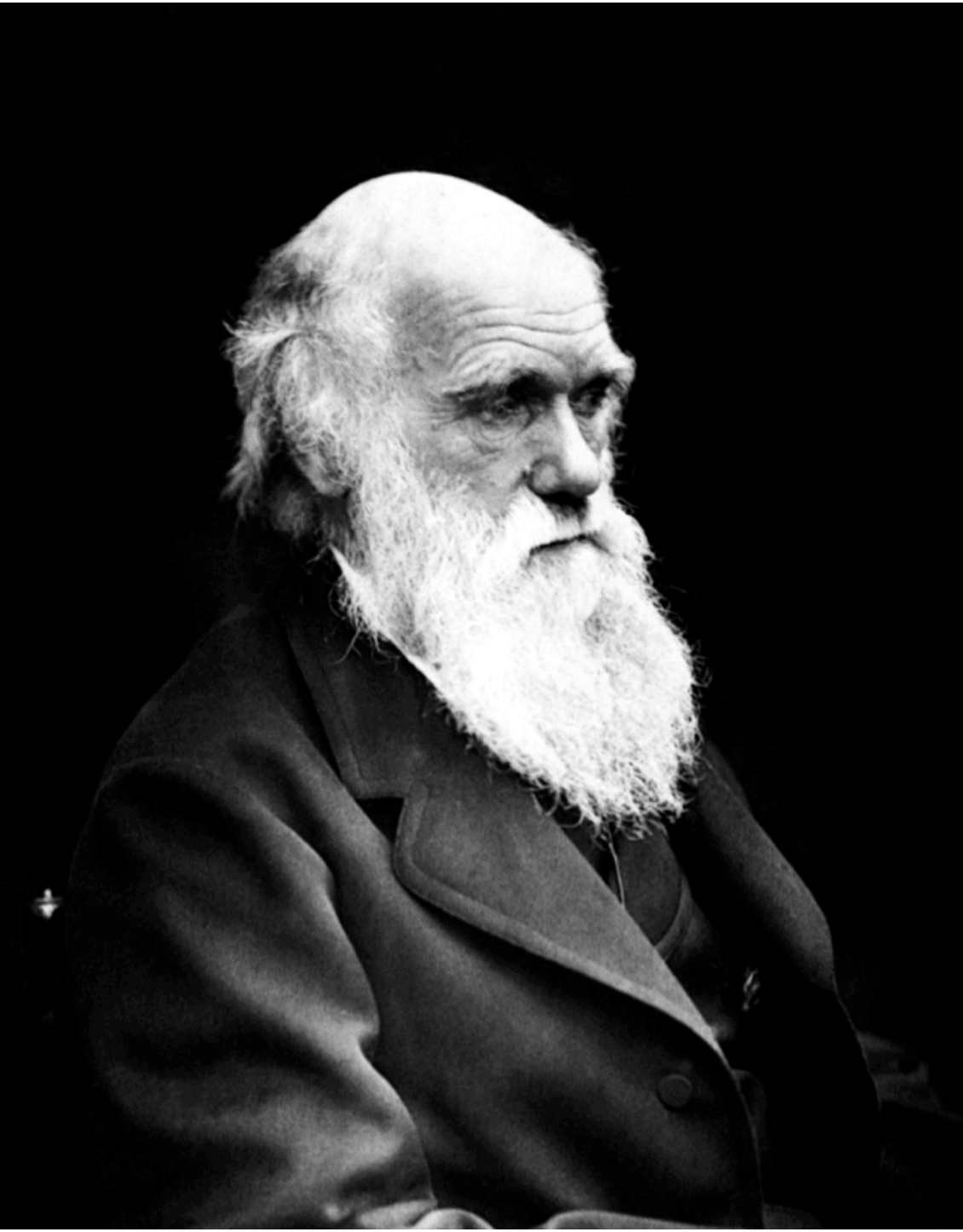
why are we so odd?

explaining the discontinuity between human and nonhuman minds

by Derek C. Penn

1. What are the fundamental differences between human and nonhuman cognition?

2. Why is there such an enormous cognitive gap between our species and every other?



"No doubt the difference… is enormous, even if we compare the mind of one of the lowest savages, who has no words to express any number higher than four and who uses hardly any abstract terms for common objects.. with that of the most highly organised ape.

The difference would, no doubt, still remain immense, even if one of the higher apes had been improved or civilised as much as a dog has been in comparison with its parent-form, the wolf or jackal."

(Darwin, *Descent of Man*, 1871)

Darwin's tendentious claim

the gap between human and nonhuman minds is enormous and is not the result of culture or language alone

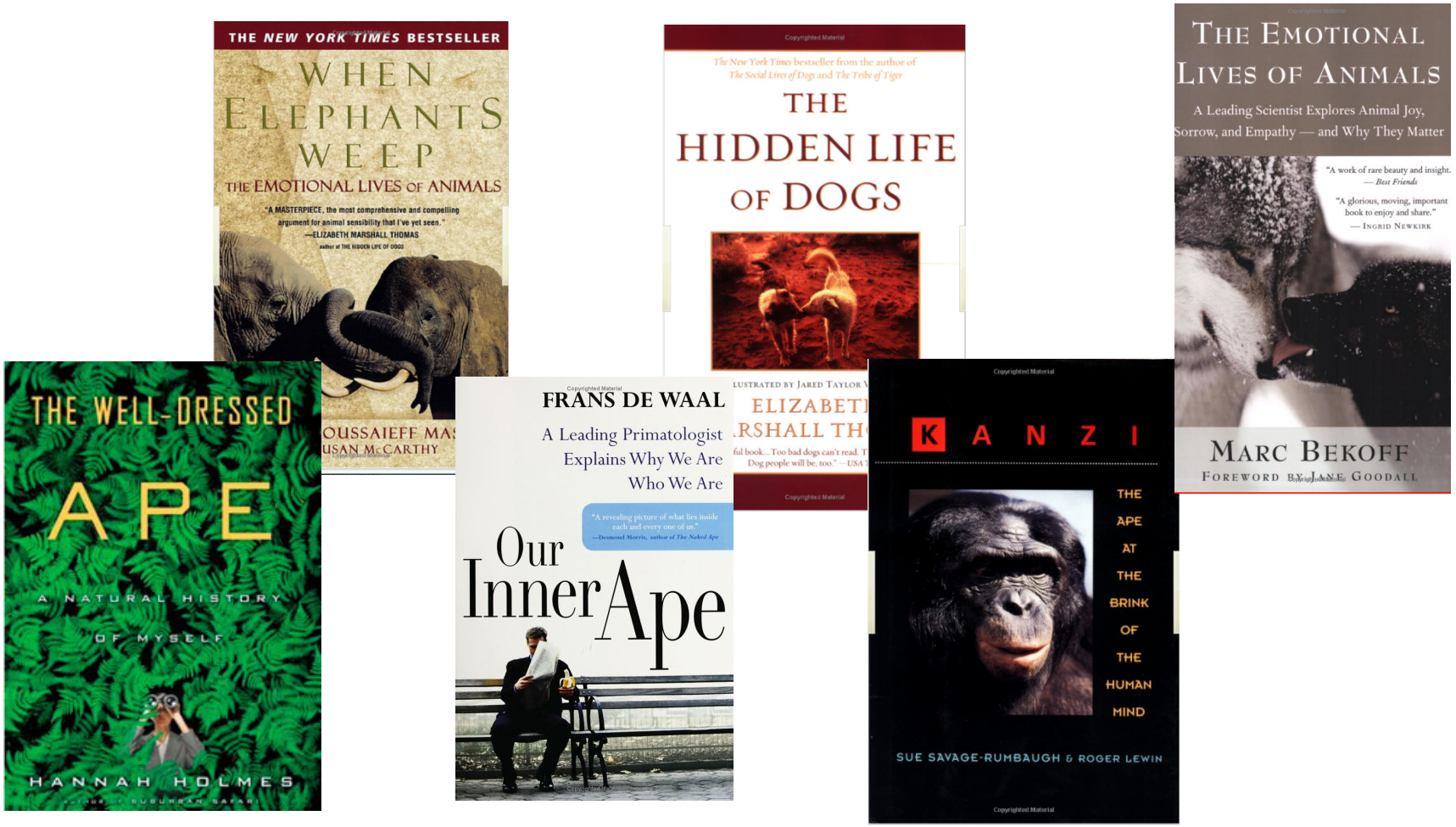
Darwin's tendentious claim (for 19th century readers)

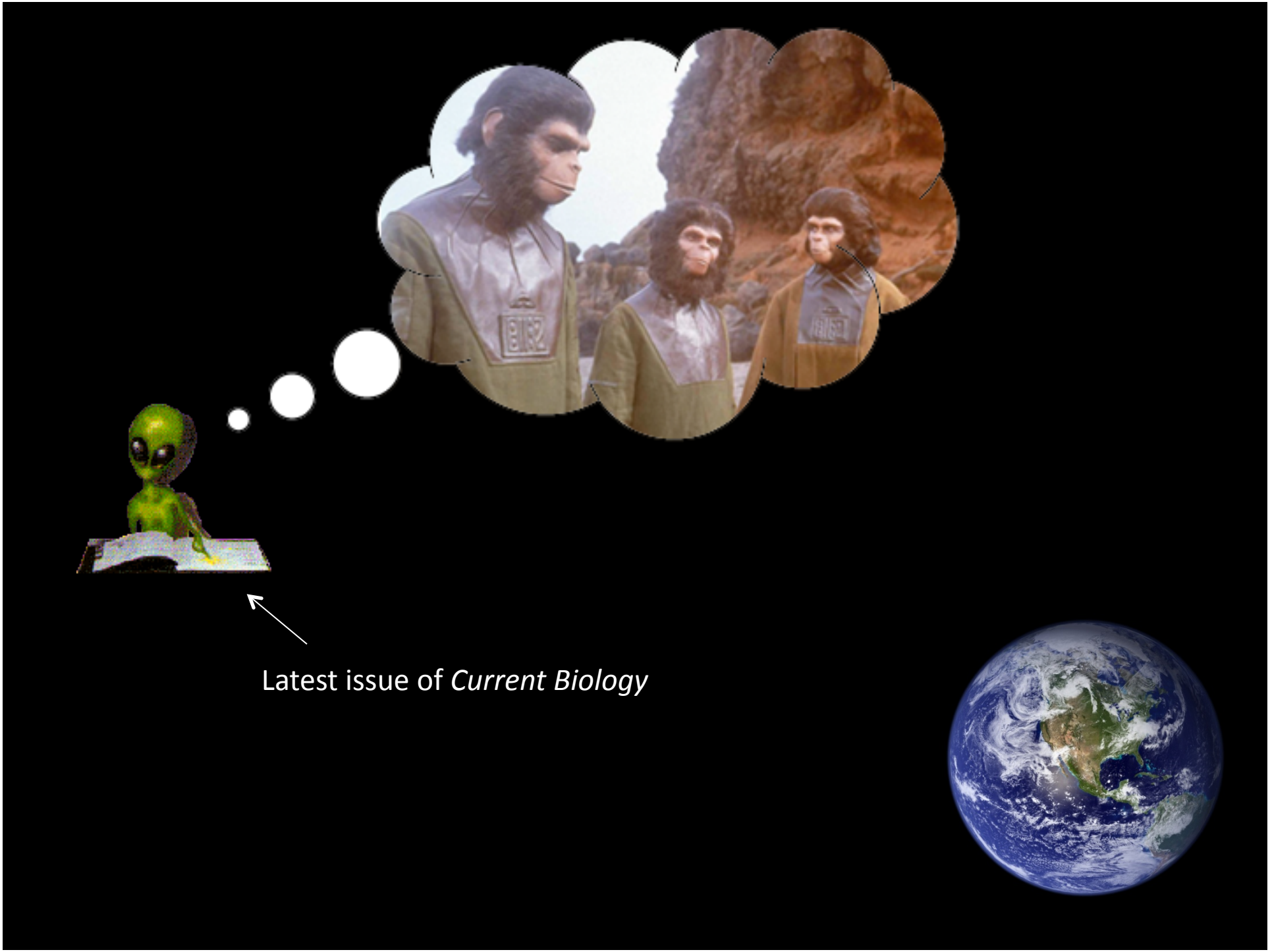
The difference in mind between man and the higher animals, great as it is, certainly is one of degree and not of kind

Darwin's tendentious claim (for 21st century readers)

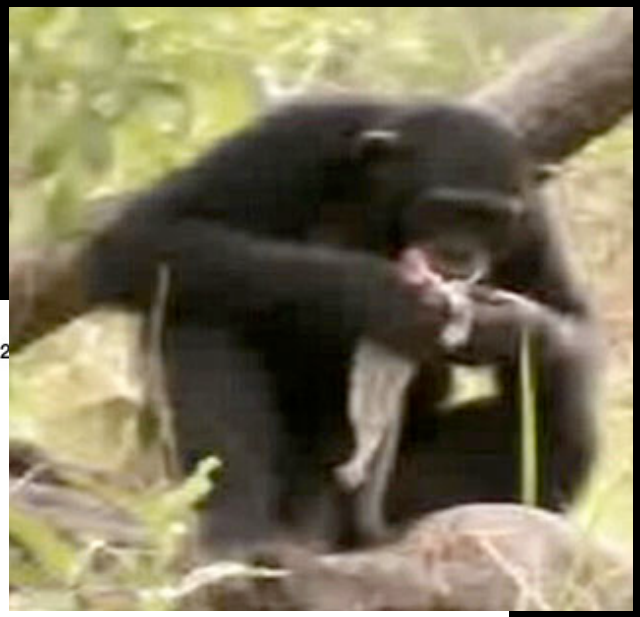
the gap between human and nonhuman minds is enormous and is not the result of culture or language alone

many comparative psychologists don't agree…




Latest issue of *Current Biology*

for example...



Current Biology *17*, 412–417, March 6, 2007 ©2007 Elsevier Ltd All rights reserved DOI 10.1016/j.cub.2

Savanna Chimpanzees, *Pan troglodytes verus*, Hunt with Tools

Jill D. Pruetz[1,*] and Paco Bertolani[2]
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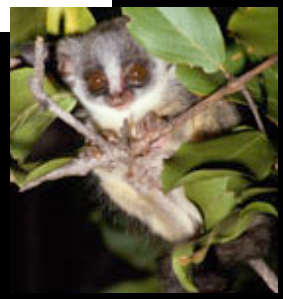
adolescent female at Mahale, Tanzania used a branch to rouse a squirrel from a hollow branch [6].

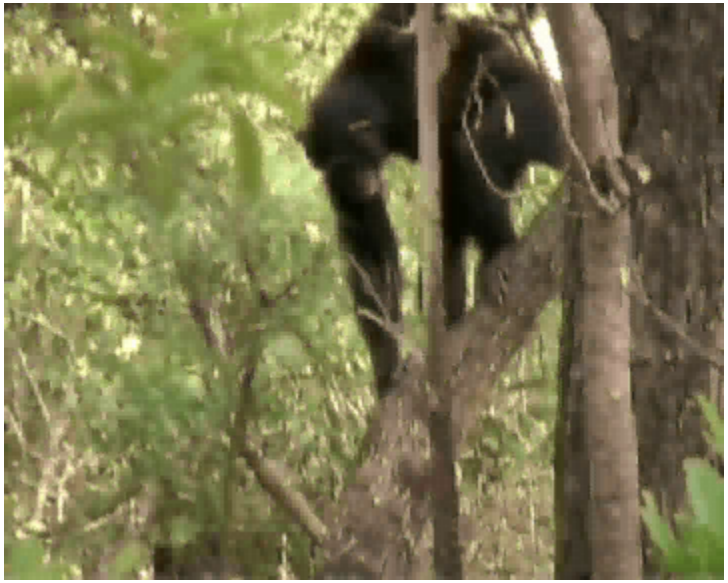
The observed hunts were recorded between March 2005 and July 2006. Bushbabies are small (weighing about 200 g [7]), nocturnal prosimians that sleep in hollow cavities or other shelters during the day [8]. Consumption of prosimian prey is itself rare for chimpanzees [4]. At most long-term study sites, red colobus monkeys (*Piliocolobus* sp.), which are absent from this dry site, are the most common prey recorded for chimpanzees [9].

