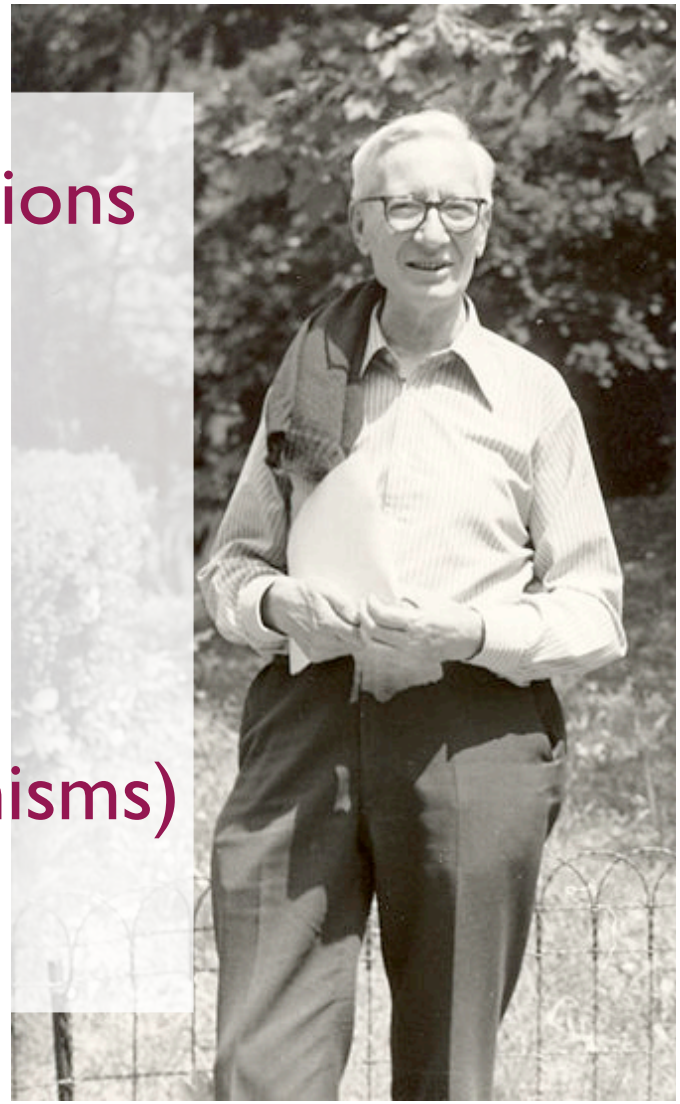
Intelligent Control
and Cognitive Systems

Social Simulation and Social Structure

Joanna J. Bryson
University of Bath, United Kingdom

Tinbergen's Questions

- Evolutionary (ultimate) explanations
  - Function (adaptation)
  - Phylogeny (evolution)
- Proximate explanations
  - Causation (proximate mechanisms)
  - Development (ontogeny)



Replication & Science

- Where there is a controversy / surprising result, the first thing to do is try to replicate it.
  - Fail → doubt on original result (and/or yourself)
  - Succeed → lets you test & extend theory.

Replication & Science

- Leading role for simulation in science: show whether a parsimonious model really could explain the data.
- Goals of replication:

1. validate experiment
2. extend results
    i. explain more data, or
    ii. understand model better

Case Study

Cognitive Minimalism

Rhesus Macaques
picture: Bernard Thierry

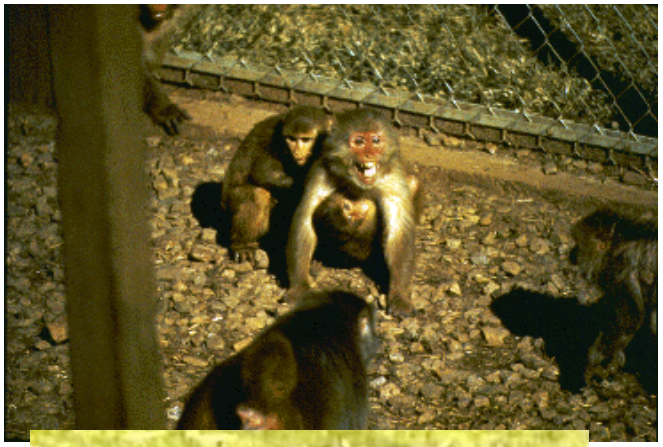
Egalitarian species show bilateral aggression, human-like reconciliation. Research Question: Is cognition necessary or incidental to their social strategy?

Why model monkeys?

- Much better quantitative data than for humans.
  - Complete interaction statistics.
  - Not significantly affected by observers.
- Understand our own origins and inclinations.
  - Political instability leading cause of ill health.

Macaque Social Order

- Some (e.g. Rhesus) show strict dominance hierarchy; violent but infrequent conflict: "despotic".
- Some (e.g. Tonkeans) show more tolerance e.g. bilateral aggression; more frequent but less violent conflicts: "egalitarian".
- van Schaik (1989), Thierry et al. (2004)

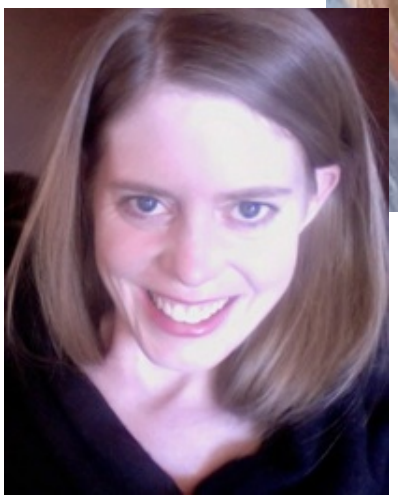


Bilateral Aggression & Reconciliation

Tonkean Macaques, an Egalitarian Species

(video: Bernard Thierry)

Two Hypotheses of Macaque Social Order



- Less resources (e.g. food) $\Longrightarrow$ more violence $\Longrightarrow$ selective pressure for social structure (Hemelrijk 2001, 2002+).
- New conflict resolution behaviour $\Longrightarrow$ less violence $\Longrightarrow$ less pressure for social structure (de Waal 2001, Flack & de Waal).

