Why do we have a big brain?
Discrete Hierarchical Organization of Social Group Sizes

(an evolutionary cognitive view on trust and group structure)

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TRUST

- Firm reliance on the integrity, ability, or character of a person or thing
- Synonyms: faith, confidence, reliance, dependence.
- Social impacts:
  - it makes social life predictable,
  - it creates a sense of community,
  - it makes it easier for people to work together.

“Mechanistic approach vs. cognitive theory

Hypothesis: Due to its ubiquity and resulting large gains/losses, trust is an ***evolutionary cognitive computational module*** which co-evolved with the brain (and social group size)

Why do we have a big brain?

- Epiphenomenal hypothesis: large brains are unavoidable consequences of a large body
- Developmental hypothesis: maternal energy constraints determine energy capacity for fetal brain growth (frugivory=richer diet)
- Ecological hypothesis: brain evolved to process information of ecological relevance (frugivory, home range navigation, extractive foraging)
- Social hypothesis: brain size constrains size of social network (group size) (memory on relationships, social skills)

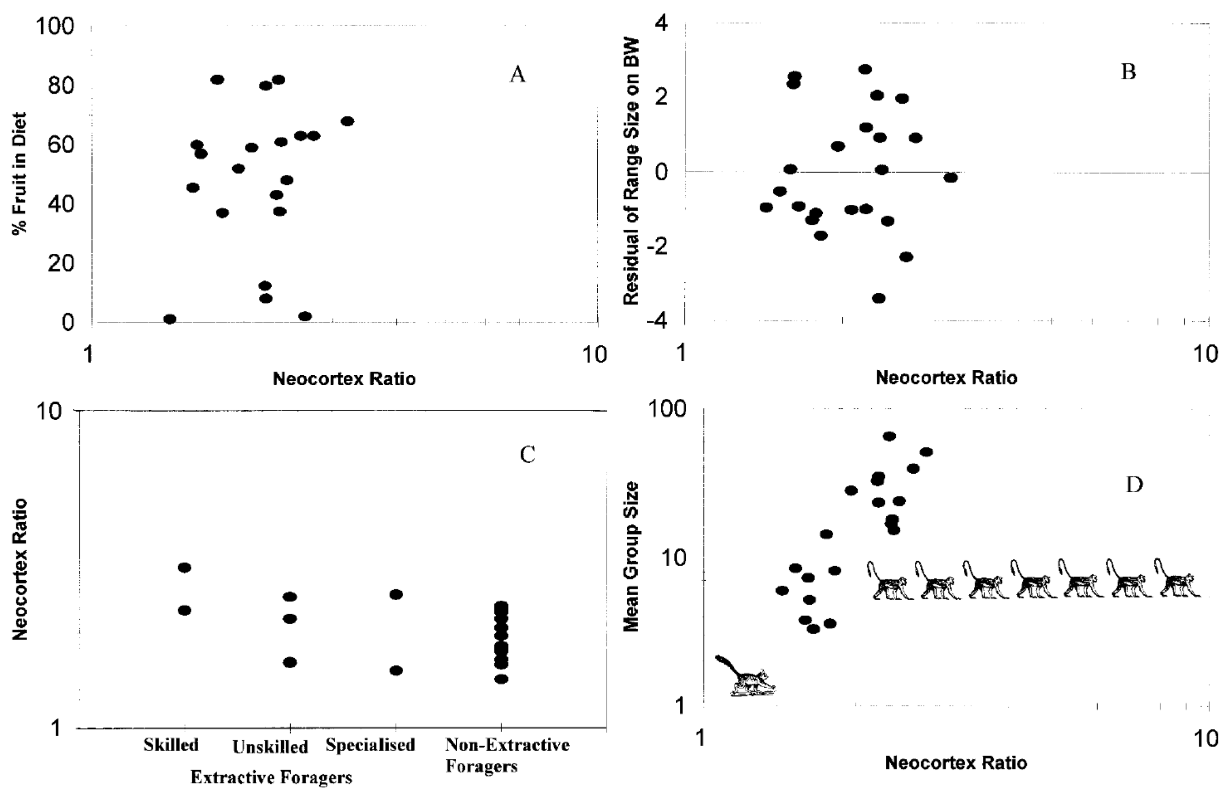


Figure 2. Relative neocortex size in anthropoid primates plotted against (a) percentage of fruit in the diet, (b) mean home-range size scaled as the residual of range size regressed on body weight (after Dunbar[24]), (c) types of extractive foraging (after Gibson[4]), and (d) mean group size. ((a), (b), and (d) are redrawn from Dunbar[24], Figures 6, 2 and 1, respectively; (c) is from Dunbar,[35] Figure 2.)

Dunbar, R.I.M., The social brain hypothesis. Evolutionary Anthropology 6, 178-190 (1998).