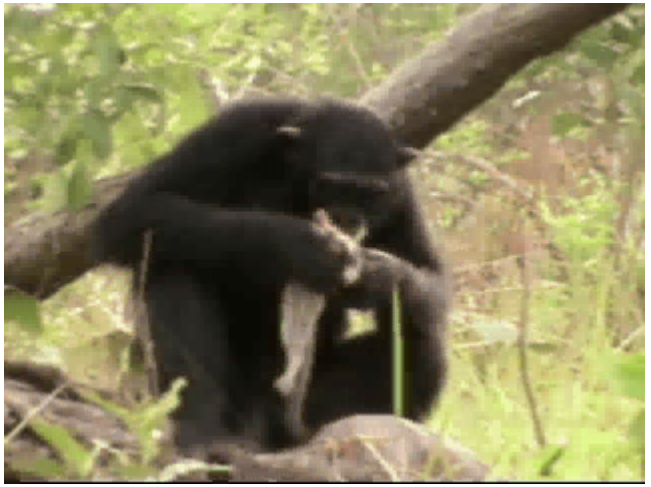


the evidence:

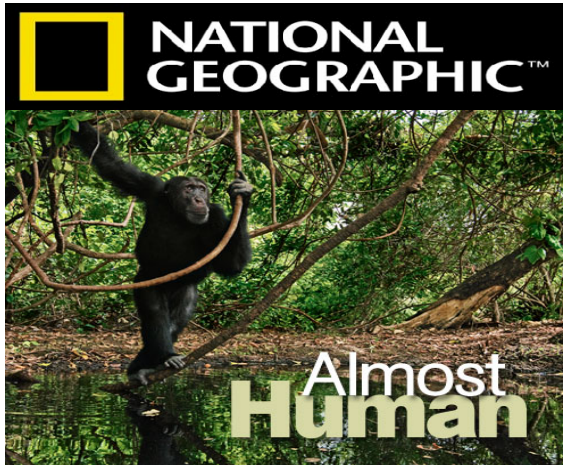
Pruetz et al. (2007) observed:

22	# of cases of a chimp poking a stick in a log
1	# of cases of a chimp eating a bushbaby shortly after poking
0	# of cases of a stick actually coming in contact with a bushbaby





the spin:



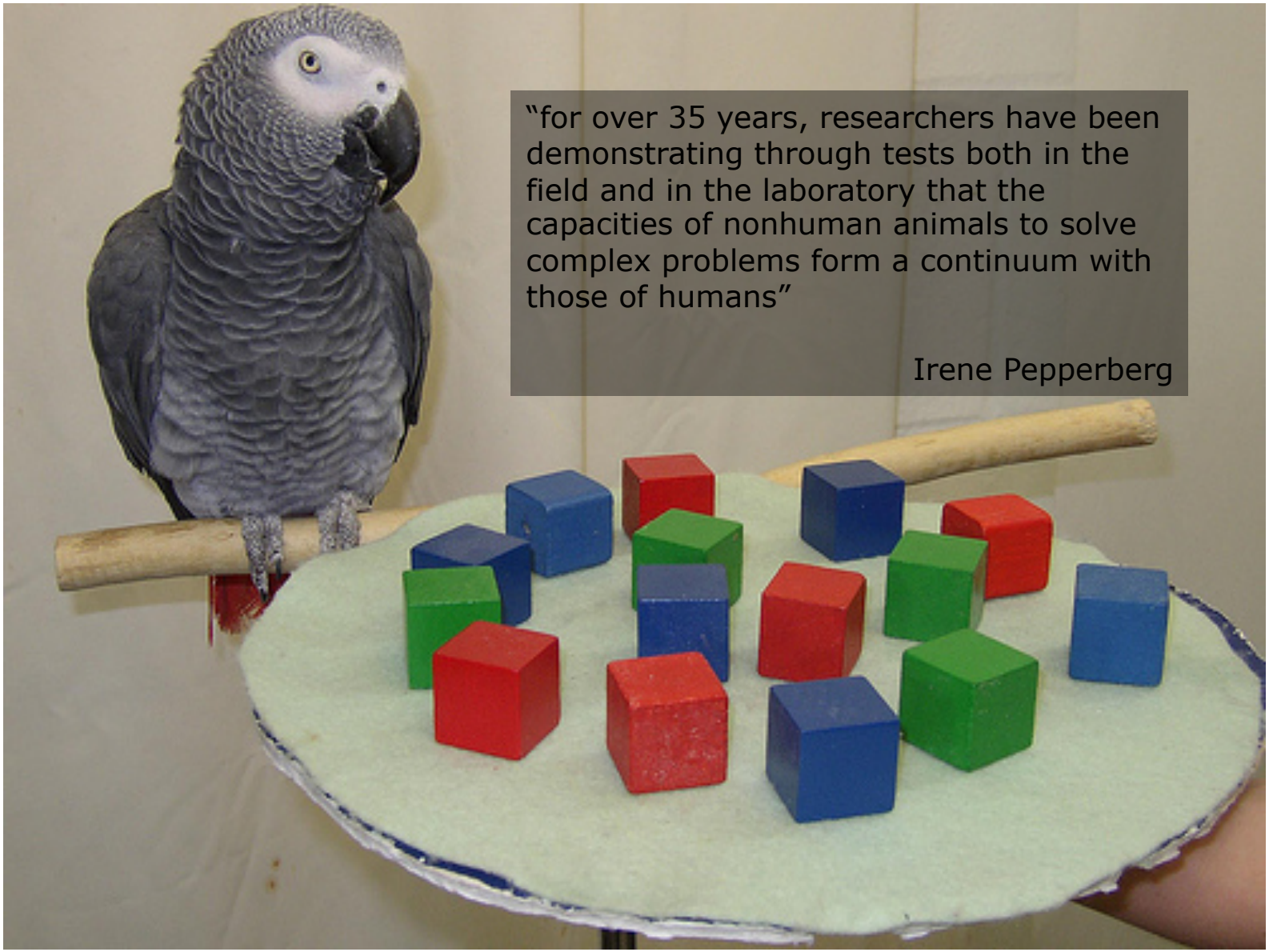
"Spear-wielding chimps snack on skewered bushbabies"
New Scientist

"How long until they fire up the barbecue?"
Nova special, "Ape Genius"

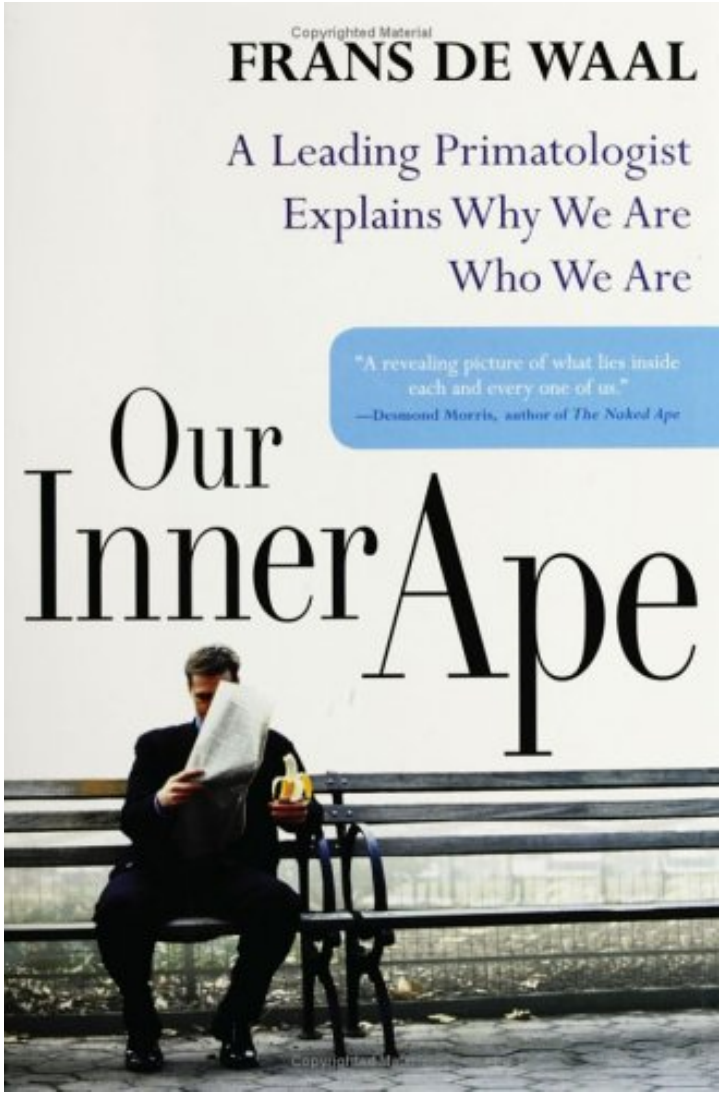
"A revelation that destroys yet another cherished notion of human uniqueness"
National Geographic special, "Almost Human"

"Back to the drawing board in terms of trying to define how humans are special"
Jill Pruetz

the dominant consensus



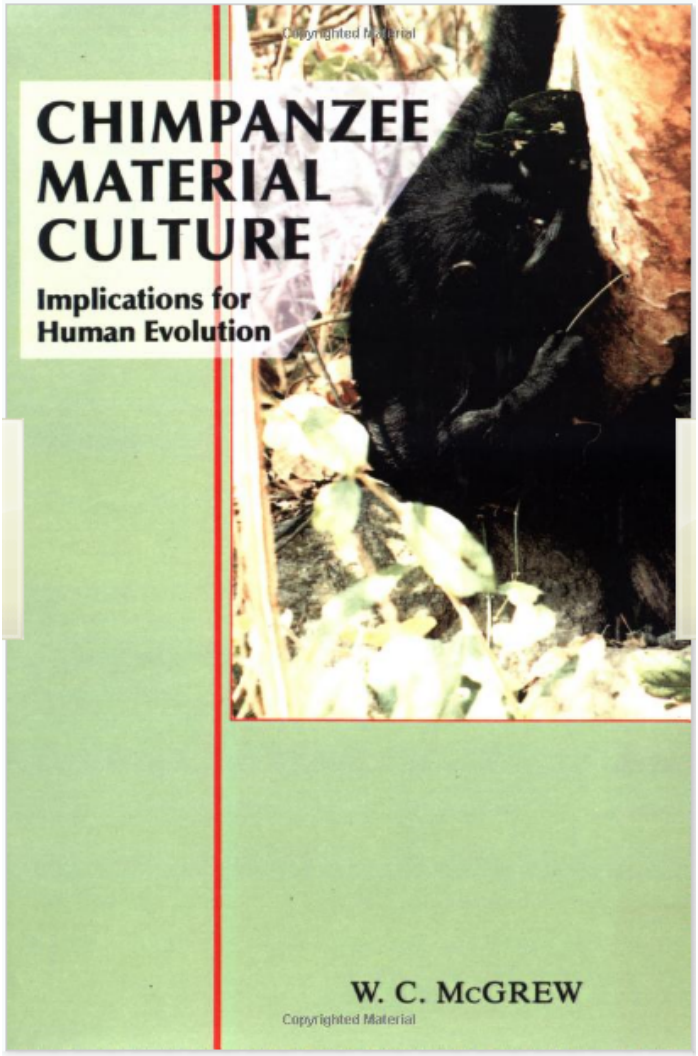
some deny there's a gap at all...



"I don't believe in a mental gap between humans and apes"

Frans de Waal

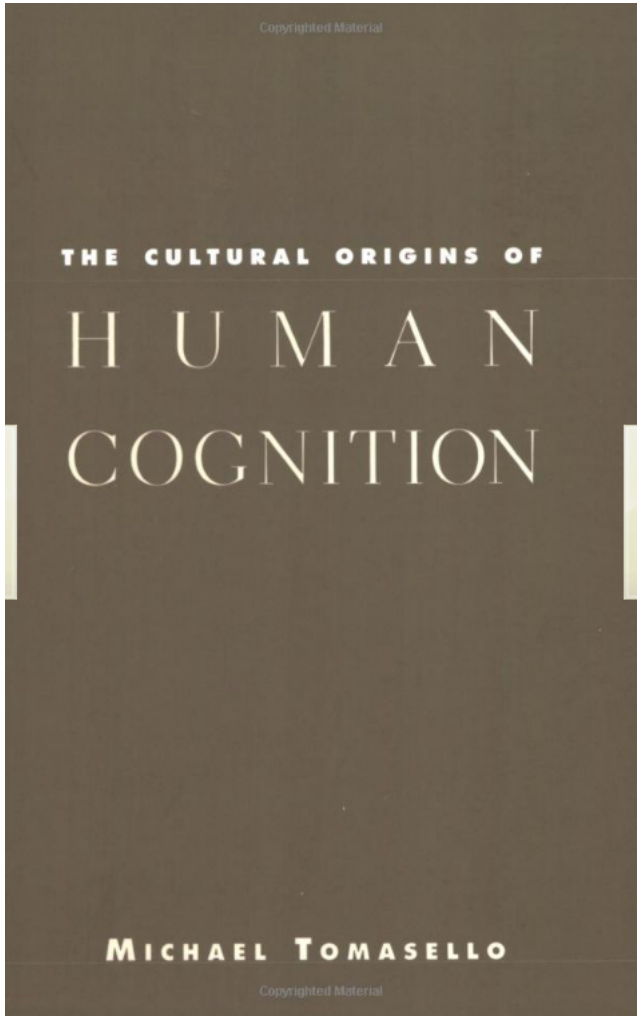
or claim the gap is actually quite small...



"The technological gap between chimpanzees and human societies that live by foraging is surprisingly narrow."

William McGrew

and most believe the gap is largely due to culture and/or language



"Many different studies suggest that nonhuman great apes understand the physical world in basically the same way as humans"

"What most clearly distinguishes human cognition from that of other primates, therefore, is their adaptations for functioning in cultural groups"

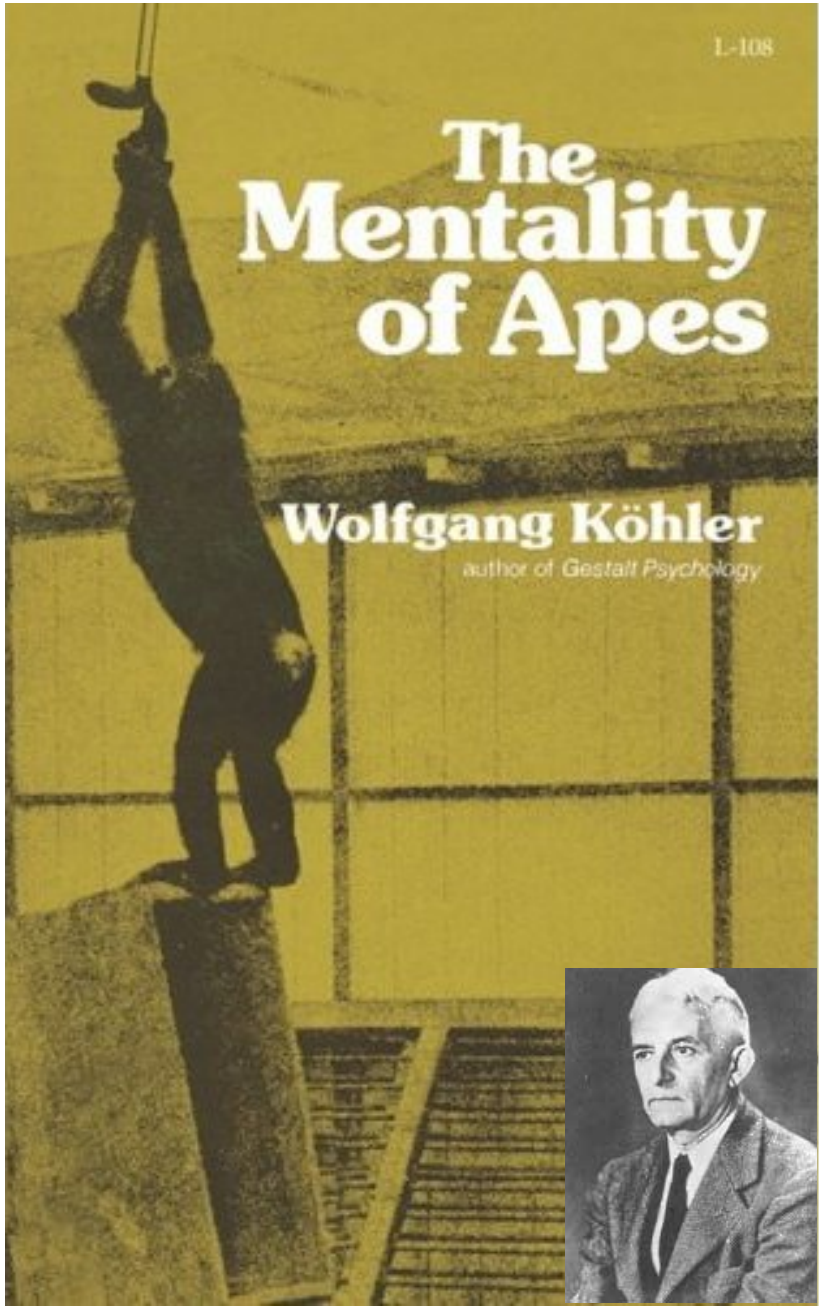
Michael Tomasello

the consensus view

animals understand the physical world in basically the same way as humans.