Hemelrijk's Model

- Simple, cognitively-minimalist boids-like model. (Reynolds 1987; Hogeweg 1988)
- Despotic (*vs.* egalitarian) attributed to greater variety in dominance rank value, consequence of aggression level.
- Side-effect: dominants in centre of troop, subordinates outside – like real troops.
  - Convergent evidence for model.

Challenges

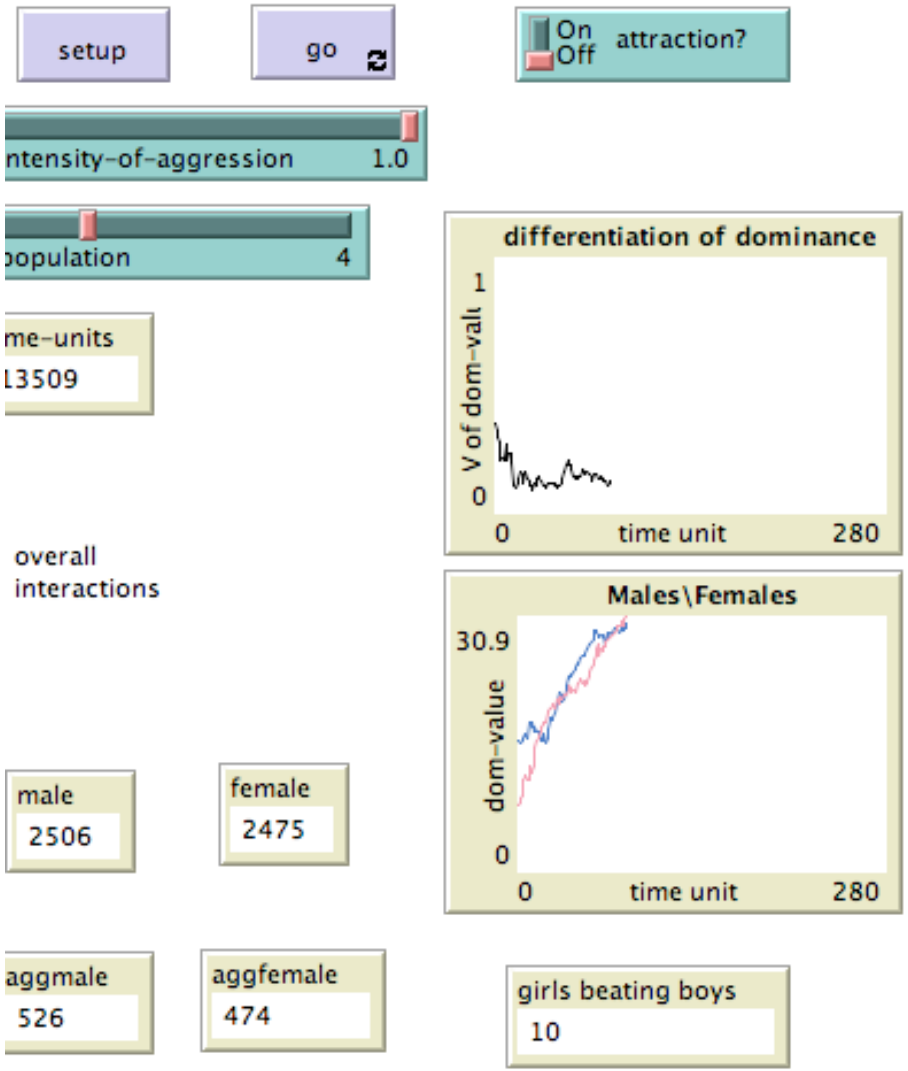
- Most researchers think something more cognitive is going on with primates.
  - Only scientific justification for a more complex model is better match to data.
- Research question: Is there room to improve on the match to data?