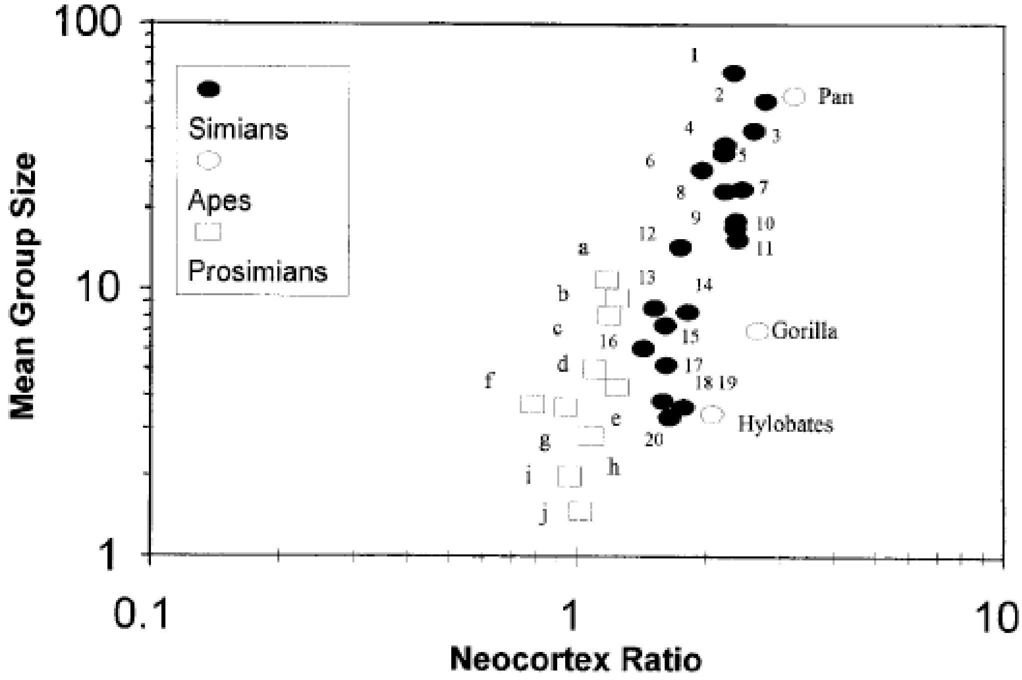


Figure 3. Mean group size plotted against neocortex ratio for individual genera, shown separately for prosimian, simian, and hominoid primates. Prosimian group size data, from Dunbar and Joffe,[25] include species for which neocortex ratio is estimated from total brain volume. Anthropoid data are from Dunbar.[24] Simians: 1, *Miopithecus;* 2, *Papio;* 3, *Macaca;* 4, *Procolobus;* 5, *Saimiri;* 6, *Erythrocebus;* 7, *Cercopithecus;* 8, *Lagothrix;* 9, *Cebus;* 10, *Ateles;* 11, *Cercocebus;* 12, *Nasalis;* 13, *Callicebus;* 14, *Alouatta;* 15, *Callimico;* 16, *Cebuella;* 17, *Saguinus;* 18, *Aotus;* 19, *Pithecia;* 20, *Callicebus.* Prosimians: a, *Lemur;* b, *Varecia;* c, *Eulemur;* d, *Propithecus;* e, *Indri;* f, *Microcebus;* g, *Galago;* h, *Hapalemur;* i, *Avahi;* j, *Perodictus.*