the gap (if there is one) is social

let's re-examine the evidence



first systematic investigation of animal tool-use

widely cited as evidence of "insight" learning

In fact:

it took Kohler's chimps hundreds of trials to solve this task

they continued to stack boxes in impossible configurations for years

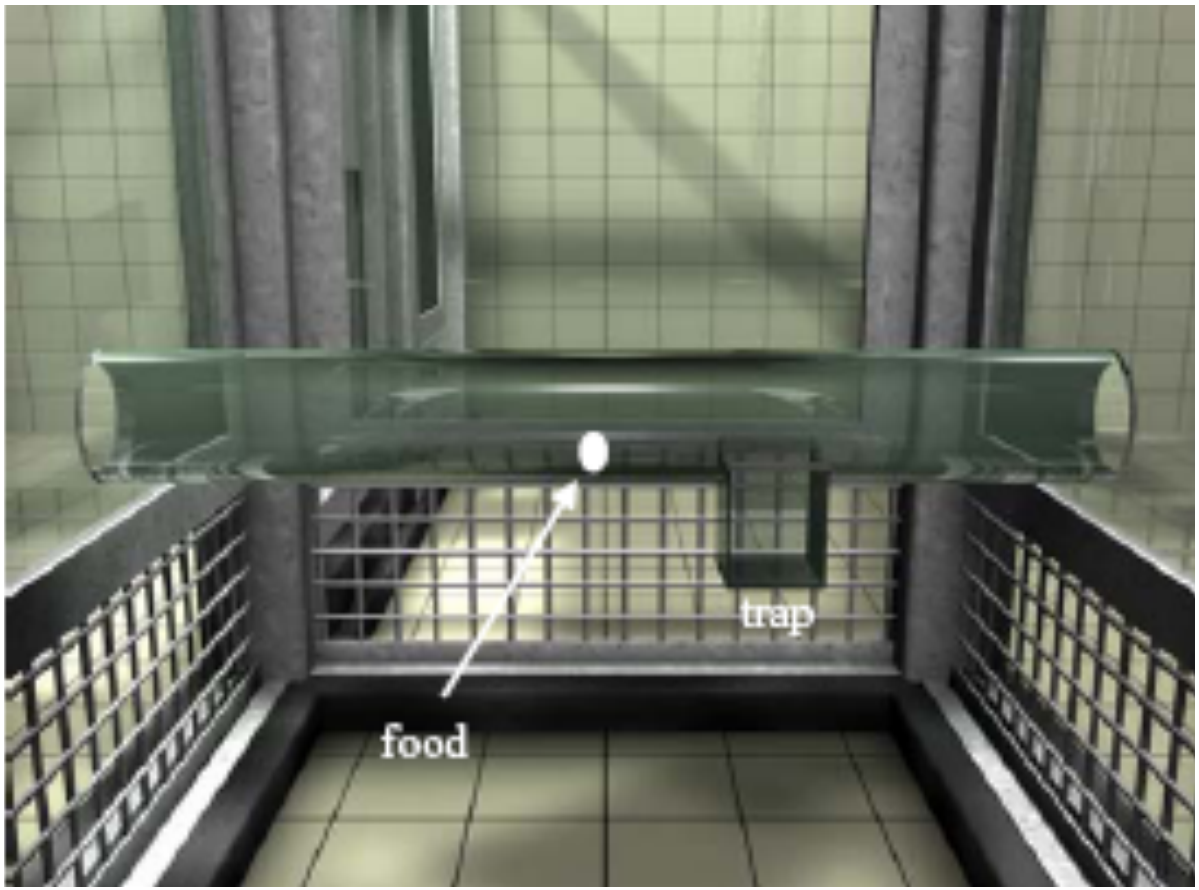
and they never generalized to novel problems

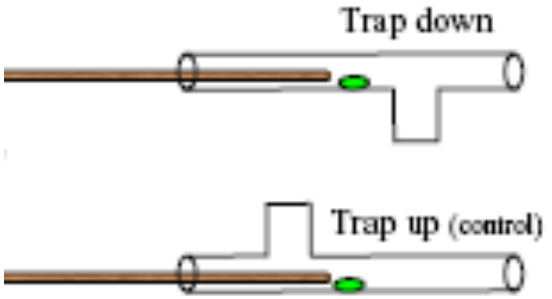
"If you did not know that the animals see perfectly well..., you might believe that you were watching extremely weak-sighted creatures."

Mentality of Apes, Wolfgang Kohler, 1925

chimps are very good at using sticks to retrieve rewards...

so why is this task so hard for them?





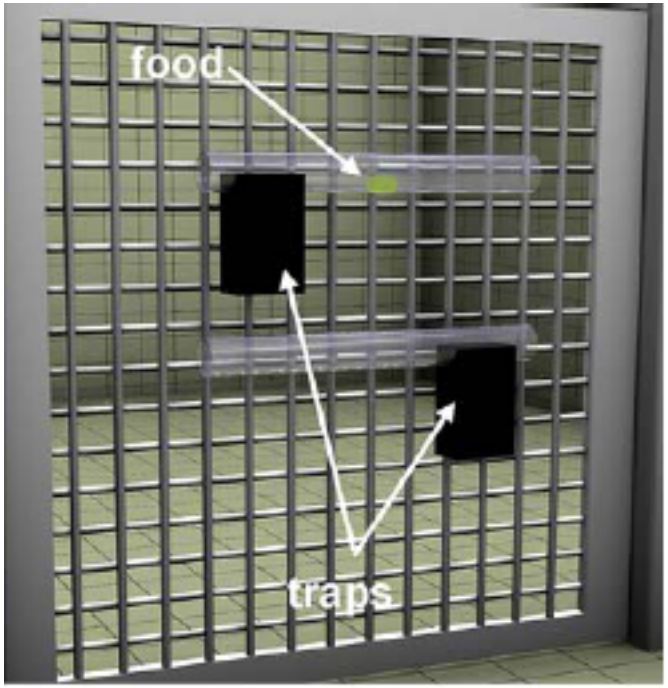
(Visalberghi et al. 1994 J. Comp. Psych)

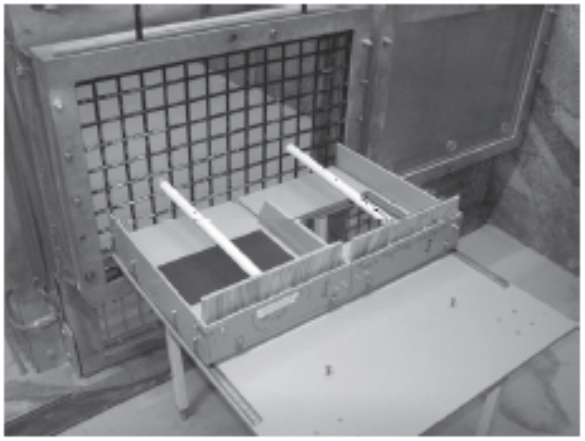
After 120 trials, only one of four capuchin monkeys learned to push the reward away from the trap... and then failed the control task

(Povinelli 2000 *Folk Physics)*

After 100 trials, only one chimp out of seven solved the task... and then failed the control task

dozens of challenges... same conclusion





- A table is easier than a tube—but success doesn't transfer (Povinelli 2000; Martin-Ordas 2008)

- Pulling is easier to learn than pushing—but success doesn't transfer (Mulcahy and Call, 2004)

- Using a finger is easier than using a stick—but success doesn't transfer (Seed et al. 2009)

- Rooks can learn to solve trap-tube problems much faster than chimps... but success doesn't transfer (Seed et al. 2006)

One fundamental difference between human and nonhuman causal cognition

- animals learn and reason about the perceptual relationships required to solve specific tasks (e.g., make contact with food, push food away from trap, align edges of boxes)

- but only humans reason about higher-order, unobservable causal mechanisms that apply across disparate tasks (e.g., gravity, connection, rigidity)

- the inability to reason by analogy is the missing link

(Penn and Povinelli, 2007, *Annual Review of Psychology*)

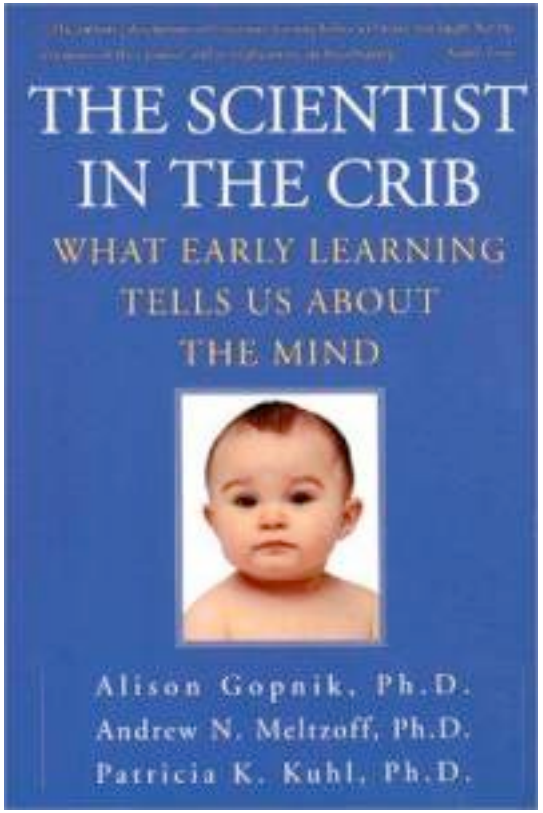
our colleagues in Leipzig (seem to) agree

"Apes may possess some specific causal knowledge but lack the ability to establish analogical relations between functionally equivalent tasks."

(Martin-Ordas and Call, 2008)

but that's not all folks...

human children are "little scientists"



"Preschoolers engage in more exploratory play when evidence is confounded"

Schulz and Bonawitz 2007, *Developmental Psychology*

"Preschool children learn about causal structure from conditional interventions "

Schulz, Gopnik and Glymour, 2007, *Developmental Science*

do chimps seek explanations?

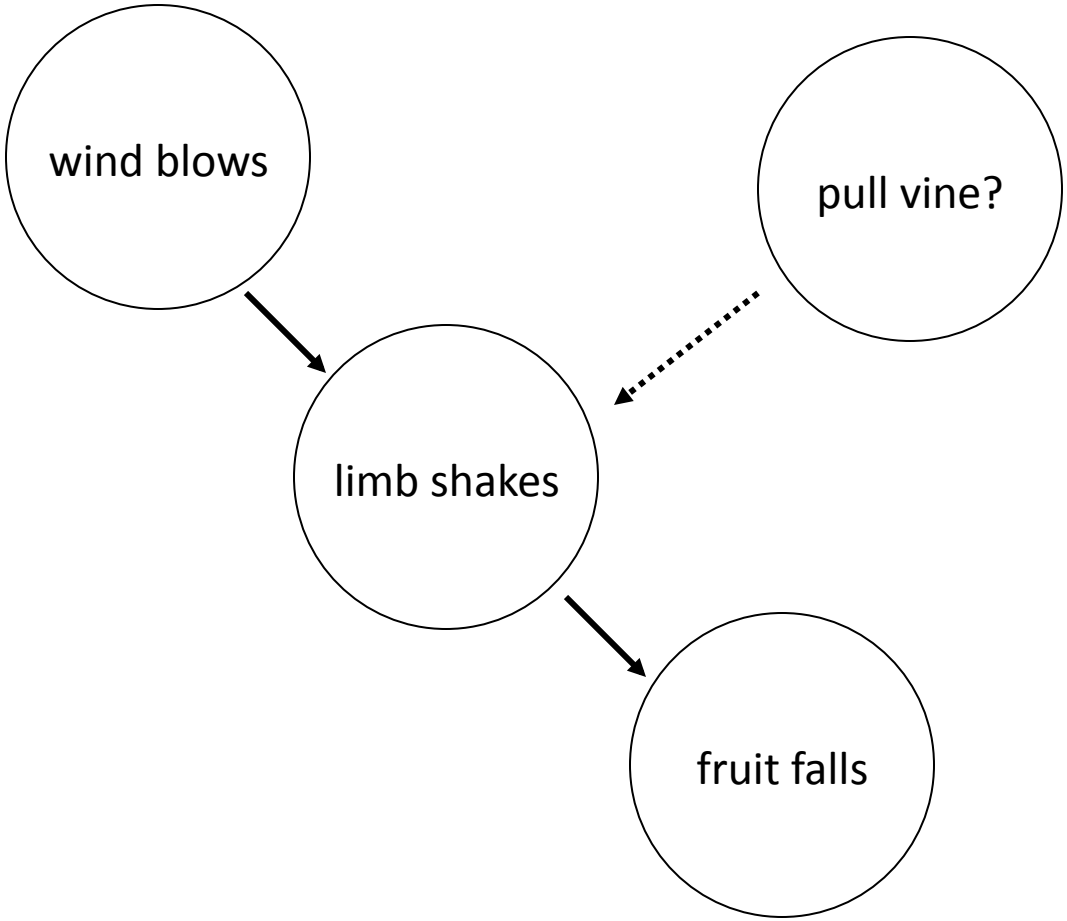
when faced by trick blocks:

the human children examined the block to try and figure out what was wrong

the chimps just kept trying... (except for one who put the block in her mouth)

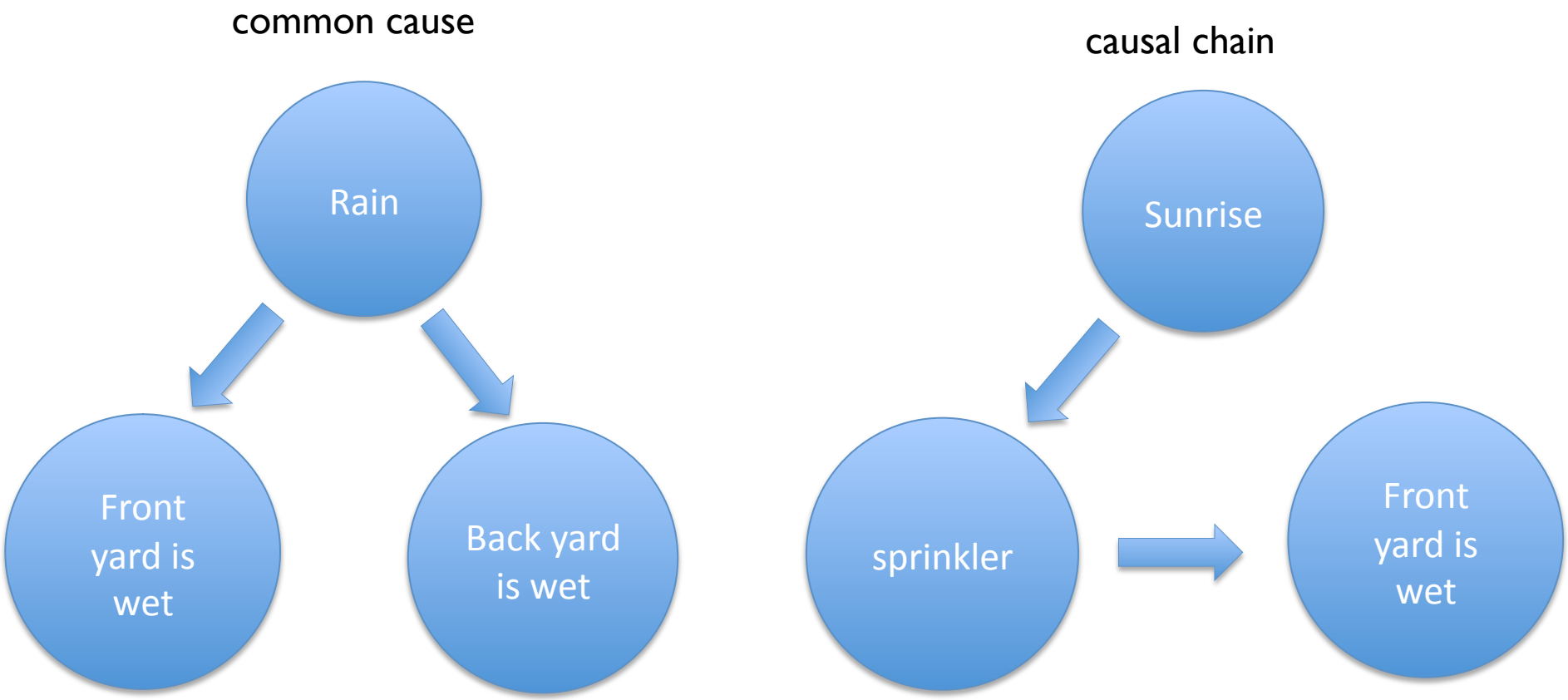
(Povinelli and Dunphy-Lelii 2001)

can animals intervene creatively?



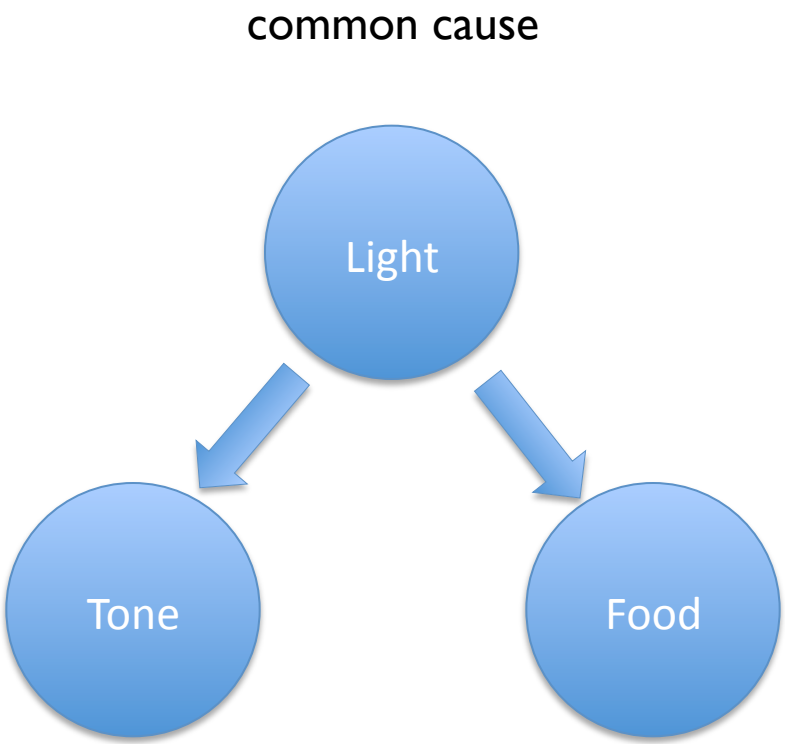
(Tomasello and Call 1997 p. 389)

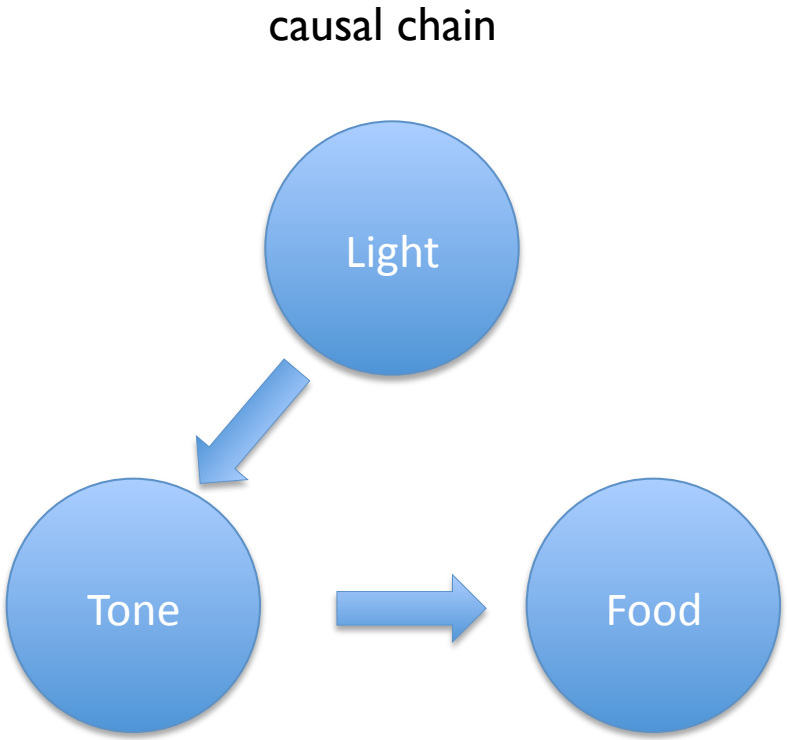
the world is full of causal structures



(Blaisdell et al., 2006, *Science*)

can animals reason about causal structures?