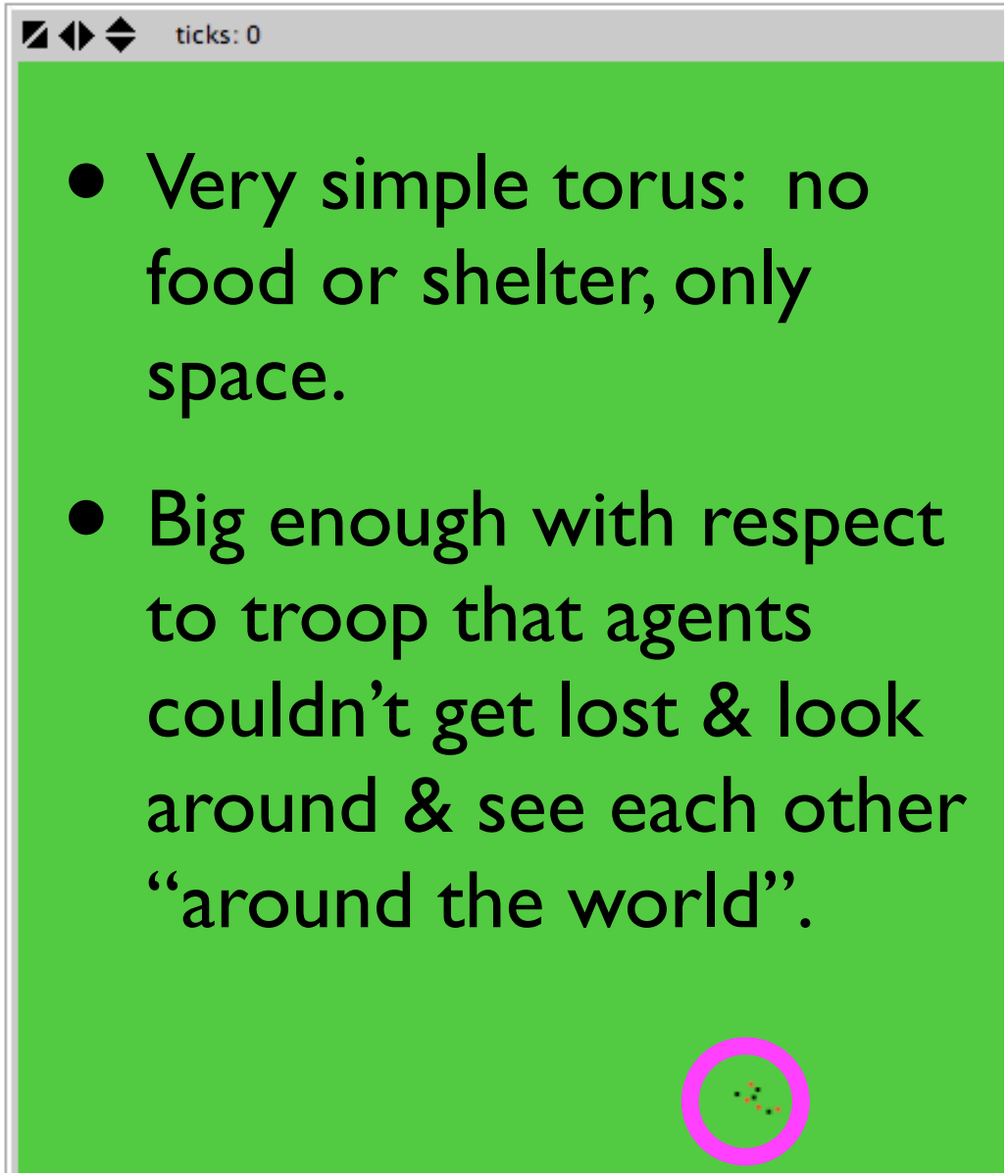
Describing a Model

Bryson, Ando & Lehmann (2007, 2011)

- Environment
- Agents' State
- Agents' Behaviour
- Results & Analysis

Environment



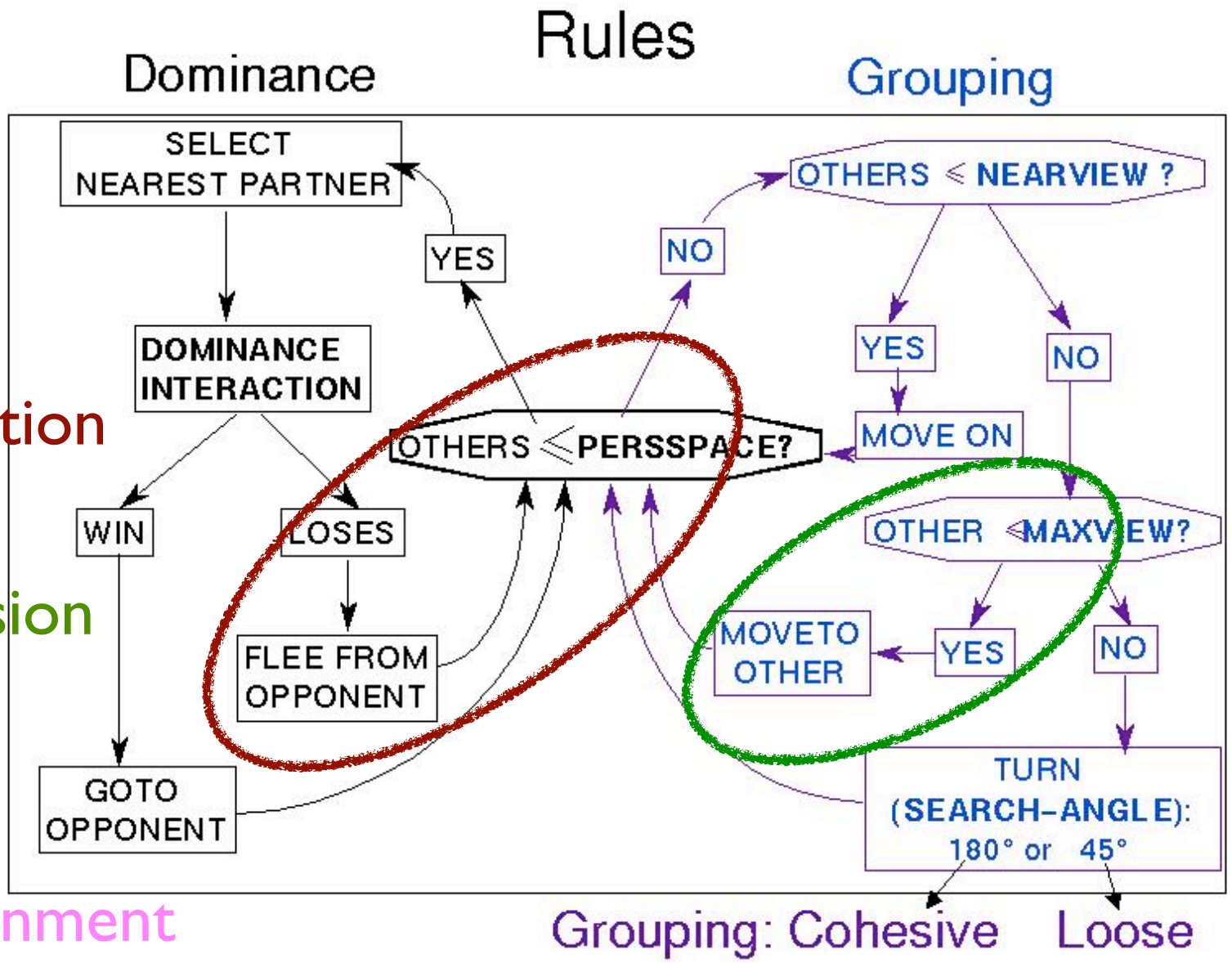


- Very simple torus: no food or shelter, only space.
- Big enough with respect to troop that agents couldn't get lost & look around & see each other "around the world".