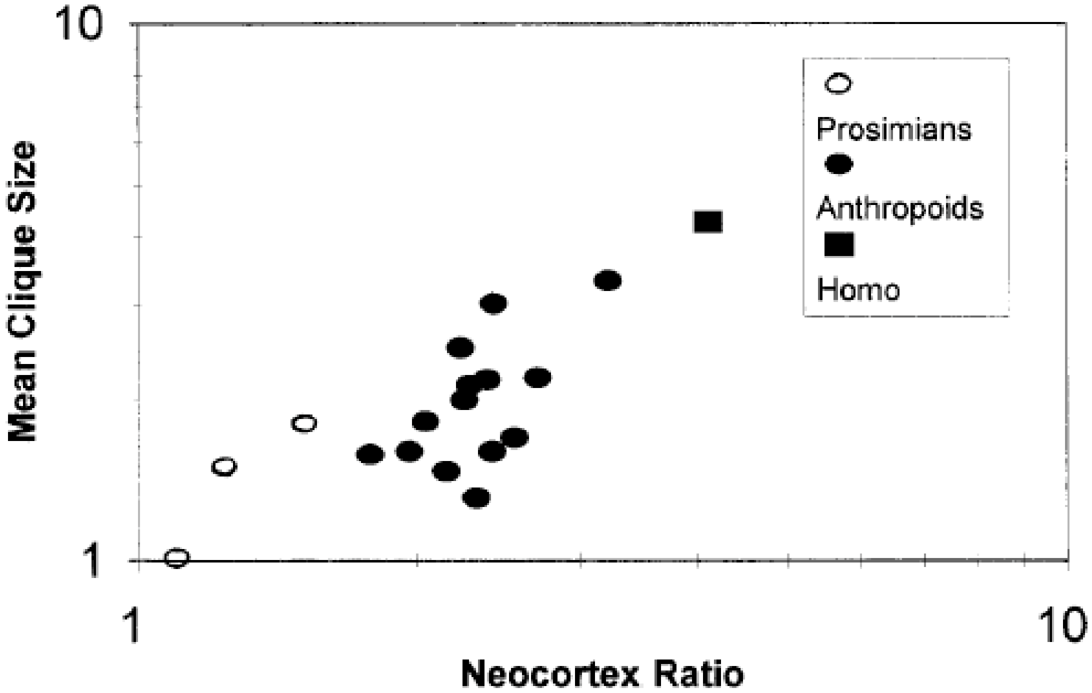


Figure 6. Mean grooming clique size plotted against mean neocortex ratio for individual primate genera. The square is *Homo sapiens.* Species sampled are *L. catta, L. fulvus, Propithecus, Indri, S. sciureus, C. apella, C. torquatus, A. geoffroyi, A. fusciceps, P. badius, P. entellus, P. pileata, P. johnii, C. campbelli, C. diana, C. aethiops, C. mitis, E. patas, M. mulatta, M. fuscata, M. arctoides, M. sylvana, M. radiata, P. anubis, P. ursinus, P. cynocephalus, P. hamadryas, T. gelada, P. troglodytes, P. paniscus.* (Redrawn from Kudo, Lowen, and Dunbar,[51] Fig. 4a.)

. . . apes seem to be good psychologists in that they are good at reading minds, whereas monkeys are good ethologists in that they are good at reading behavior . . .

Fair trade. Capuchin monkeys refuse to cooperate when they see a comrade receive a better reward for the same task.

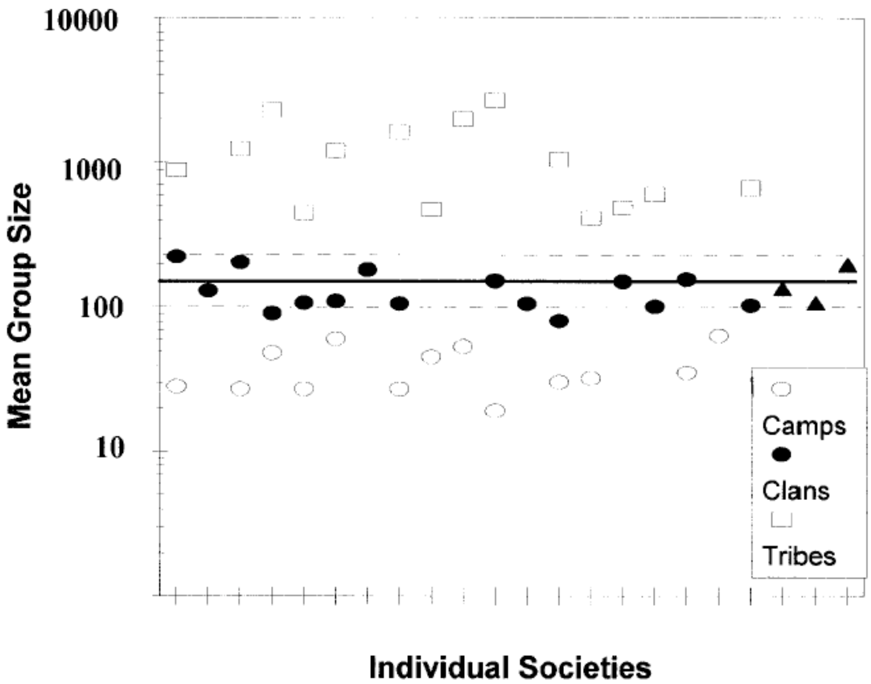
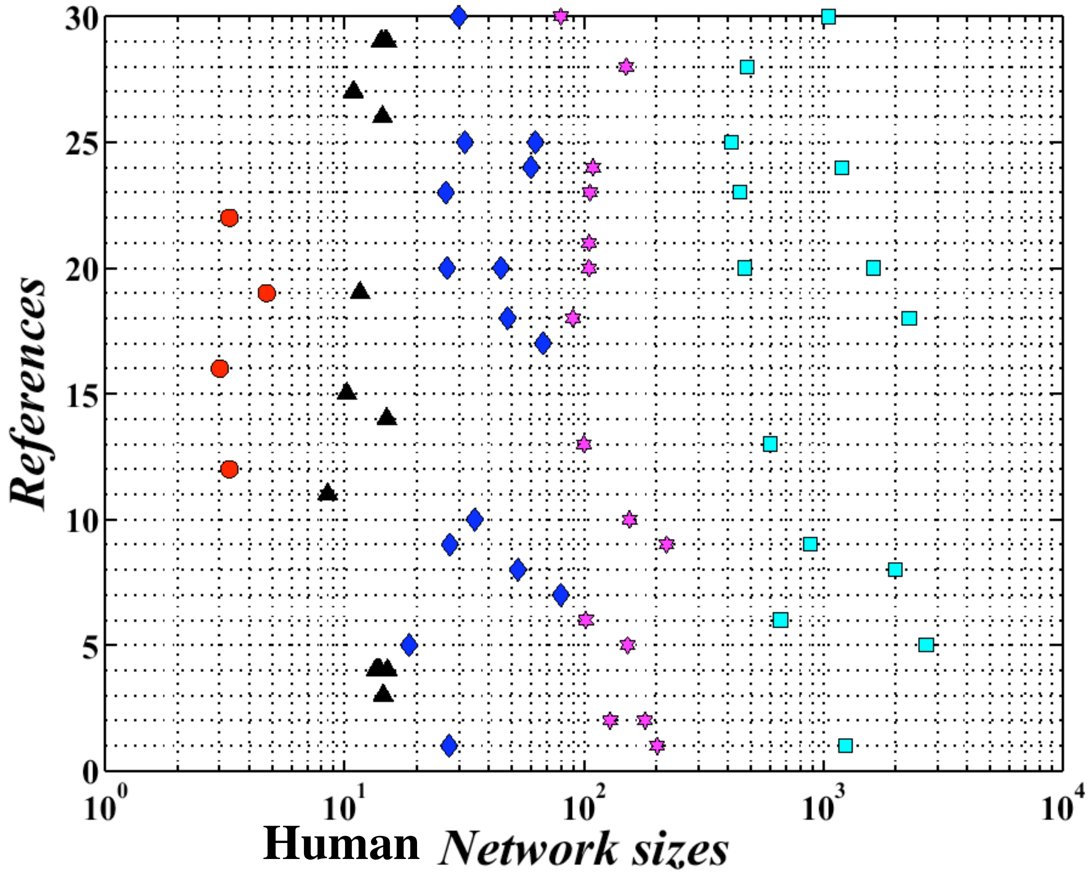