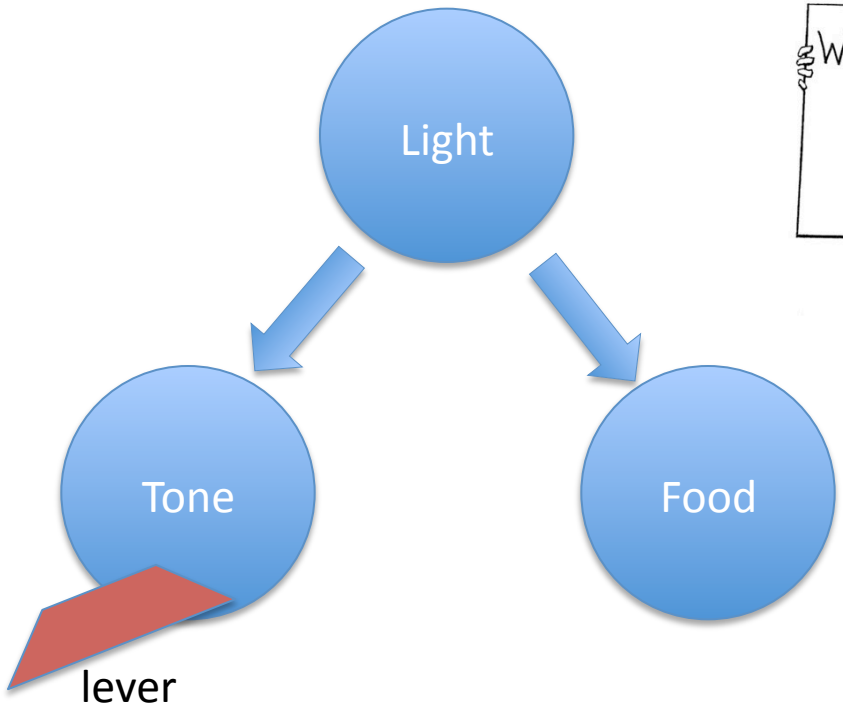


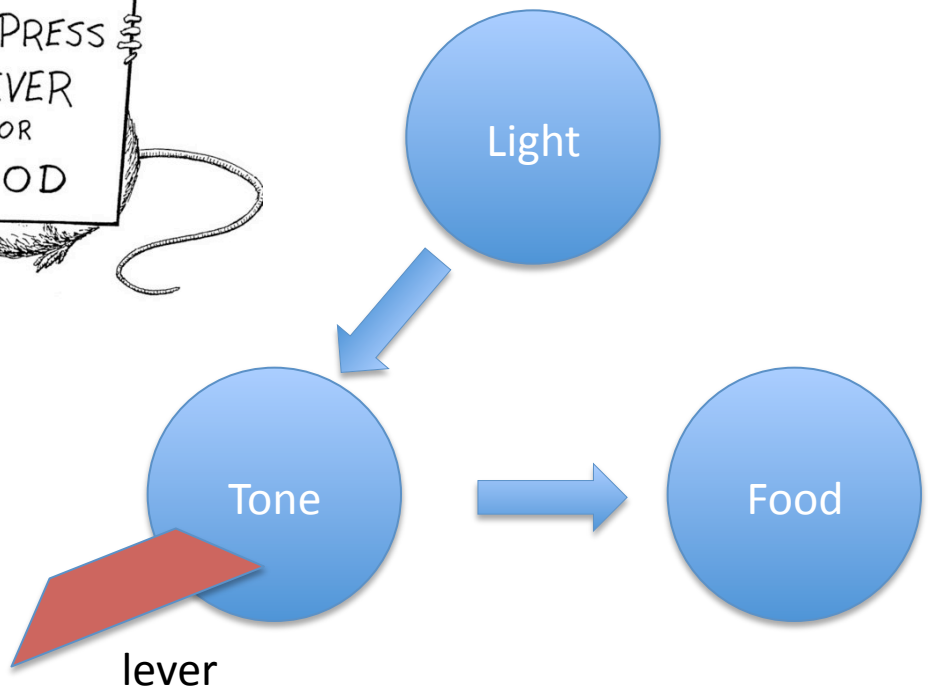
(Blaisdell et al., 2006, *Science*)

can animals reason about causal structures?

common cause

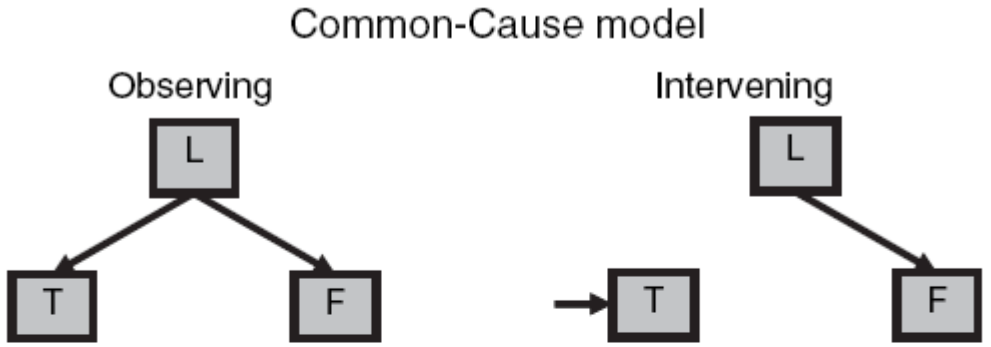
causal chain



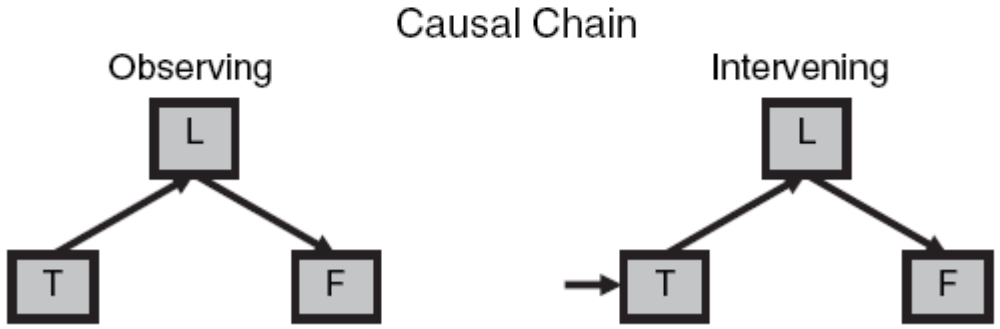


(Blaisdell et al., 2006, *Science*)

rats do learn about causal relations



rats who observed T nose-poked for food more frequently than rats who intervened on T

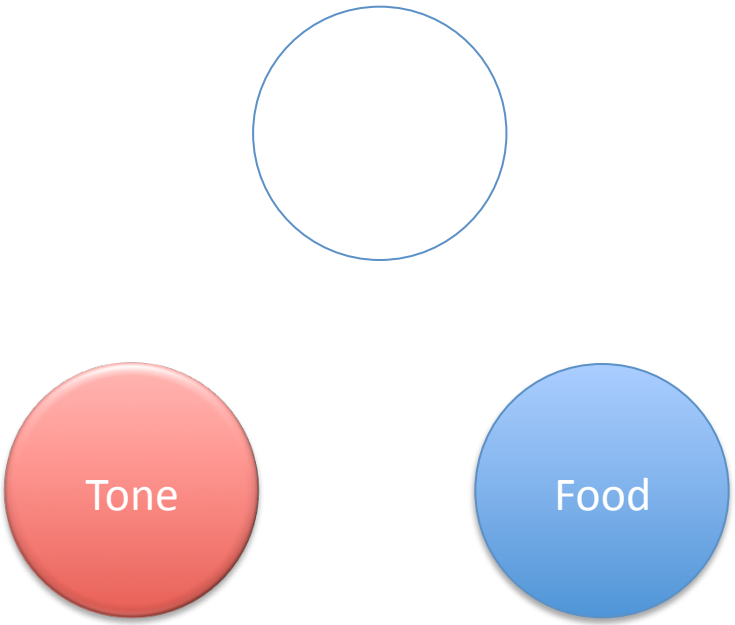


no difference in nose-poking between observe and intervene groups for rats trained on causal chain model

(Blaisdell et al., 2006, *Science*)

but no evidence of diagnostic reasoning

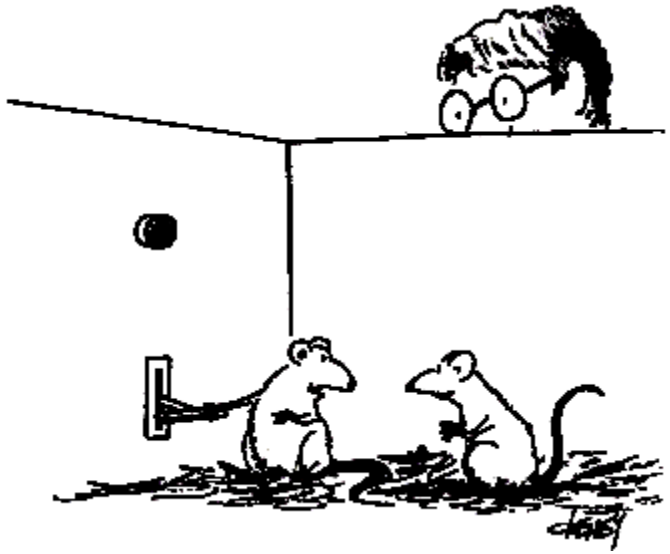
Observe Tone but no Light



rats in the common-cause condition who observed T nose-poked for F even though L was conspicuously absent!

(Blaisdell et al., 2006, *Science*)

in short, animals don't cognize their interventions in a human-like fashion



It's a rather interesting phenomenon. Every time I press this lever, that post-graduate student breathes a sigh of relief

the many epistemic uses of interventions

- to disambiguate causal structures
- to probe for hidden causes
- to hold alternative causes constant
- to test the causal properties of a tool
- etc…

only one of these creatures is a
'little scientist'

Tomasello's "cultural intelligence" hypothesis

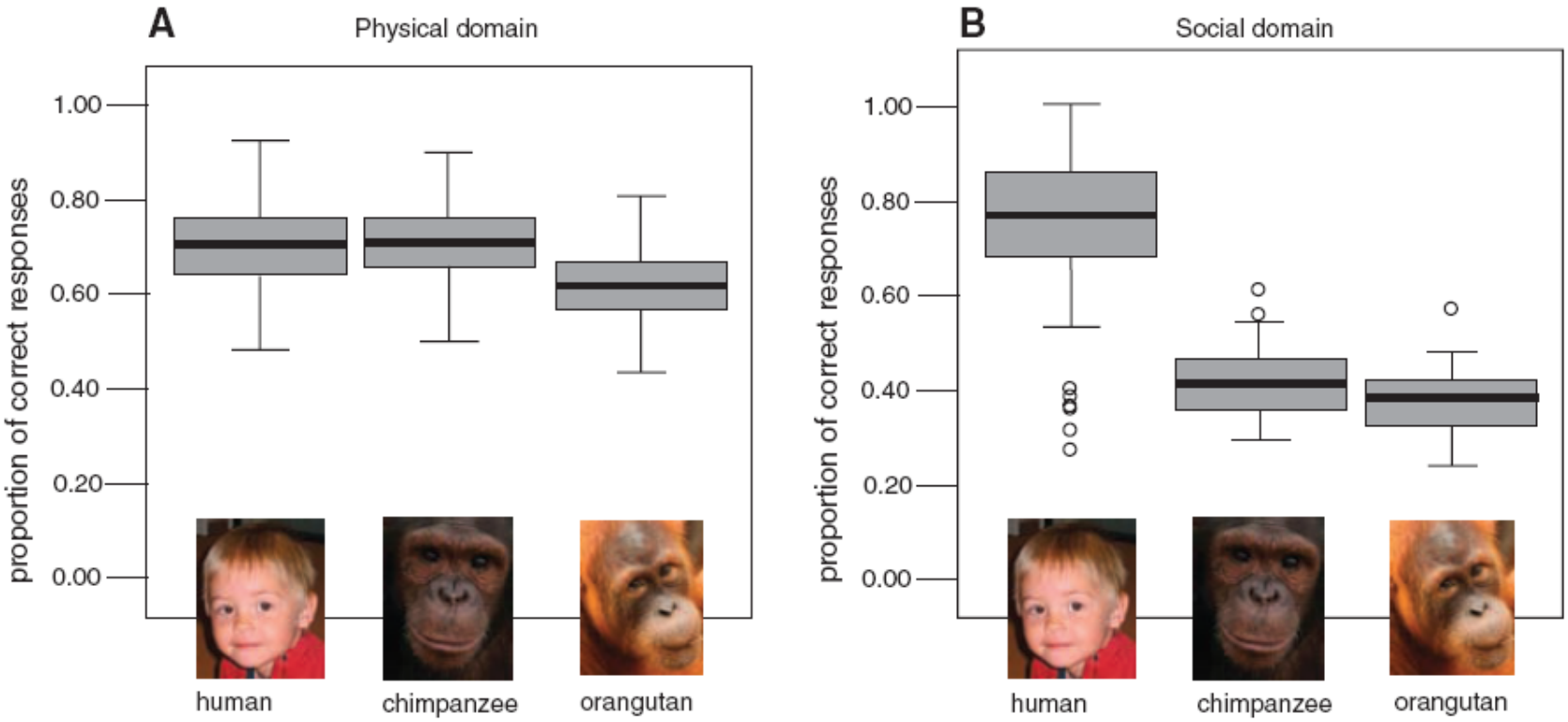
Humans Have Evolved Specialized Skills of Social Cognition: The Cultural Intelligence Hypothesis

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

Humans have many cognitive skills not possessed by their nearest primate relatives. The cultural intelligence hypothesis argues that this is mainly due to a species-specific set of social-cognitive skills, emerging early in ontogeny, for participating and exchanging knowledge in cultural groups. We tested this hypothesis by giving a comprehensive battery of cognitive tests to large numbers of two of humans' closest primate relatives, chimpanzees and orangutans, as well as to 2.5-year-old human children before literacy and schooling. Supporting the cultural intelligence hypothesis and contradicting the hypothesis that humans simply have more "general intelligence," we found that the children and chimpanzees had very similar cognitive skills for dealing with the physical world but that the children had more sophisticated cognitive skills than either of the ape species for dealing with the social world.

There have been no direct tests of the cultural intelligence hypothesis, nor any direct comparisons of it with other hypotheses of human cognitive evolution. The social intelligence hypothesis for primates in general is supported by positive correlations between relative brain size (i.e., neocortex size) and social variables such as group size or grooming clique size [as an index of social complexity (*11*, *17*–*20*)]. This evidence provides support for the general social direction of the cultural intelligence hypothesis, but overall correlations do not tell us the basis of the brain size differences in terms of particular cognitive skills, nor do they help us to identify which cognitive skills humans may have that other primates lack. There have also been some experimental studies that directly compared the performance of several primate species on a few cognitive tasks, but in the only meta-analysis of those studies, none of the tasks targeted social cognition and humans were not represented (*21*). Several other experimental studies have directly

Herrmann et al. reported that the differences were only "social"



(Herrmann et al. 2007, *Science*)

but their own results tell a different story...