Hemelrijk's Agents' State

- Individual: DomValue (initially determined by gender, changes by Eq. 2); X,Y position.
- Experimental Condition: StepDom (aggression)–determined by gender and species;
  - 2002 only: attraction (boolean: ♂⇒♀).
- Statics: field of view; near view; max view; personal space.

Hemelrijk's AS



Separation

Cohesion

No Alignment

Interaction Equations

1

$$w_i = \begin{cases} 1 & \frac{Dom_i}{Dom_i + Dom_j} > Random(0,1) \\ \\ 0 & else \end{cases}$$

2

$$Dom_i = Dom_i + \left(w_i - \frac{Dom_i}{Dom_i + Dom_j} \right) * StepDom$$

$$Dom_j = Dom_j + \left(w_i - \frac{Dom_i}{Dom_i + Dom_j} \right) * StepDom$$

for bees!

Hogeweg & Hesper 1988

Hemelrijk 2002

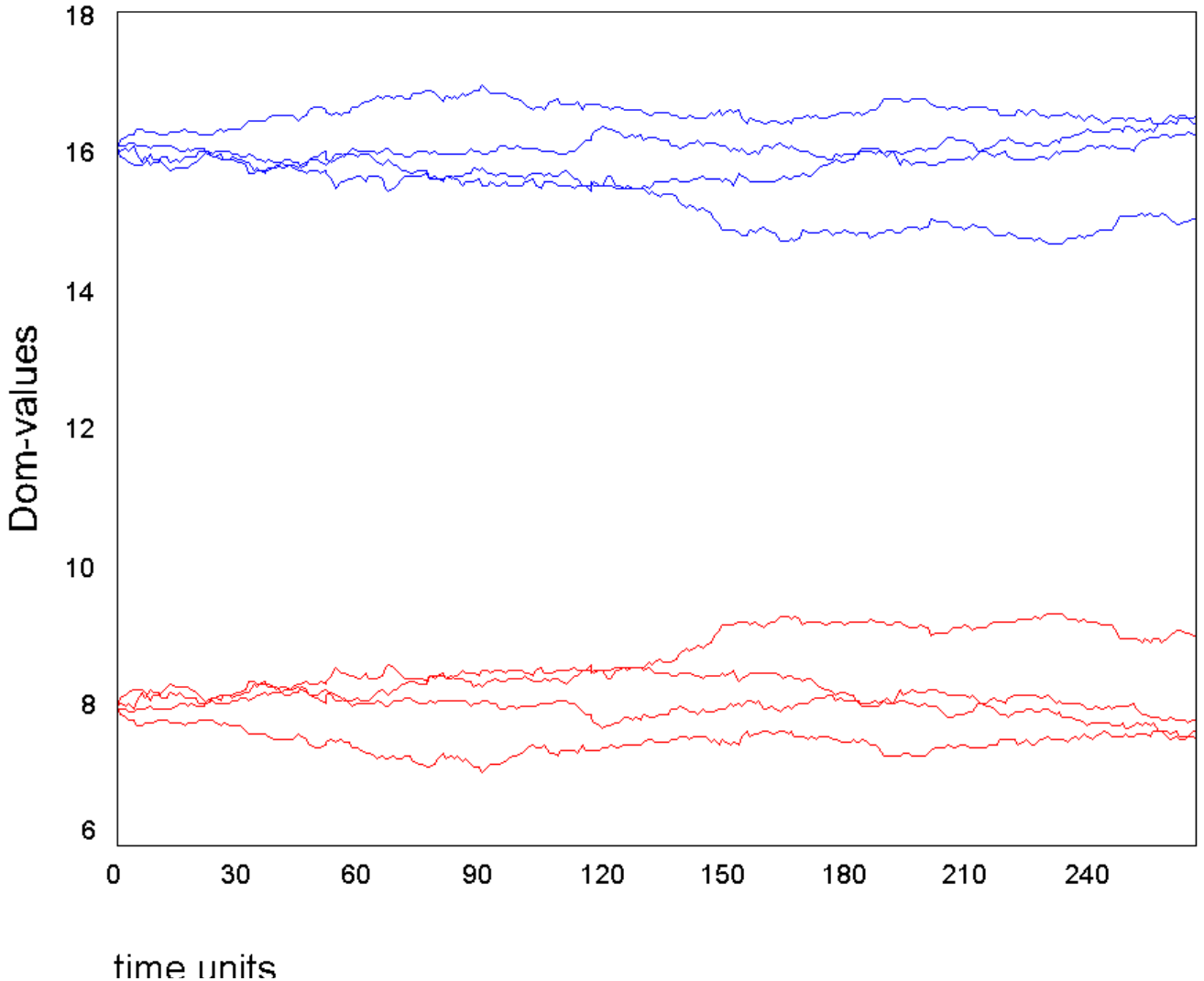
"Self-Organization and Natural Selection in the Evolution of Complex Despotic Societies", *Biological Bulletin*, **202**(3):283-288

- Difference between despotic & egalitarian only increase of aggression (StepDom).
- Increased tolerance of females during tumescence due only to their attractiveness.