Figure 7. Mean sizes for different types of groups in traditional human societies. Individual societies are ordered along the bottom, with data for three main types of social groups (overnight camps, clans or villages, and tribes). Societies include hunter-gatherer and settled horticulturalists from Australia, Africa, Asia, and North and South America. The triangles give mean group sizes for three contemporary United States samples: mean network size from small-worlds experiments (N = 2),[67] mean Hutterite community size,[68] and the size of an East Tennessee mountain community.[69] The value of 150 predicted by the primate neocortex size relationship (from Fig. 1d) is indicated by the horizontal line, with 95% confidence intervals shown as dashed lines.

Source	Support Clique	Sympathy group	Camp	Village	Tribe
[11]	3.01				
[12]	3.3				
[13]	4.47	11.6			
[14]	3.30				
[15]		10.9			
[16]		14.0/15.1/13.5/13.8			
[17]		$8 \sim 9$			
[18]		14.5			
[19]		10.2			
[20, 21]		15			
[22, 23]		15.0/14.3/14.8/14.2			
[24]		14.4			
[25]			25-30	221.5	886
[26]			27.3	202.5	1237.3
[27]			48	90	2290
[28]			26.5	53-159	450
[29]			60	109.1	1200
[30]			26.8/40-50	90-120	471/1625
[31]			21-85		2000
[32]			18.6	152.3	2693
[33]			25-35	60-100	1050
[34]			31.8/62.7		413
[35]			10-60	60-250	
[36]			50-75		
[37]			40-120		
[38]				128.7/180	
[39, 40]				60-150	
[41]				150	483
[42]				100	600
[43]				101.9	663

circle (support clique), triangle (sympathy group), diamond (bands), stars (cognitive groups),

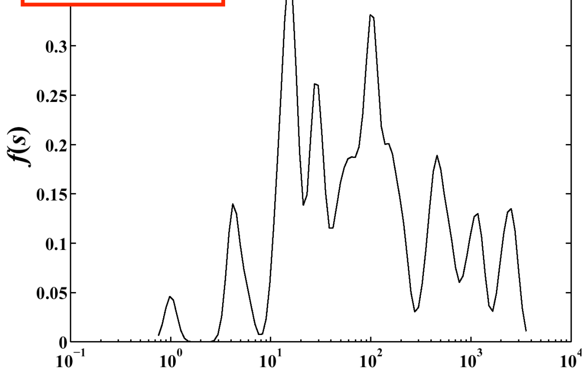


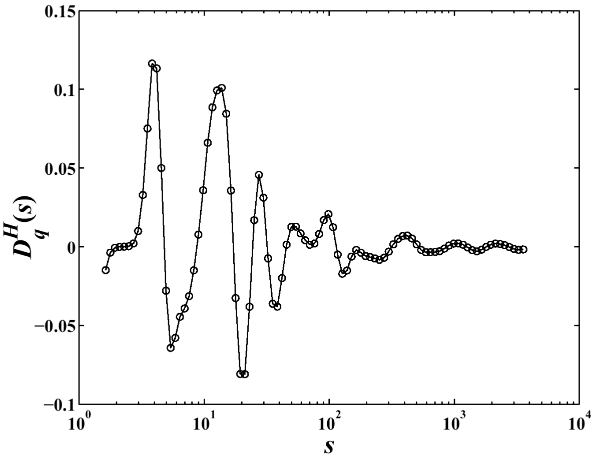
Method 1: Average sizes of different network layers. To summarize the previously cited data, we denote S_1 as the mean support clique size, S_2 the mean sympathy group, S_3 the mean band size, S_4 the mean cognitive group size, and S_5 and S_6 the size of small and large tribes. Here, we do not address the relevance of this classification (which will be done below) but only characterize it quantitatively. The previously cited data gives $S_0 = 1$ (individual or ego), $S_1 = 4.6$, $S_2 = 14.3$, $S_3 = 42.6$, $S_4 = 132.5$, $S_5 = 566.6$, and $S_6 = 1728$. In order to determine the possible existence of a discrete hierarchy, we construct the series of ratios S_i/S_{i-1} of successive mean sizes:

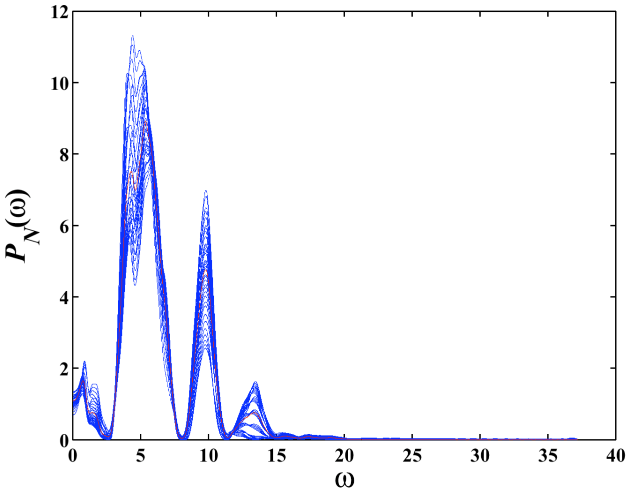
$$S_i/S_{i-1} = 4.58, 3.12, 2.98, 3.11, 4.28, 3.05\,, \quad \text{for } i = 1, \cdots, 6\,. \tag{1}$$

This result suggests that humans form groups according to a discrete hierarchy with a prefered scaling ratio between 3 and 4: the mean of S_i/S_{i-1} is 3.50.

Method 2







Preferred scaling ratio close to 3

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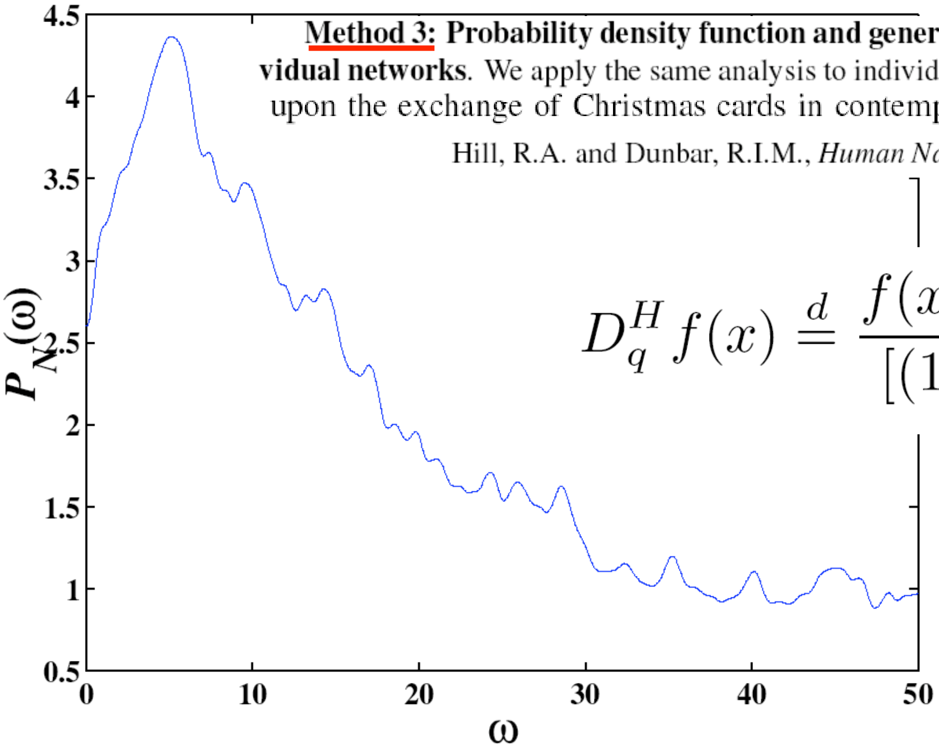


Method 3: Probability density function and generalised q-analysis of individual networks. We apply the same analysis to individual social networks based upon the exchange of Christmas cards in contemporary Western Society.

Hill, R.A. and Dunbar, R.I.M., *Human Nature* **14**. 53-72 (2003).

$$D_q^H f(x) \stackrel{d}{=} \frac{f(x) - f(qx)}{[(1-q)x]^H}$$

Figure 5: Average Lomb periodogram $P_N(\omega)$ of the (H,q)-derivative $D_q^H(s)$ with respect to the number of receivers of the residual contact frequency for each individual in the Christmas card experiment, as a function of the angular log-frequency ω of the (H,q)-derivative, over the 42 individuals and different pairs of (H,q) with $-1 \leq H \leq 1$ and $0.80 \leq q \leq 0.95$.