	Human	Chimpanzee	Orangutan
Physical	0.68^{O}	0.68^{O}	0.59
Space	0.71^{O}	0.71^{O}	0.60
Spatial memory	0.91	0.95	0.85
Object permanence	0.79^{C,O}	0.64	0.60
Rotation	0.55	0.56^{O}	0.46
Transposition	0.57	0.70^{H,O}	0.47
Quantities	0.67	0.68	0.63
Relative numbers	0.71	0.66	0.64
Addition numbers	0.64	0.69^{H,O}	0.61
Causality	0.65^{O}	0.66^{O}	0.55
Noise	0.85^{C,O}	0.61	0.56
Shape	0.83^{C,O}	0.68	0.64
Tool use	0.23	0.74^{H,O}	0.38
Tool properties	0.71^{C,O}	0.61	0.63
Social	0.74^{C,O}	0.36	0.33
Social learning	0.86^{C,O}	0.10	0.07
Communication	0.72^{C,O}	0.57	0.55
Comprehension	0.84^{C,O}	0.63	0.65
Pointing cups	0.72	0.74	0.73
Attentional state	0.59^{C,O}	0.34	0.26
Theory of mind	0.65^{C,O}	0.40	0.36
Gaze following	0.45^{C,O}	0.22	0.17
Intentions	0.85^{C,O}	0.59	0.56

Superscripts indicate that values are significantly higher than human (H), chimpanzee (C), or orangutan (O) values.

the children beat the apes on every test of causal reasoning except the stick-task...

as they admit in the final pages...

"we should note that because the children were somewhat more skillful than the apes in the causality tasks not involving active tool manipulation, as well as in the tasks of social cognition, it is possible that what is distinctively human is not social-cultural cognition as a specialized domain, as we have hypothesized. Rather, what may be distinctive is the ability to understand unobserved causal forces in general, including (as a special case) the mental states of others as causes of behavior."

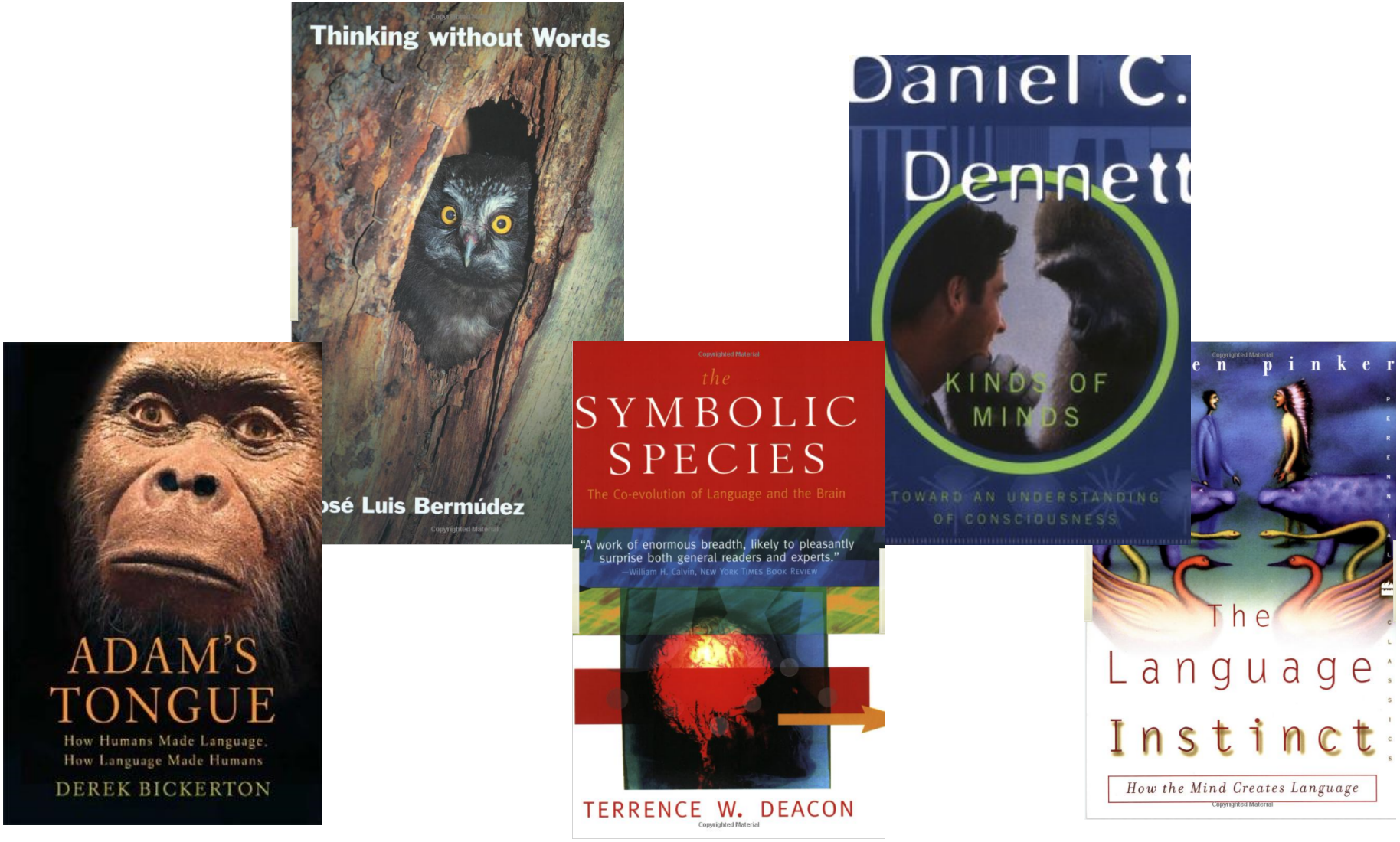
(Herrmann et al. , 2007, p. 1365)

tendentious claim #2

the gap between human and nonhuman causal cognition is at least as large as the gap between human and nonhuman social cognition

So why does human causal cognition stick out like an elephant's trunk?

Is language the key?

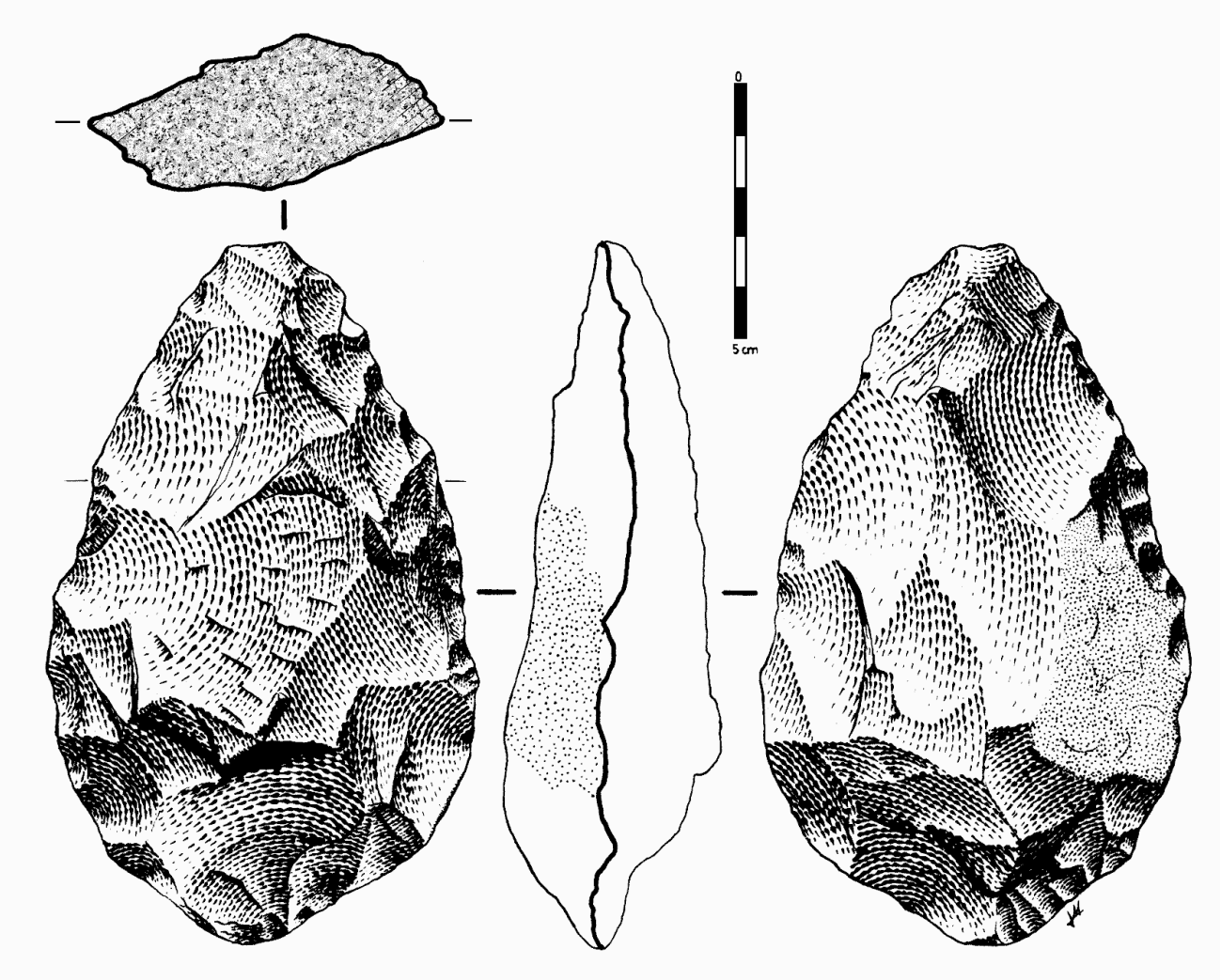


Language is clearly instrumental

but language alone is not enough...

- symbol-trained chimps are not any more adept at tools or causal reasoning
- human minds are unique *without* language (e.g., aphasics)
- children are “little scientists” before they have words for their theories

Uniquely human tool-use began long before language



And language relies largely on domain-general, uniquely human abilities

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Language as shaped by the brain

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S (2009) **32**, 429–492

The myth of language universals: Language diversity and its importance for cognitive science

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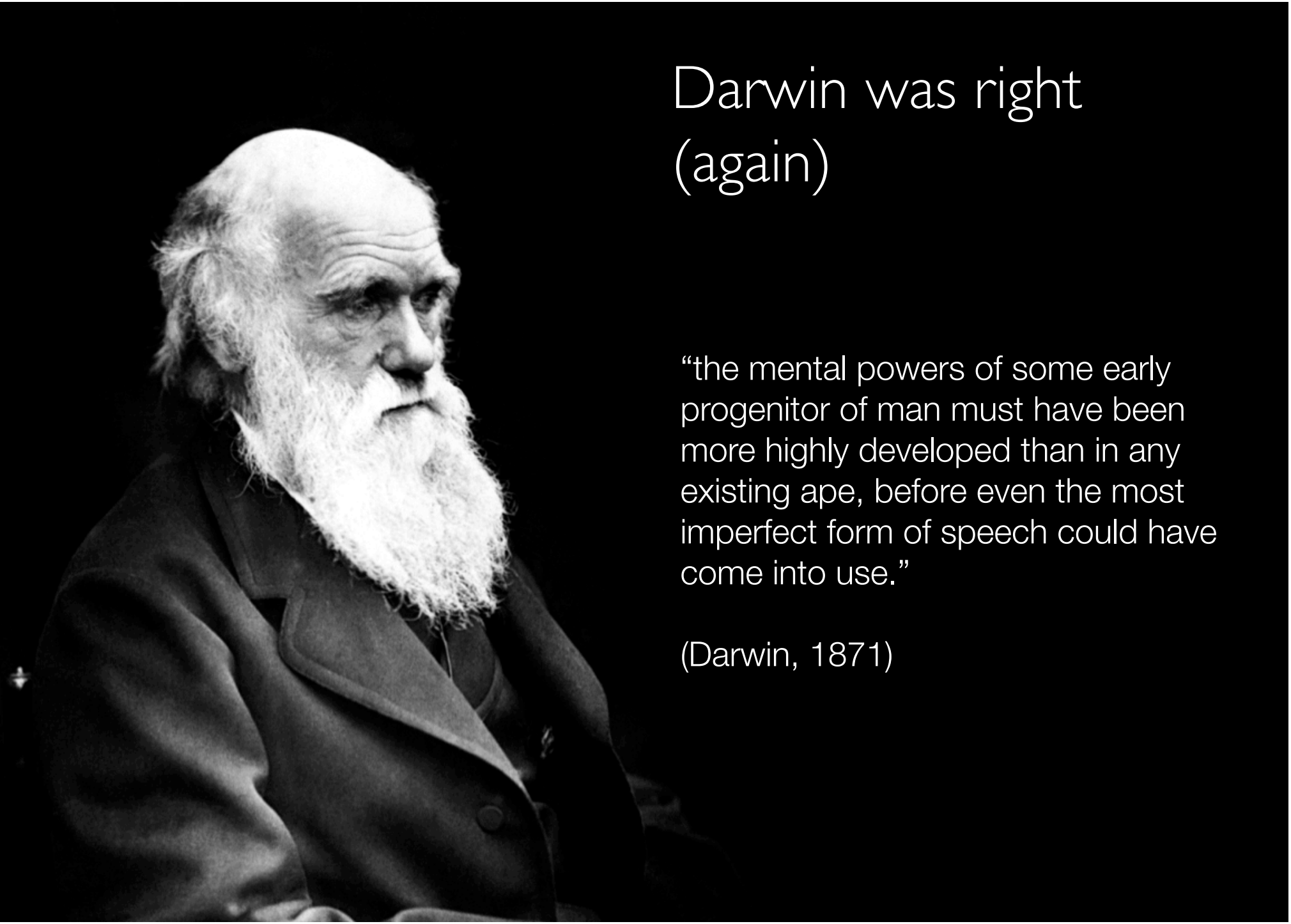
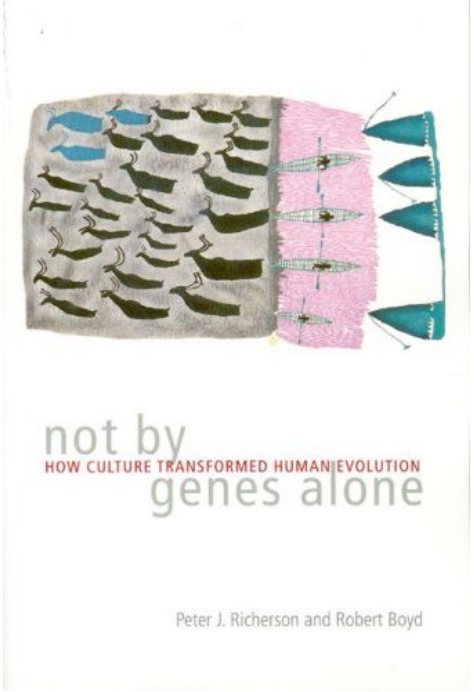


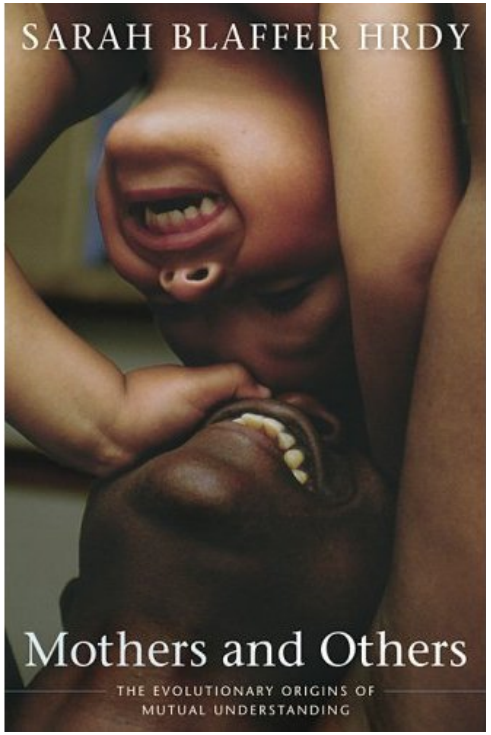
Darwin was right (again)

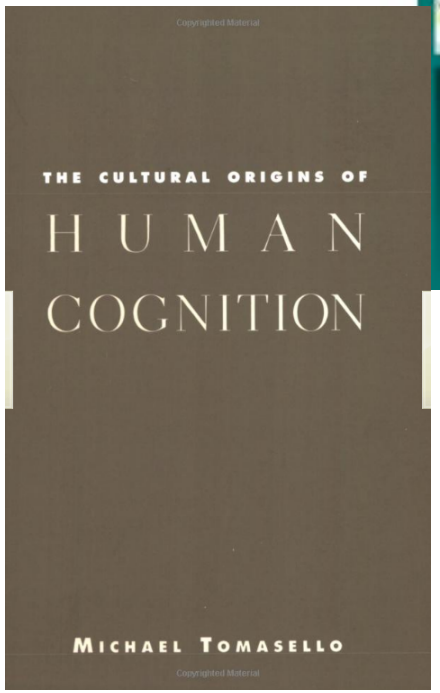
"the mental powers of some early progenitor of man must have been more highly developed than in any existing ape, before even the most imperfect form of speech could have come into use."

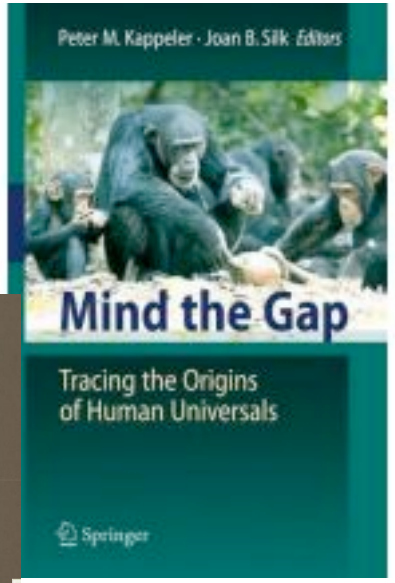
(Darwin, 1871)

so is human culture what makes humans unique?