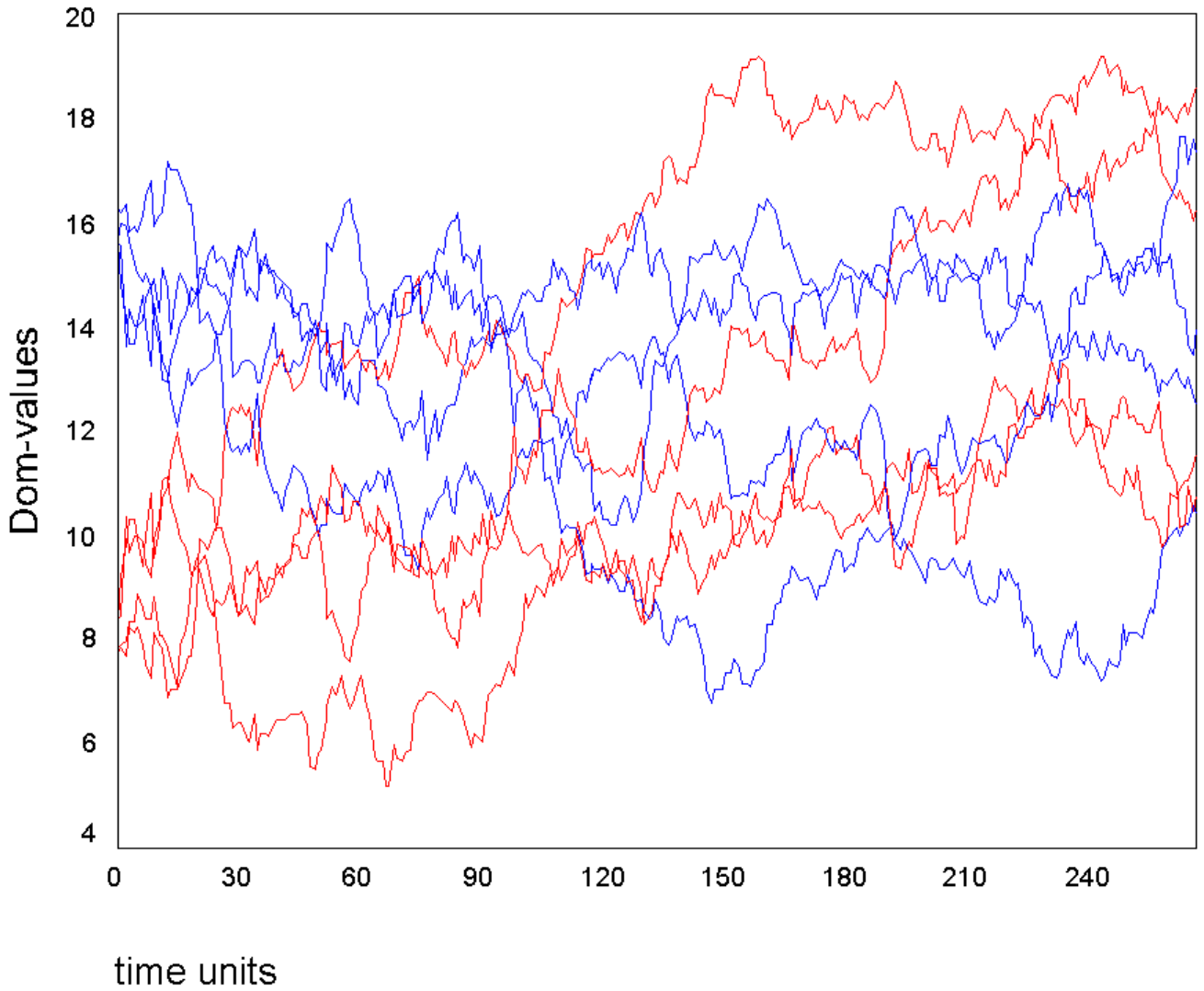
Replication

By Hagen Lehmann & JingJing Wang

Egalitarian, Normal Dominance Rankings

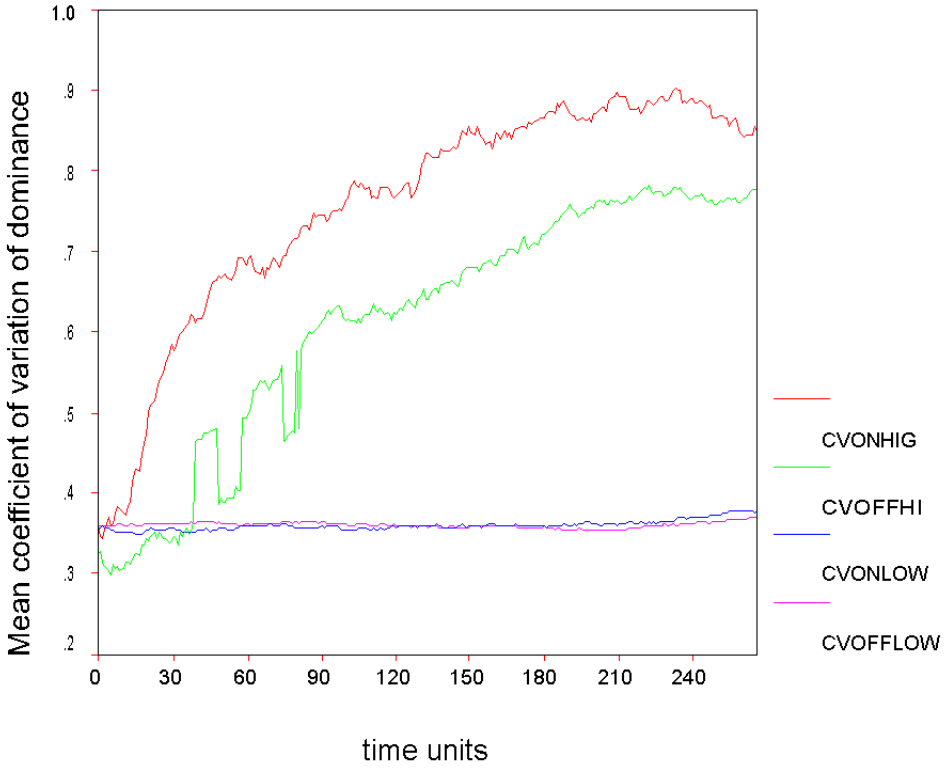


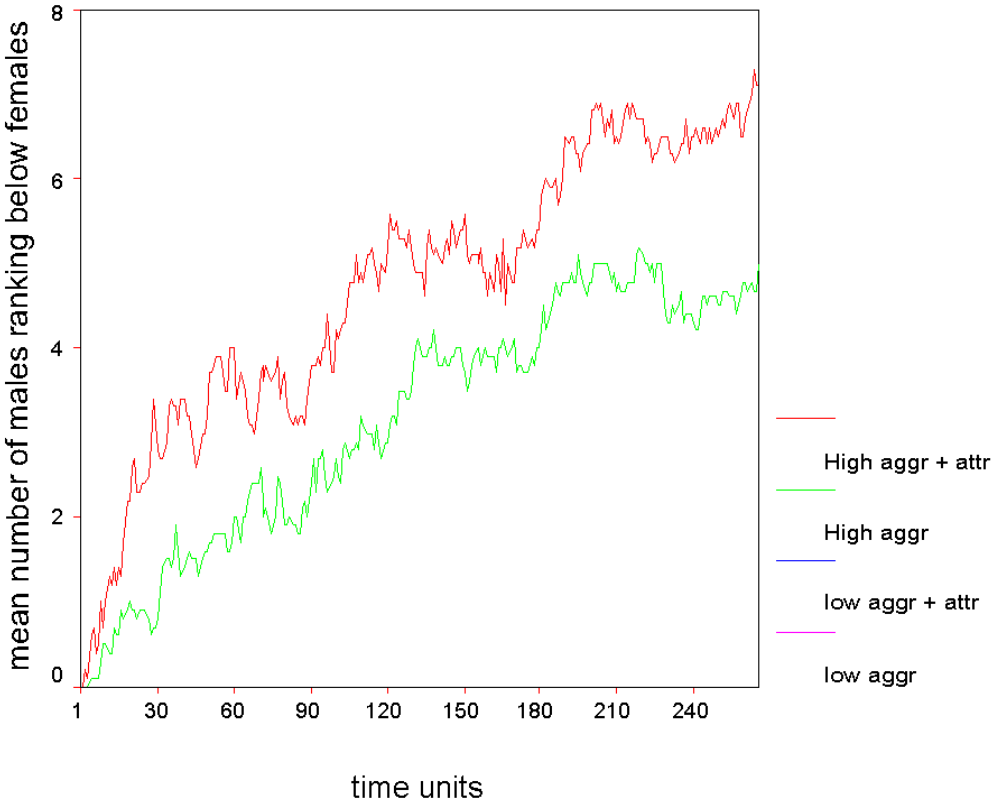