A real-life example of a hierarchical network

- **Sections (squads): 10-12 soldiers**
- **Platoons (of 3 sections, ≈ 35 soldiers)**
- **Companies (3-4 platoons, ≈ 120-150 soldiers)**
- **Battalions (3-4 companies plus support units, ≈ 550-800)**
- **Regiments (or brigades) (3 battalions plus support,2500+)**
- **Divisions (3 regiments)**
- **Corps (2-3 divisions)**
- **Armies**
- **Country**

Level of Intentionality

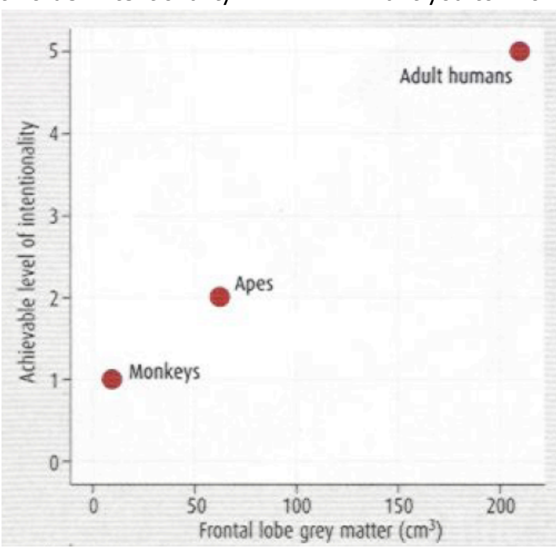
. . . apes seem to be good psychologists in that they are good at reading minds, whereas monkeys are good ethologists in that they are good at reading behavior . . .

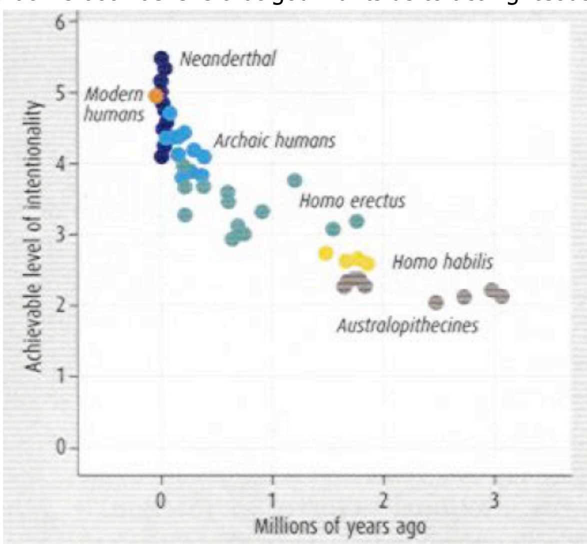
Fair trade. Capuchin monkeys refuse to cooperate when they see a comrade receive a better reward for the same task.

The origin of Religion

THE ORIGIN OF RELIGION (R. Dunbar, 2006):
role to bring a sense of communality, of group membership, to strengthen the group, which can only occur with a brain allowing for FIFTH-ORDER INTENTIONALITY.

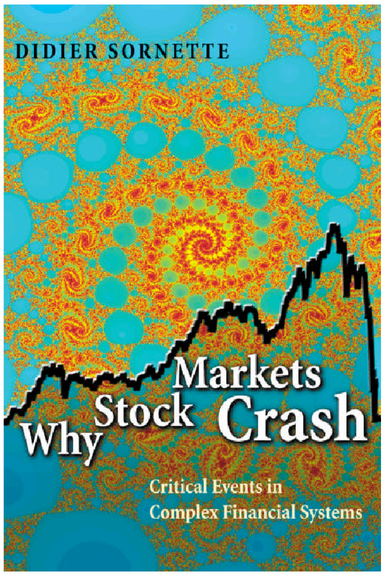
Second-order intentionality:	I believe that god wants good
Third-order intentionality:	I believe that god wants us to act with righteous intent
Fourth-order intentionality:	I want you to believe that god wants us to act righteously
Fifth-order intentionality:	I want you to know that we both believe that god wants us to act righteously