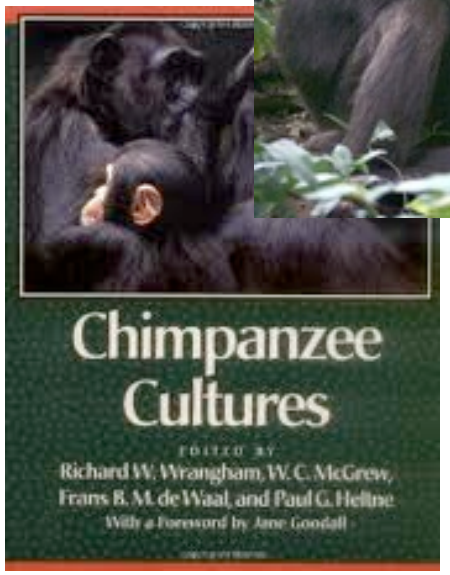






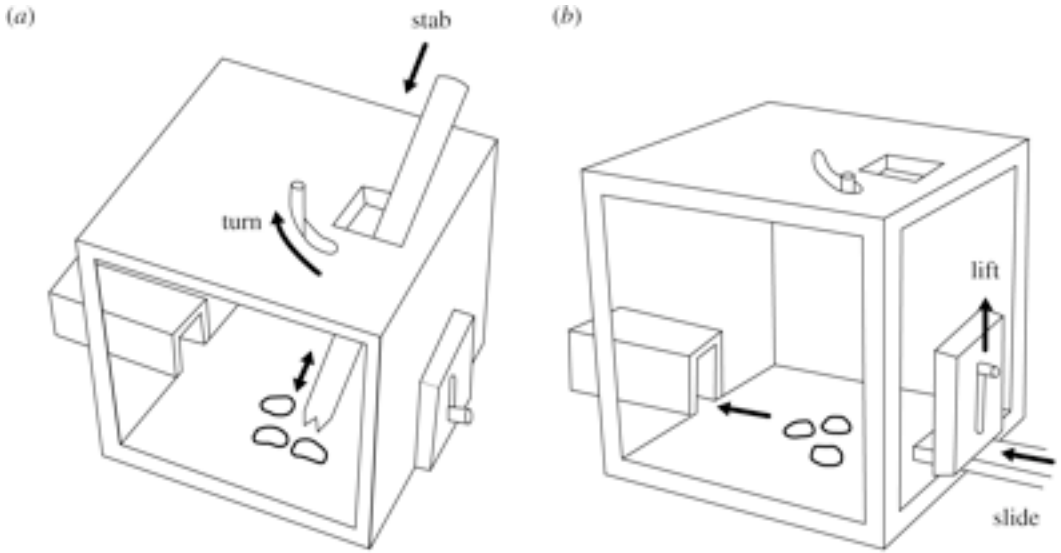
human culture is exceptional

but animals have "cultures" as well



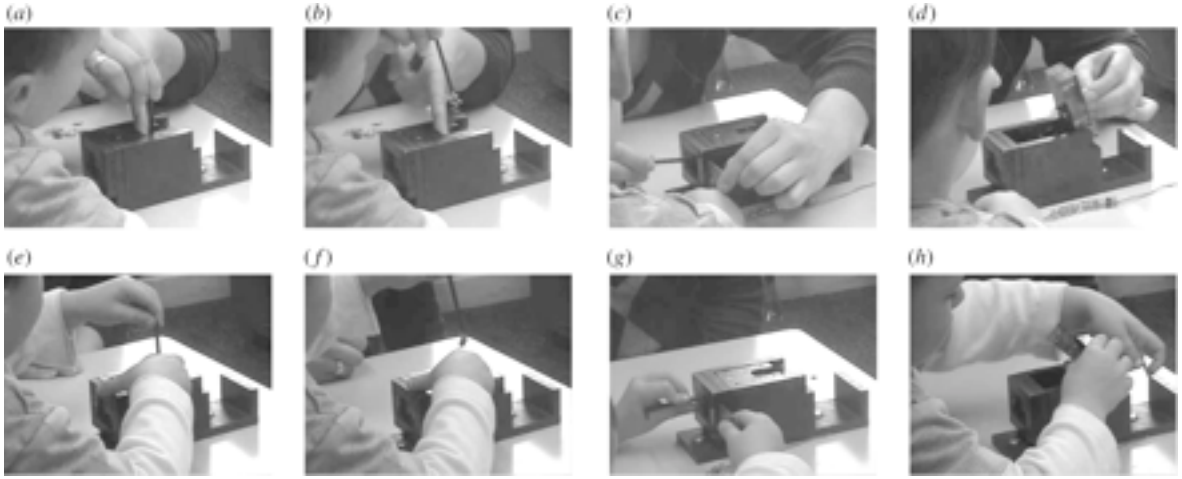
so why is *cumulative* cultural evolution uniquely human?

chimpanzees can copy and learn from each other



Transmission of alternative foraging techniques within and across groups of chimpanzees (Whiten et al. 2007 *Current Biology*).

but chimpanzees get "stuck"



"young chimpanzees exhibit a tendency to become 'stuck' on a technique they initially learn, inhibiting cumulative social learning and possibly constraining the species' capacity for cumulative cultural evolution"

(Marshall-Pescini and Whiten, 2008, *Animal Cognition)*

human teachers are unique (and underpaid)

but even with human teachers, animals don't learn like children

where would human culture be without:

- the ability to reason diagnostically?
- the ability to reason in terms of unobservable causal mechanisms such as weight and force?
- the ability to see functional similarities among perceptually disparate examples?
- or any epistemic curiosity?

tendentious claim #3

human culture would not be possible without human causal cognition

how did this multifarious gap evolve?

the "massively modular" hypothesis

social cognition

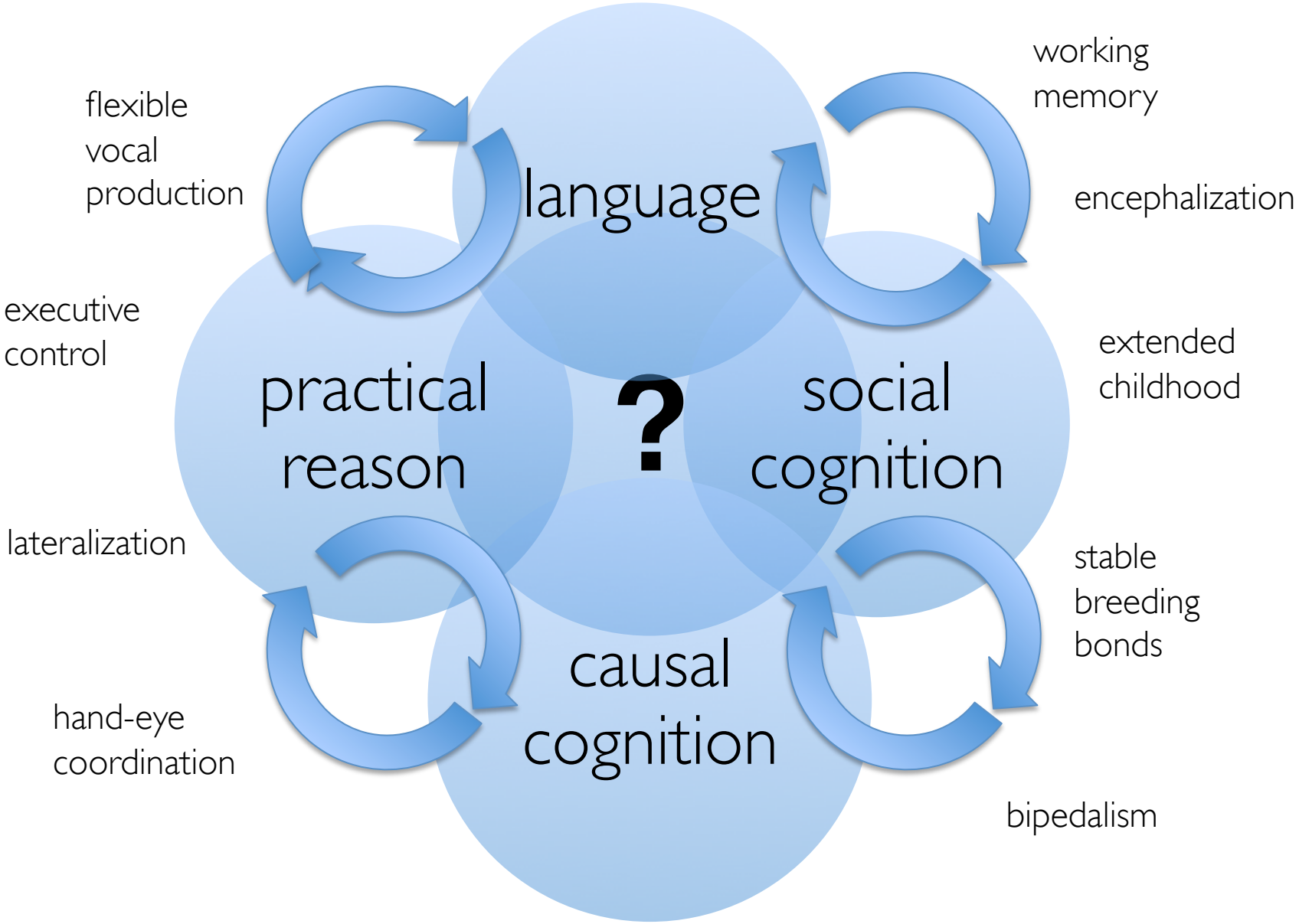
causal cognition

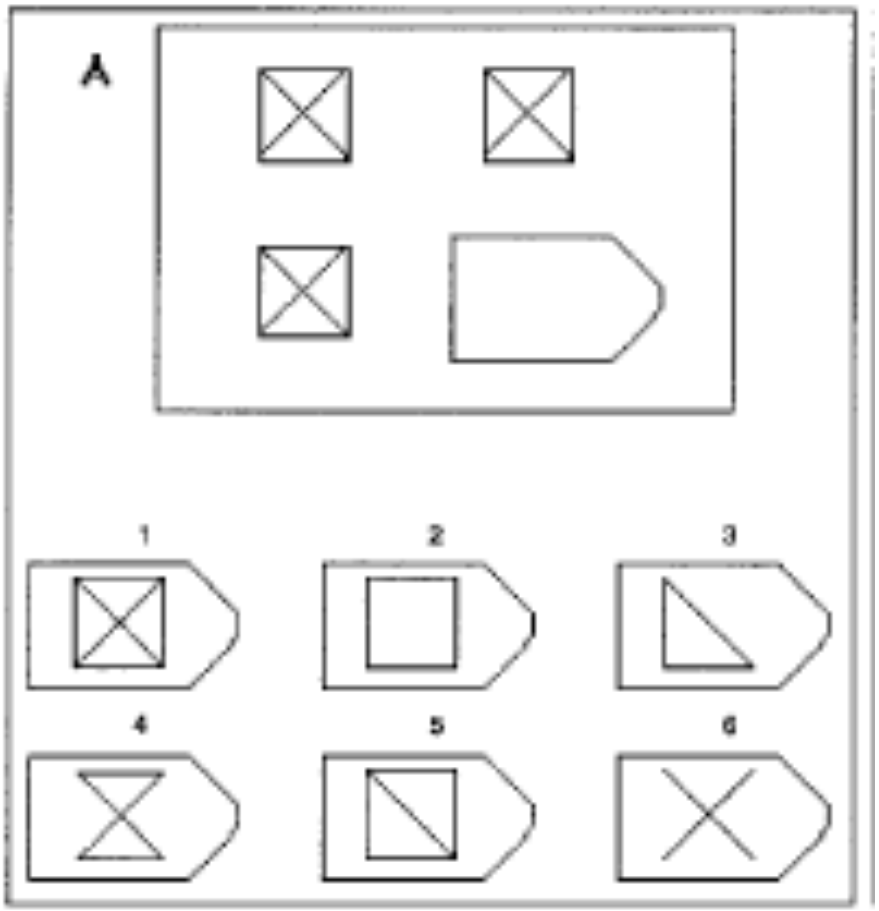
language

practical reason

domain-general ("abductive") reasoning

this seems more likely…

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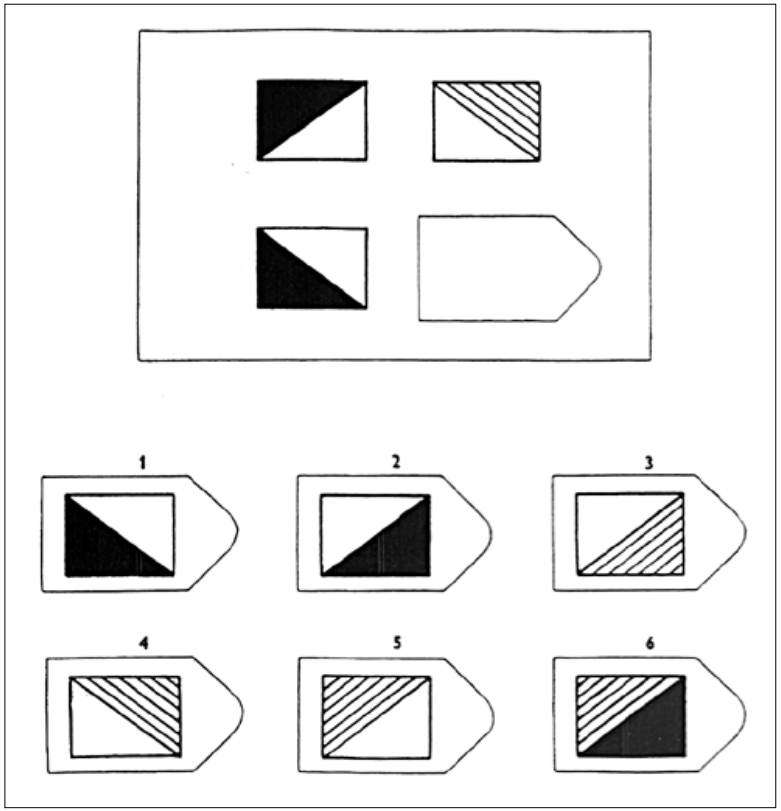
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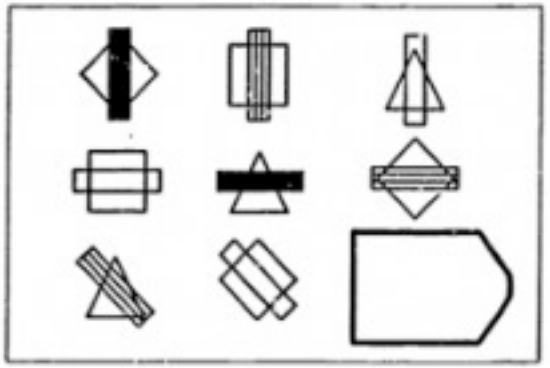

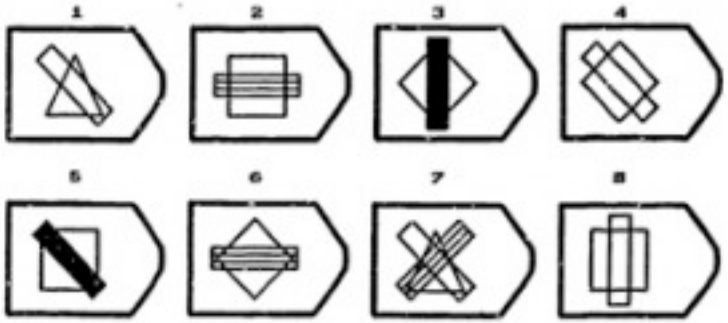
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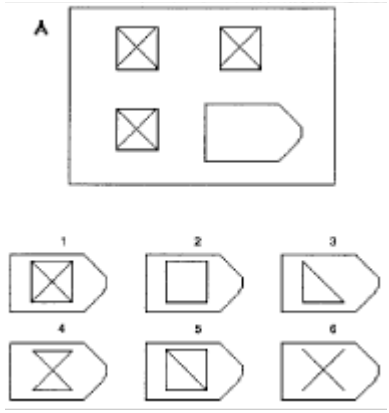
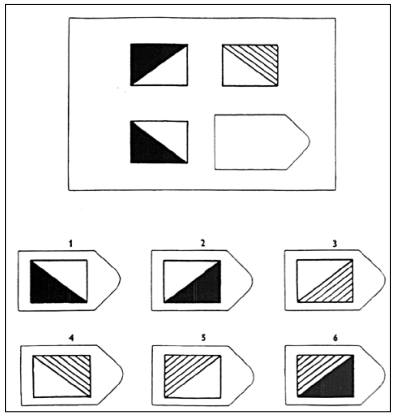
relational complexity