Attraction On & Aggression High (Despotic)



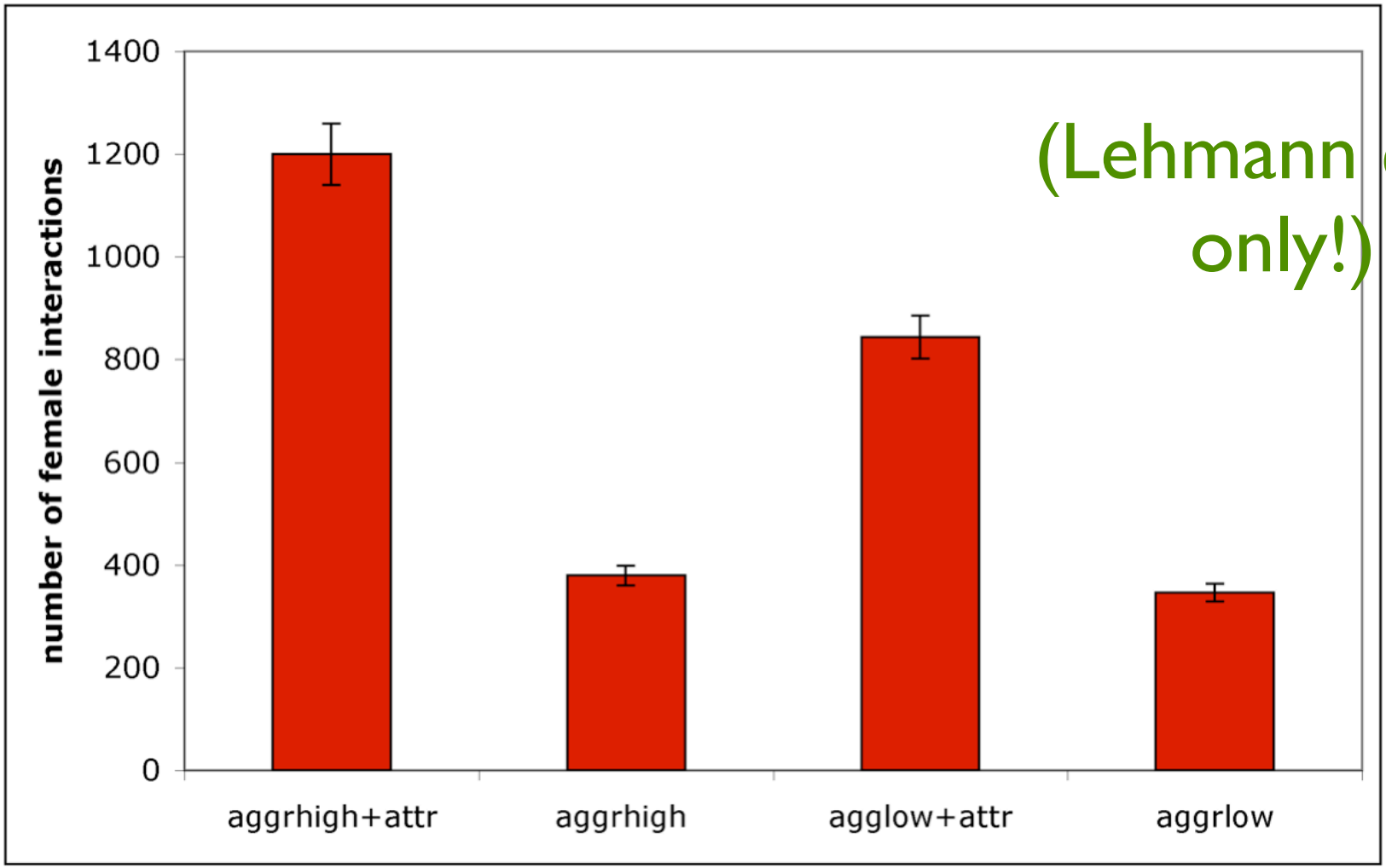
Dominance

L–coefficient of variation; R–mean # of ♂<♀





Number of Female Dominance Interactions



(Lehmann *et al.* only!)