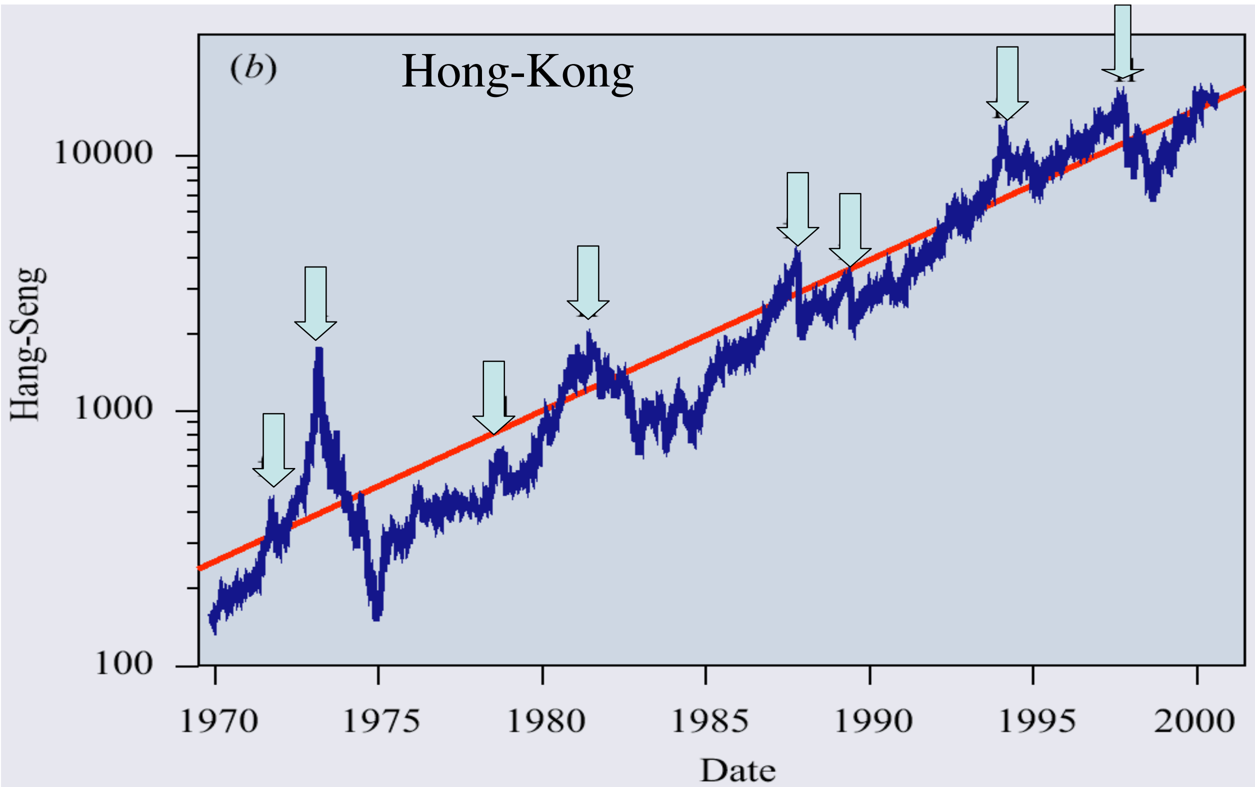


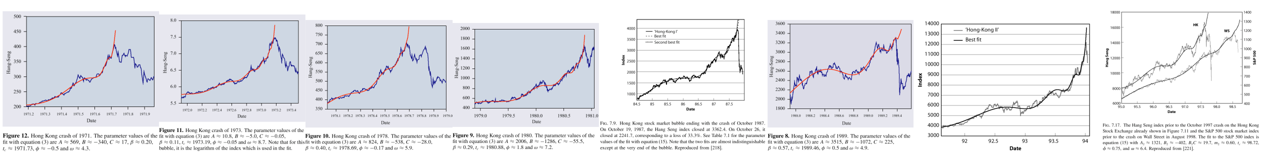


Conclusions

- Discrete social hierarchies may be deeply rooted in the cognitive processing abilities of human brains.
- We suggest that this has observable consequences, such as in financial markets.
- Implications for the optimization of
  - Corporate management
  - Politics
  - Departments and universities








JUST A NORMAL DAY AT THE NATION'S MOST IMPORTANT FINANCIAL INSTITUTION...
I'VE GOT A STOCK HERE THAT COULD REALLY EXCEL
REALLY EXCEL?
EXCEL?
SELL?
SELL?
SELL
SE
SELL!
SELL!
CARTOONISTS & WRITERS SYNDICATE http://CartoonWeb.com
KAL
SELL!
SELL!
ELL!
SELL!
THIS IS MADNESS! I CAN'T TAKE ANYMORE
GOOD BYE!
GOOD BYE?
BYE?
Buy?
BUY!
Buy!
BUY!!
Buy!
Buy!
Bu
I'VE GOT A STOCK HERE..

Kal


THIS WAY TO THE
Bull Market!
Almost there. . . 300 feet. . . Don't Miss The Fun!
I'm a trader.
Hey this Koolaid tastes great!
Must own Yahoo
Don't be negative.
Stoopid bears.
Take a deep breath!
I'm flying mommy!
El Cliffo

Imitation

-Imitation is considered an efficient mechanism of social learning.

- Experiments in developmental psychology suggest that infants use imitation to get to know persons, possibly applying a ‘like-me’ test (‘persons which I can imitate and which imitate me’).

- Imitation is among the most complex forms of learning. It is found in highly socially living species which show, from a human observer point of view, ‘intelligent’ behavior and signs for the evolution of traditions and culture (humans and chimpanzees, whales and dolphins, parrots).

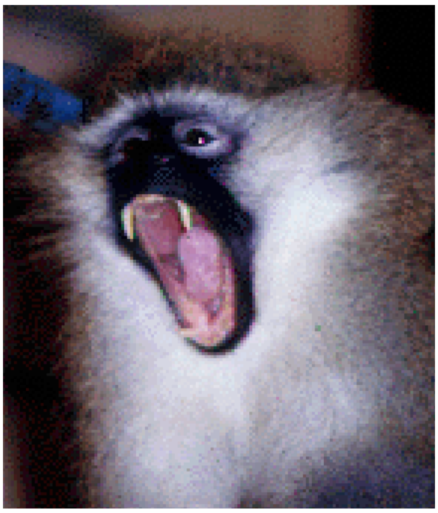
- In non-natural agents as robots, tool for easing the programming of complex tasks or endowing groups of robots with the ability to share skills without the intervention of a programmer. Imitation plays an important role in the more general context of interaction and collaboration between software agents and human users.

OBSERVATIONAL LEARNING

For evolutionary fears, monkeys and people learn by watching what other animals and people do (not by doing themselves and learning from the consequences).