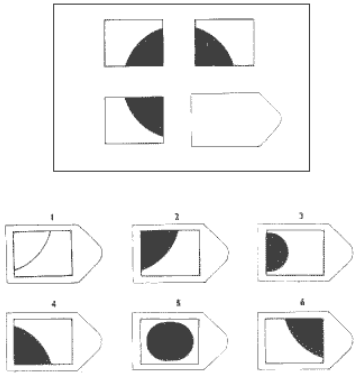


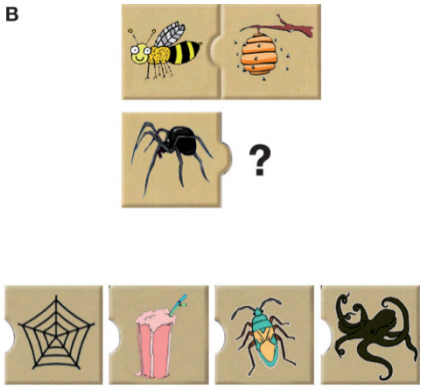
0 relations (i.e., MTS)



2 relations

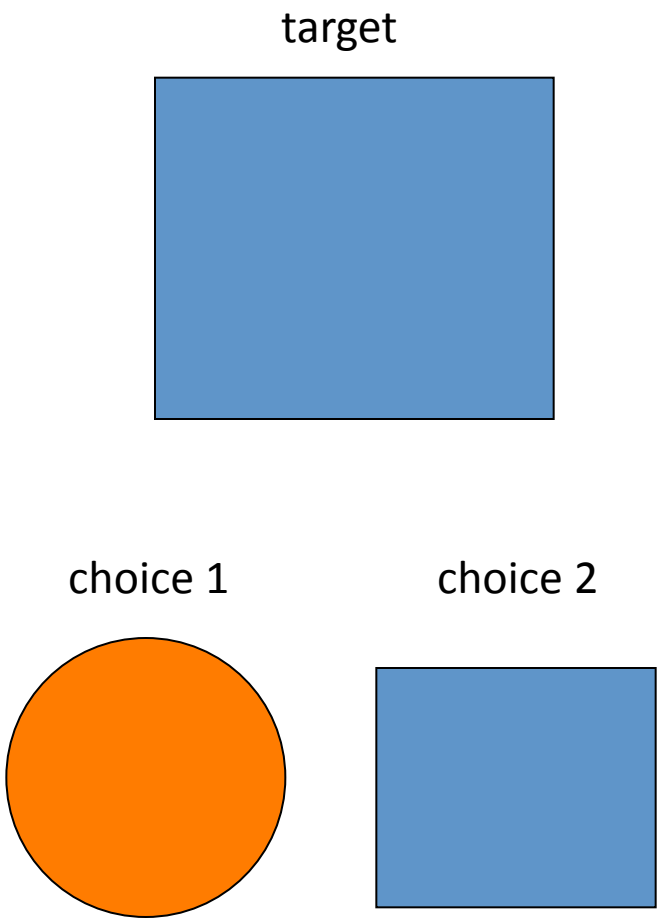
1 relation





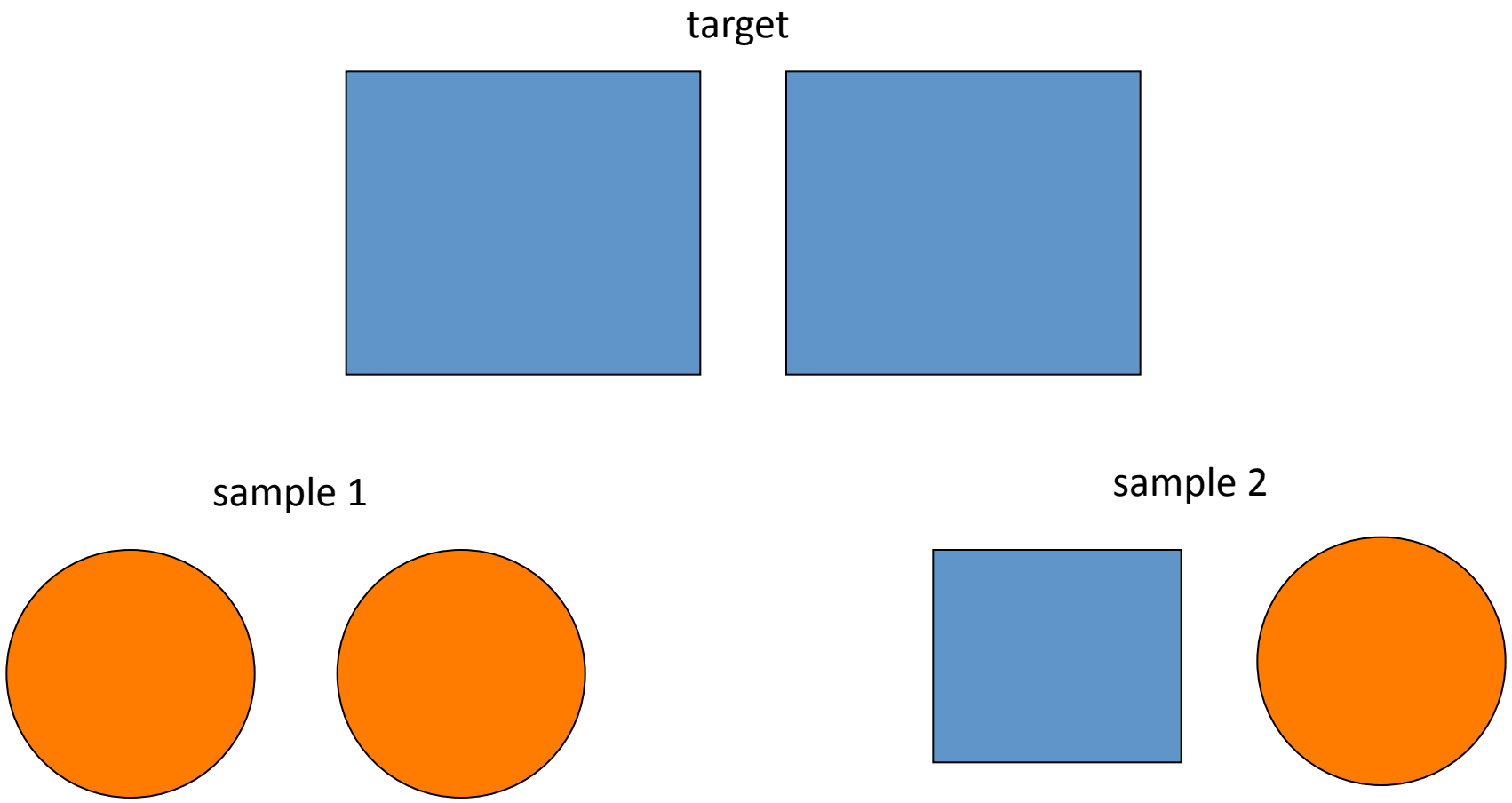
analogies

lots of animals can solve 0-relation problems (i.e., MTS)



e.g., honeybees, desert ants, pigeons, fish, etc...

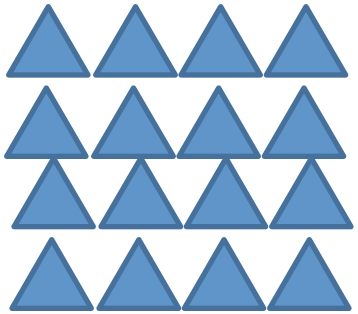
and some animals can pass RMTS tasks



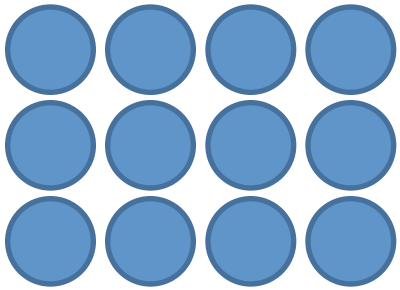
e.g., chimps, pigeons, monkeys, etc...

but they appear to solve RMTS tasks using variability not relations

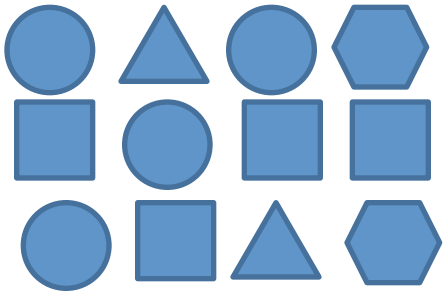
Target



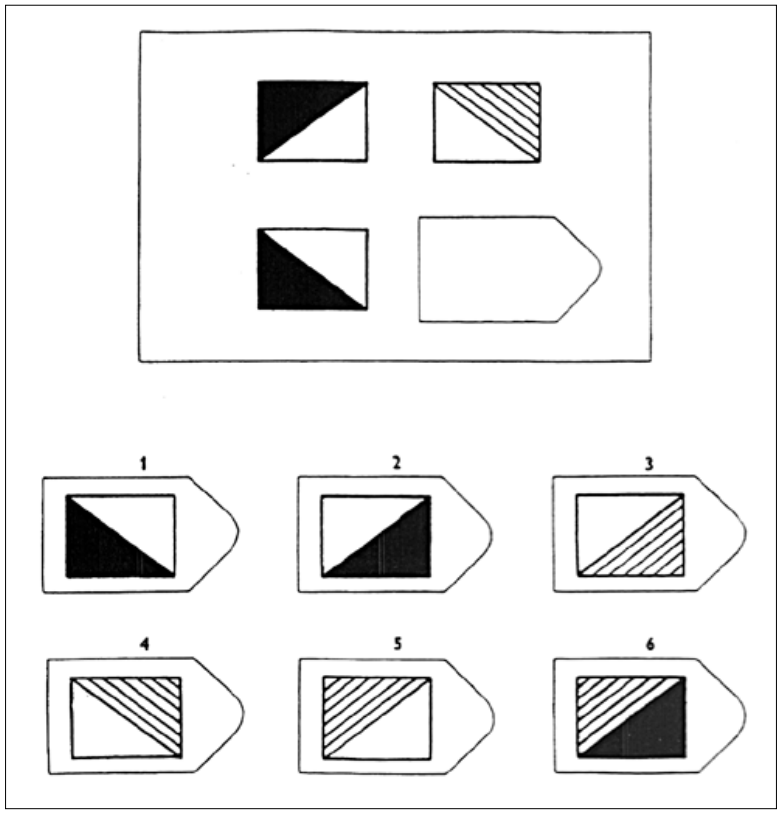
Var (small)



Var(big)



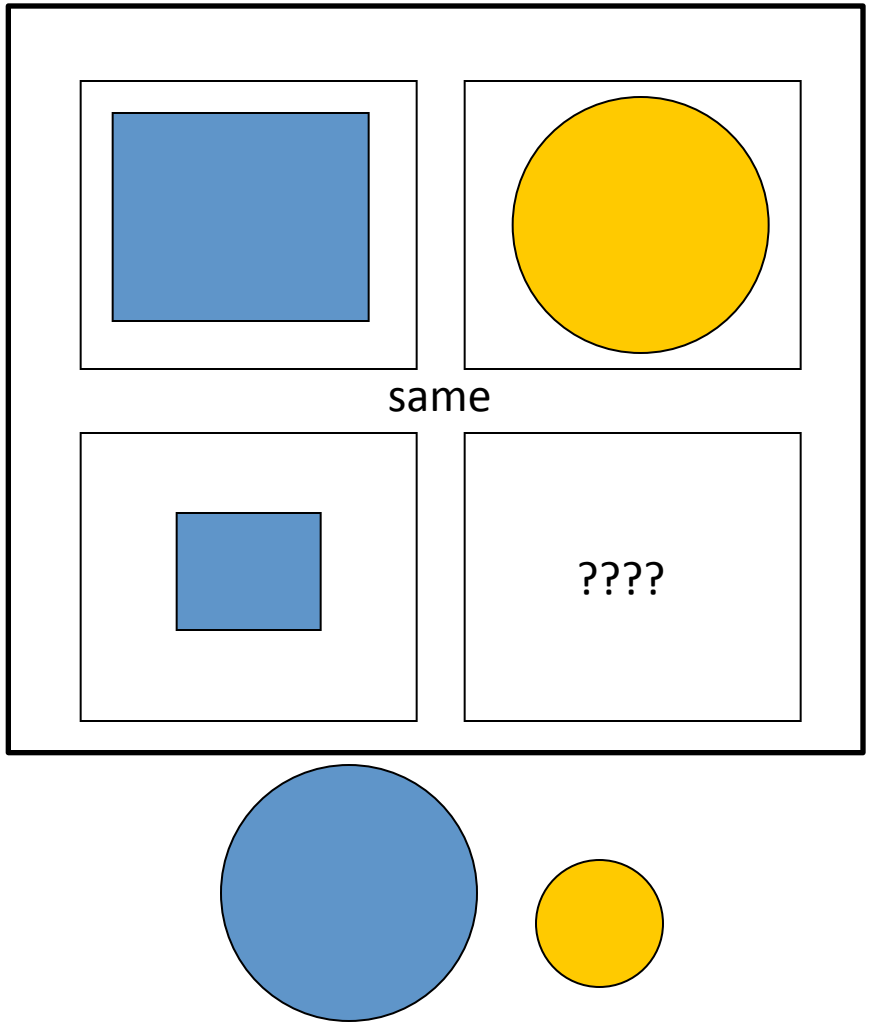
but no animal has ever passed a general test of 2nd order relations



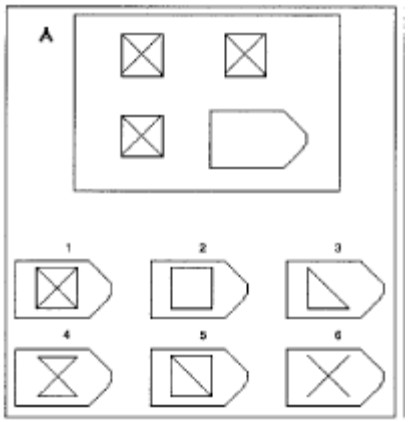
and no animal reasons analogically

- Only evidence of analogical reasoning comes from Sarah, the chimp
  (Gillan, Premack et al. 1981)

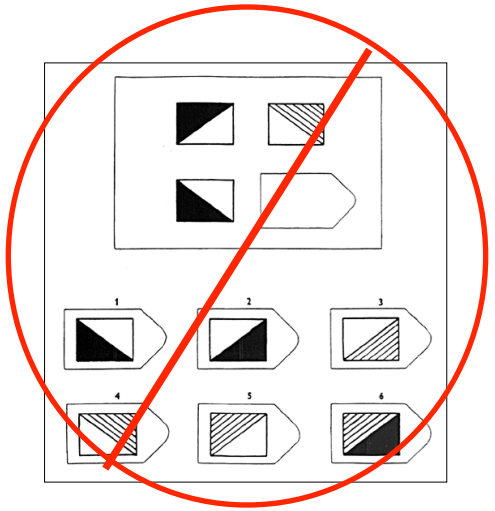
- *But* it turns out that Sarah solved these "analogies" by counting feature changes, not by mapping relational roles
  (Oden et al. 2001):



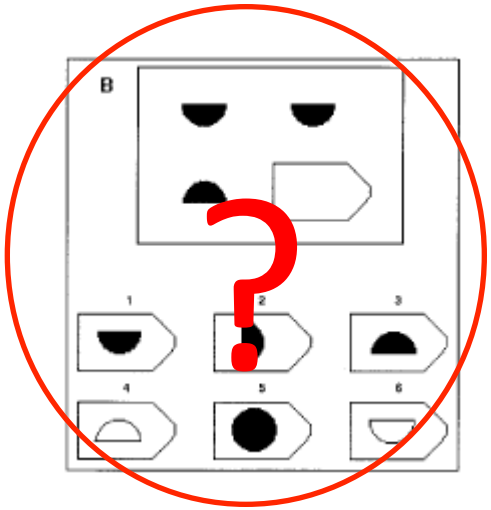
no evidence that animals can solve problems by integrating multiple relations



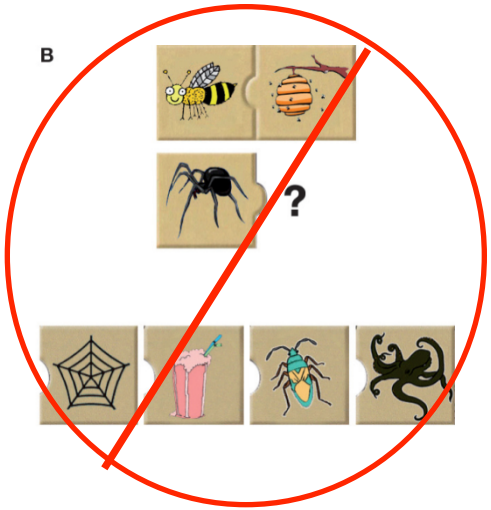
0 relations (i.e., MTS)