Analysis

Analysis Methodology

- Understand (replicate) model.
- Find assumptions (implicit or explicit).
- Treat assumptions as predictions.
- Test predictions against data.

1. If one agent defeats another that vastly outranks it in a dominance interaction, do the two agents immediately change ranks within the troop? (Unexpected outcome results in dramatic effect, Equation 2.)

2. Does it take fewer interactions to advance rank in a 'despotic' species? (StepDom in Equation 2.)

3. Within species, if a fight is more violent (e.g. if blood is drawn) does it have more impact on the dominance hierarchy? (StepDom as 'aggression', Equation 2.)

4. Are females more likely to engage in fights when they are in tumescent? If not then this model cannot account for their increased dominance.

5. Do females only become dominant during their tumescence in despotic species?

6. When an animal in an egalitarian species is clearly outranked by another animal, are those two animals' interactions similar to two more nearly ranked animals in a less egalitarian species?

Science Requires Expertise

long-tailed macaques

Teeth baring as a gesture of submission
(Bernard Thierry)

Checked Questions with Thierry

- Not enough data to check (because...)
- Ranks almost never change.

1. If one agent defeats another that vastly outranks it in a dominance interaction, do the two agents immediately change ranks within the troop? (Unexpected outcome results in dramatic effect, Equation 2.)
2. Does it take fewer interactions to advance rank in a 'despotic' species? (*StepDom* in Equation 2.)
3. Within species, if a fight is more violent (e.g. if blood is drawn) does it have more impact on dominance hierarchy? (*StepDom* as 'aggression', Equation 2.)

Bryson, Ando & Lehmann 2007, 2011

4. Are females more likely to engage in fights when they are in tumescent? If not then this model cannot account for their increased dominance.

No!

5. Do females only become dominant during their tumescence in despotic species?

Probably Not

6. When an animal in an egalitarian species is *clearly* outranked by another animal, are those two animals' interactions similar to two more nearly ranked animals in a less egalitarian species?

Probably Not

Hemelrijk Replication Conclusions

- Problems with existing model:
  - Predicts too much dominance volatility.
  - Inverts observed female violence.
- A different (more complex?) model is justified.

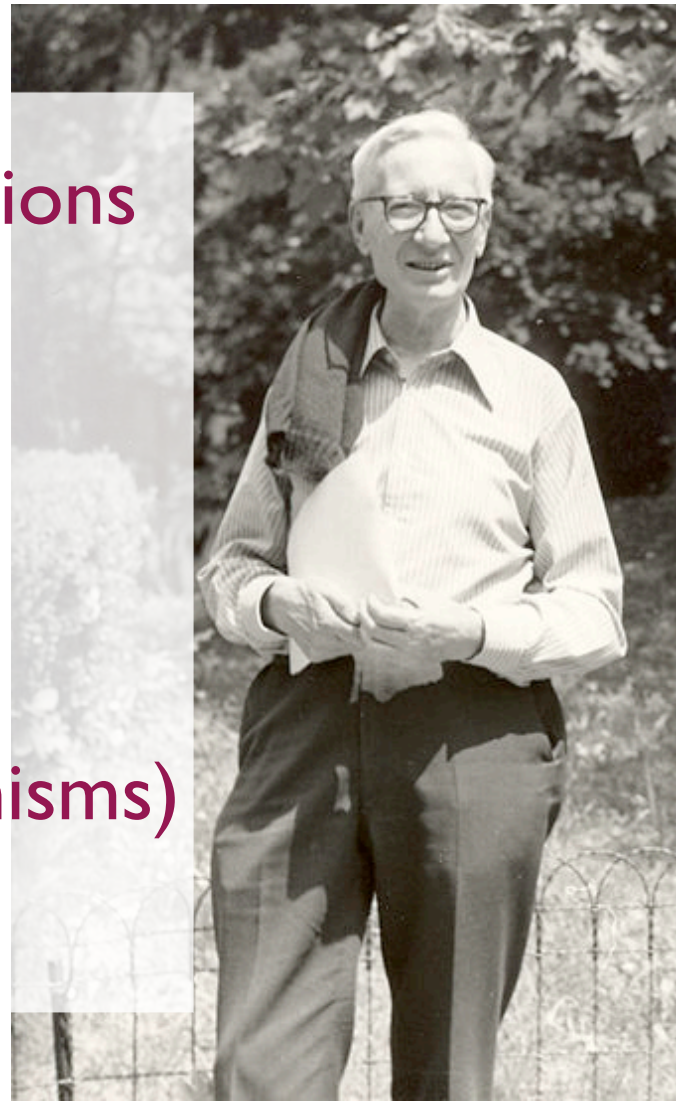
From evolution lecture...

Science as Evolution

- Evolution requires variation, reproduction and selection.
- Variety of theories get taught.
- Theories in new experiments bare some resemblance to what got taught.
- Memory of scientists, peer review, & prediction success perform selection.

Tinbergen's Questions

- Evolutionary (ultimate) explanations
  - Function (adaptation)
  - Phylogeny (evolution)
- Proximate explanations
  - Causation (proximate mechanisms)
  - Development (ontogeny)



Weirdly Common Mistake

- The simplest explanation "wins".
- But an ultimate explanation and a proximate explanation explain different things.
- You can have–in fact you need at least two "winners".

Two More Theories...

1. Socio-Ecological Theory (van Schaik 1989)

- Soc. structure responds to environment.
- Key factor is inter-individual distance. Egalitarians further apart: better for foraging, worse for predation.