Hands-on learning may not always be the best! THE APE AND THE SUSHI MASTER (Frans de Waal’s book): in Japan, apprentic sushi cooks spend three years just watching the sushi master prepare sushi. When the apprentice finally prepares his first sushi, he does a good job of it. (“The watching of skilled models firmly plants action sequences in the Head that come in handy, sometimes much later, when the same taskes need to be carried out.” The ape and the sushi Master: cultural reflections of a primatologist (New York: Basic Books, 2001)

Temple Grandin and C. Johnson,
Animals in translation (Scribner, New York, 2005)



VERVET MONKEY

Optimal strategy obtained under limited information

Equation showing optimal imitation solution of decision in absence of intrinsic information and in the presence of information coming from actions of connected "neighbors"

$$s_i(t-1) = \mathrm{sign}\left(K \sum_{j\in N_i} s_j + \varepsilon_i\right)$$

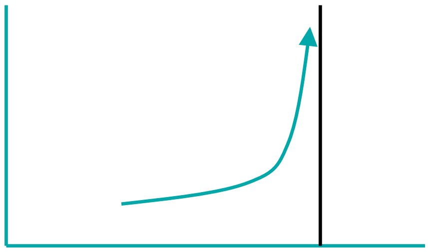
This equation gives rise to critical transition=bubbles and crashes

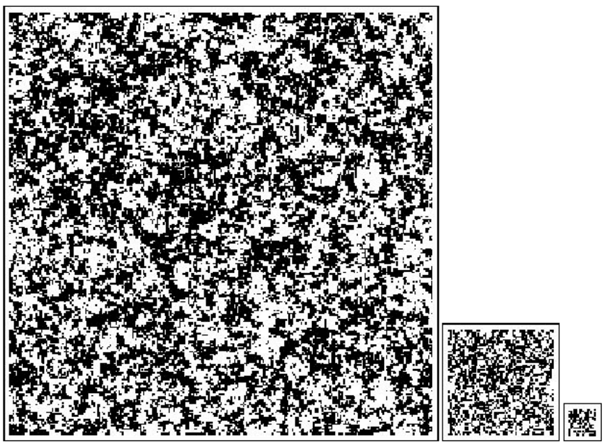
-Crash = coordinated sell-off of a large number of investors
-single cluster of connected investors to set the market off-balance
-Crash if 1) large cluster s>s* and 2) active

-Proba(1) = n(s)
-Proba(2) ~ s^a with $1 < a < 2$ (coupling between decisions)

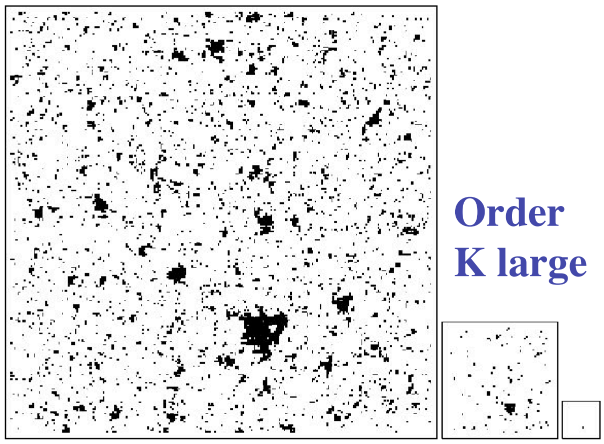
Proba(crash) ~ $\sum_{s>s^*} n(s)\, s^a$

If a=2, $\sum_{s>s^*} n(s)\, s^2 \sim |K-K_c|^{-\gamma}$



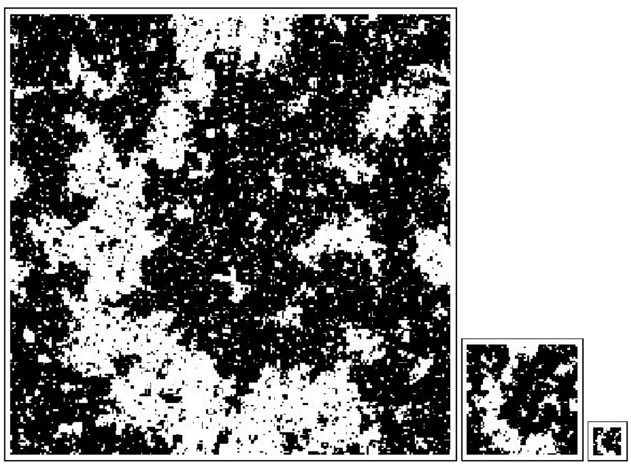


Disorder : K small



Order
K large

Renormalization group:
Organization of the description scale by scale



Critical: K=critical value

Importance of Positive Feedbacks and Over-confidence in a Self-Fulfilling Ising Model of Financial Markets

$$s_i(t) = \text{sign}\left[\sum_{j \in \mathcal{N}} K_{ij}(t)\text{E}[s_j](t) + \sigma_i(t)G(t) + \epsilon_i(t)\right]$$

Imitation **News** **Private information**

$$K_{ij}(t) = b_{ij} + \alpha_i K_{ij}(t-1) + \beta r(t-1)G(t-1)$$

β<0: rational agents

β>0: over-confident agents
All stylized facts reproduced

Didier Sornette and Wei-Xing Zhou
in press in Physica A (2006)
(http://arxiv.org/abs/cond-mat/0503607)