2 relations



1 relation

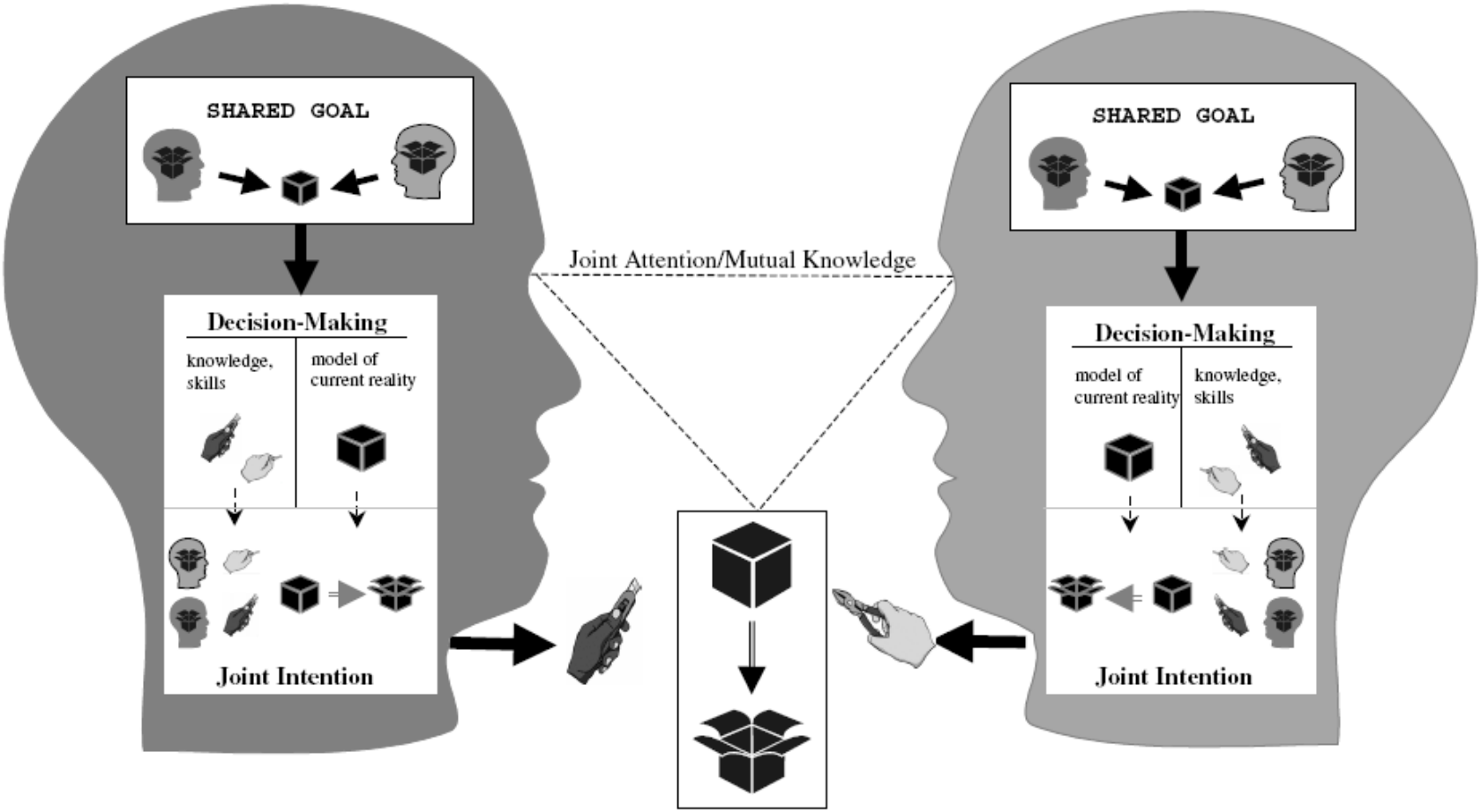


analogies

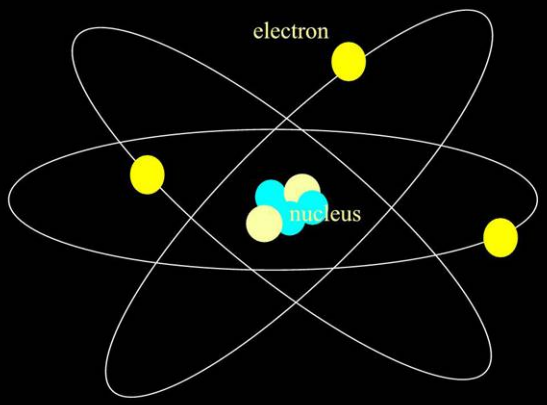
what would human cognition be like without the ability to reason about higher-order relations?

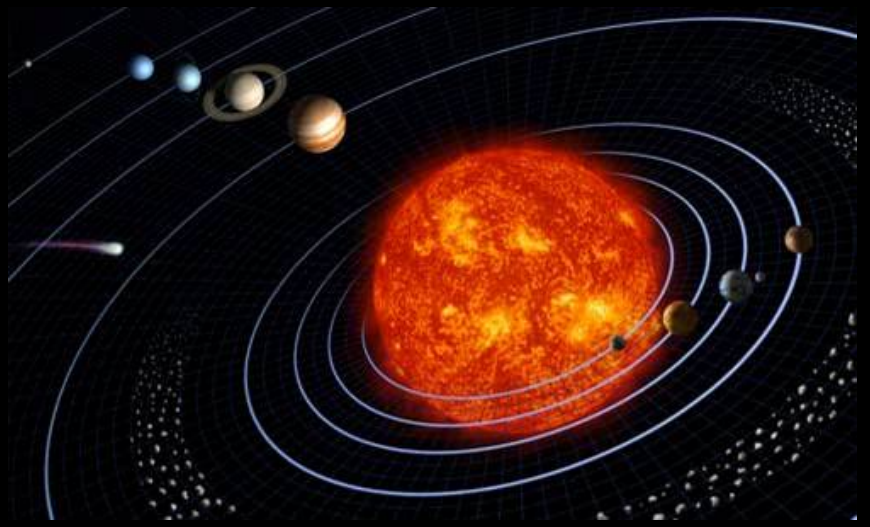
language and numbers are all about higher-order relations

We understand others' thoughts and feelings by analogy to our own

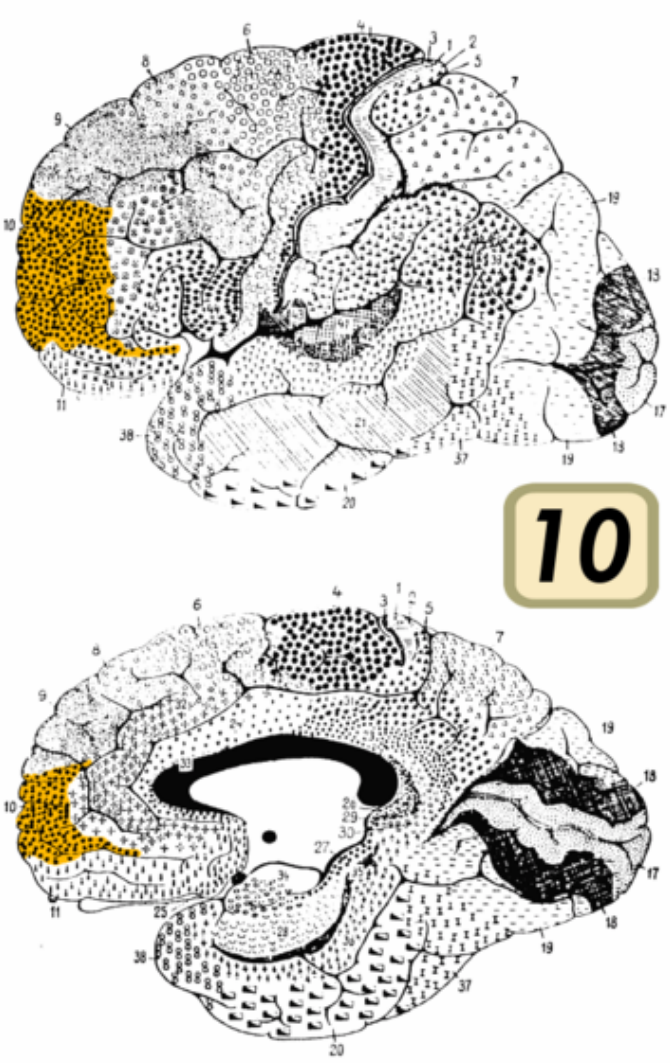


we understand the world through analogies

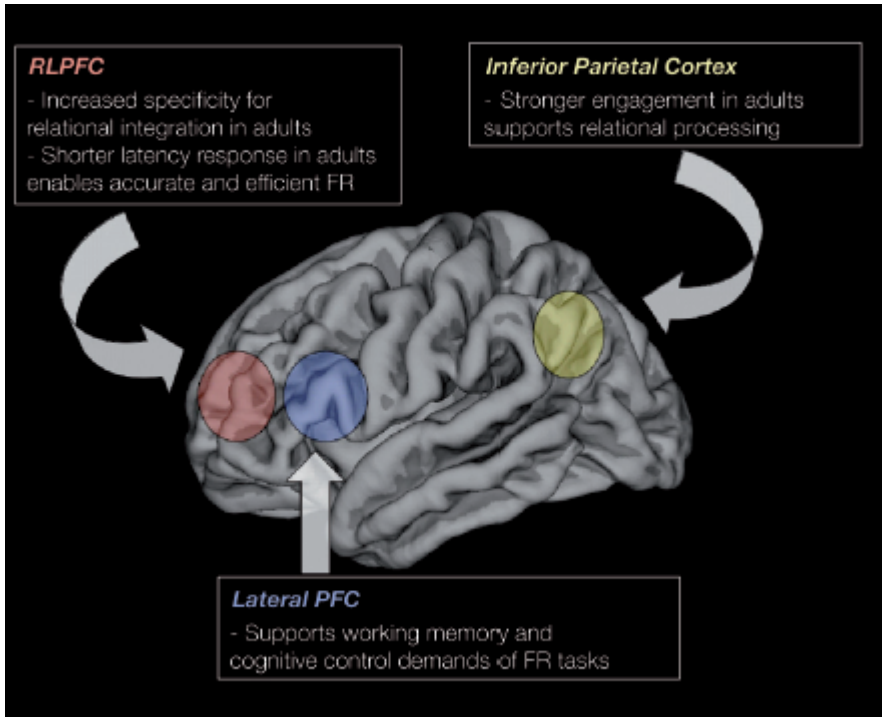




the *human* brain is wired to reason about higher-order relations



The rostrolateral prefrontal cortex (roughly Brodmann area 10) is centrally implicated in fluid reasoning in general, and higher-order relational integration in particular, including ToM tasks



(Bunge et al., 2009, *Neuroimage)*

growing evidence for a 'dual-process' model of human cognition

Psychological Review
2009, Vol. 116, No. 4, 953–970

0033-295X/09/$12.00 DOI: 10.1037/a0016923

Do Humans Have Two Systems to Track Beliefs and Belief-Like States?

Ian A. Apperly
University of Birmingham

Stephen A. Butterfill
University of Warwick

SOCIAL NEUROSCIENCE, 2006, 1 (3–4), 309–319 Psychology Press Taylor & Francis Group

What's domain-specific about theory of mind?

Valerie E. Stone
University of Queensland, St Lucia, Australia

Philip Gerrans
University of Adelaide, Adelaide, Australia

Dual-Processing Accounts of Reasoning, Judgment, and Social Cognition

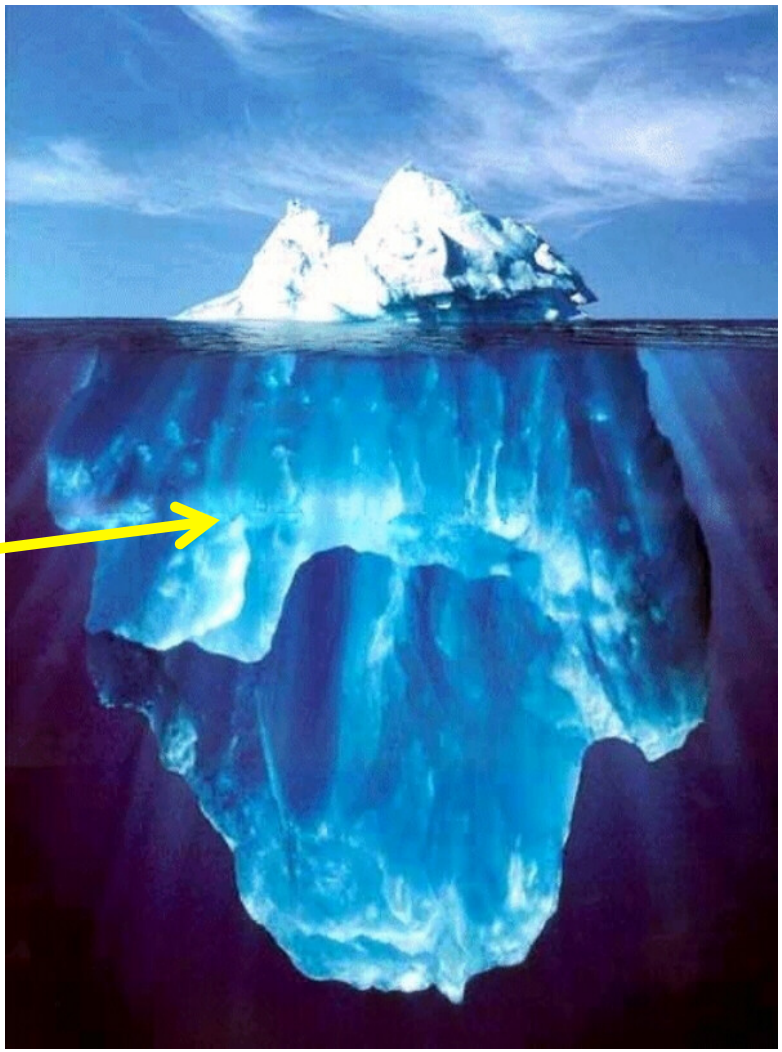
Jonathan St. B. T. Evans

Center for Thinking and Language, School of Psychology, University of Plymouth, Plymouth PL4 8AA, United Kingdom; email: jevans@plymouth.ac.uk

the relational reinterpretation hypothesis

the great bulk of human cognition is qualitatively similar to that of other animals

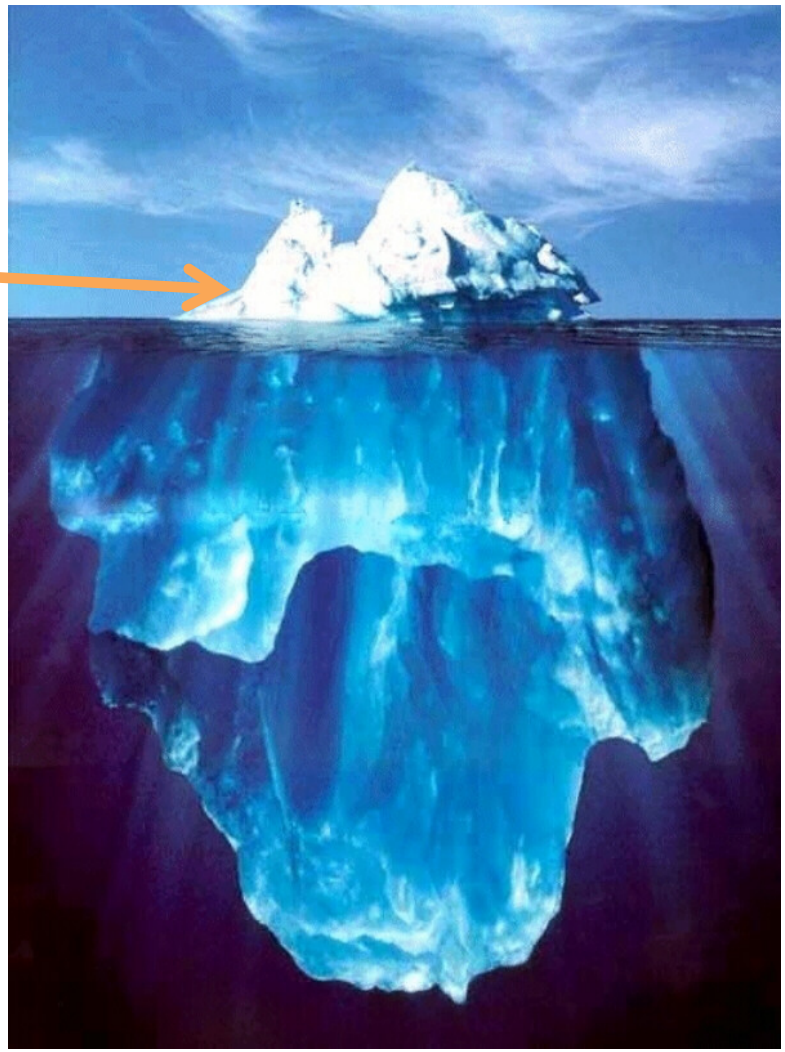
(i.e., compositional, productive and relational)



(Penn, Holyoak and Povinelli, 2008, *BBS*)

the relational reinterpretation hypothesis

But only humans have a domain-general "supermodule" for reasoning about higher-order relations



(Penn, Holyoak and Povinelli, 2008, *BBS*)

4 tendentious claims

1. the gap between human and nonhuman minds is enormous and is not the result of culture or language alone

2. the gap between human and nonhuman causal cognition is at least as large as the gap between human and nonhuman social cognition

3. human culture would not be possible without human causal cognition

4. our ability to reason about higher-order relations subserves a wide variety of distinctively human capabilities, including language, ToM, teaching, cumulative culture and human causal cognition.

5 falsifiable predictions

1. no animal will pass tasks that requires 2nd-order relations

2. no animal will pass tests of analogical reasoning

3. no human incapable of passing 2nd-order relational tasks will pass a robust false-belief test

4. humans with deficits in higher-order relational reasoning will exhibit deficits in higher-order causal cognition

5. the ontogeny of social, linguistic and causal cognition is strongly dependent on the ontogeny of higher-order relational reasoning

5 open questions

1. is there a single or multiple neural systems responsible for higher-order reasoning in the human brain?

2. what are the respective roles of the medial and lateral PFC in higher-order operations (e.g., ToM)

3. how does the brain implement higher-order relational operations?

4. which higher-order process came first: causal reasoning or ToM?

5. what makes higher-order relational reasoning such a costly and/or improbable adaptation?