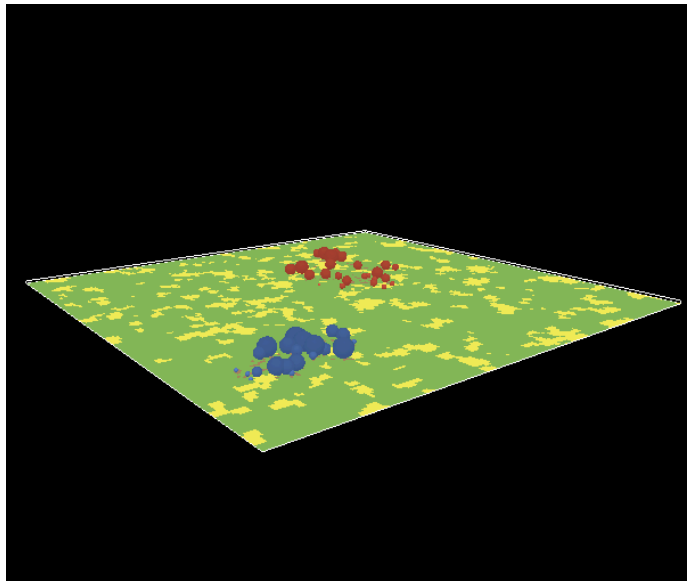
2. Phylogenetic Inertia Theory (Thierry '04)

- Migration history and genetic drift.
- Despotics observed to be further apart.

...Unified through Simulation

- Predation pressure does select for despotism.
- More recently evolved species do seem more able to shift to this structure.
- Individuals can be more distant on average, but have a lower minimum distance.

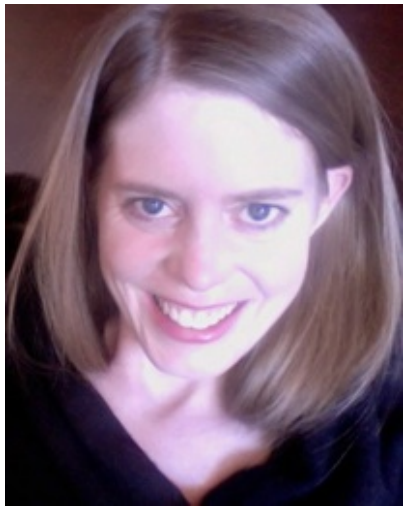
(Lehmann, PhD 2009)



Two Hypotheses of Macaque Social Order

Winner!

- Less resources (e.g. food) $\Longrightarrow$ more violence $\Longrightarrow$ selective pressure for social structure (Hemelrijk 2001, 2002+).



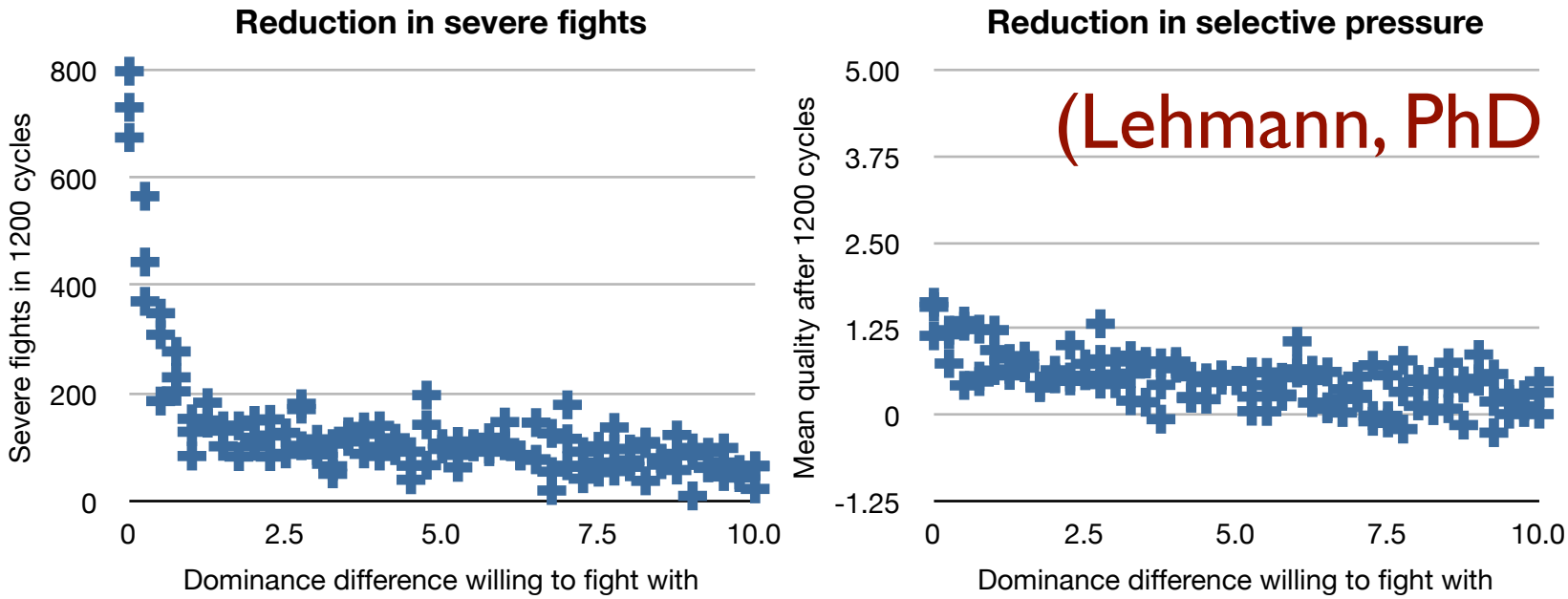
- New conflict resolution behaviour $\Longrightarrow$ less violence $\Longrightarrow$ less pressure for social structure (de Waal 2001, Flack & de Waal).

What is Status For?

Winner!

- Less resources (e.g. food) $\Longrightarrow$ more violence $\Longrightarrow$ selective pressure for social structure (Hemelrijk 2001, 2002+).
- Status does not indicate fitness, it's only about conflict resolution (2008).

Explanations of Dominance Ranks



(Lehmann, PhD 2009)

1. Dominance certainly reduces conflict by establishing priority.

2. Dominance can still also increase distribution of beneficial traits (genetic or memetic).

Summary

- AI simulation is a method of doing science.
- Cannot be the sole method, must have data about the real world.
- But can be a source of evidence, lead us to better understand the plausibility and consequences of our theories.