FROM THEORY TO EXPERIMENTS AND BACK

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MANY MANY THANKS TO THE ORGANISERS

Nice **Picture of**

Claudia

here

Funny **Picture of**

Nicola

here

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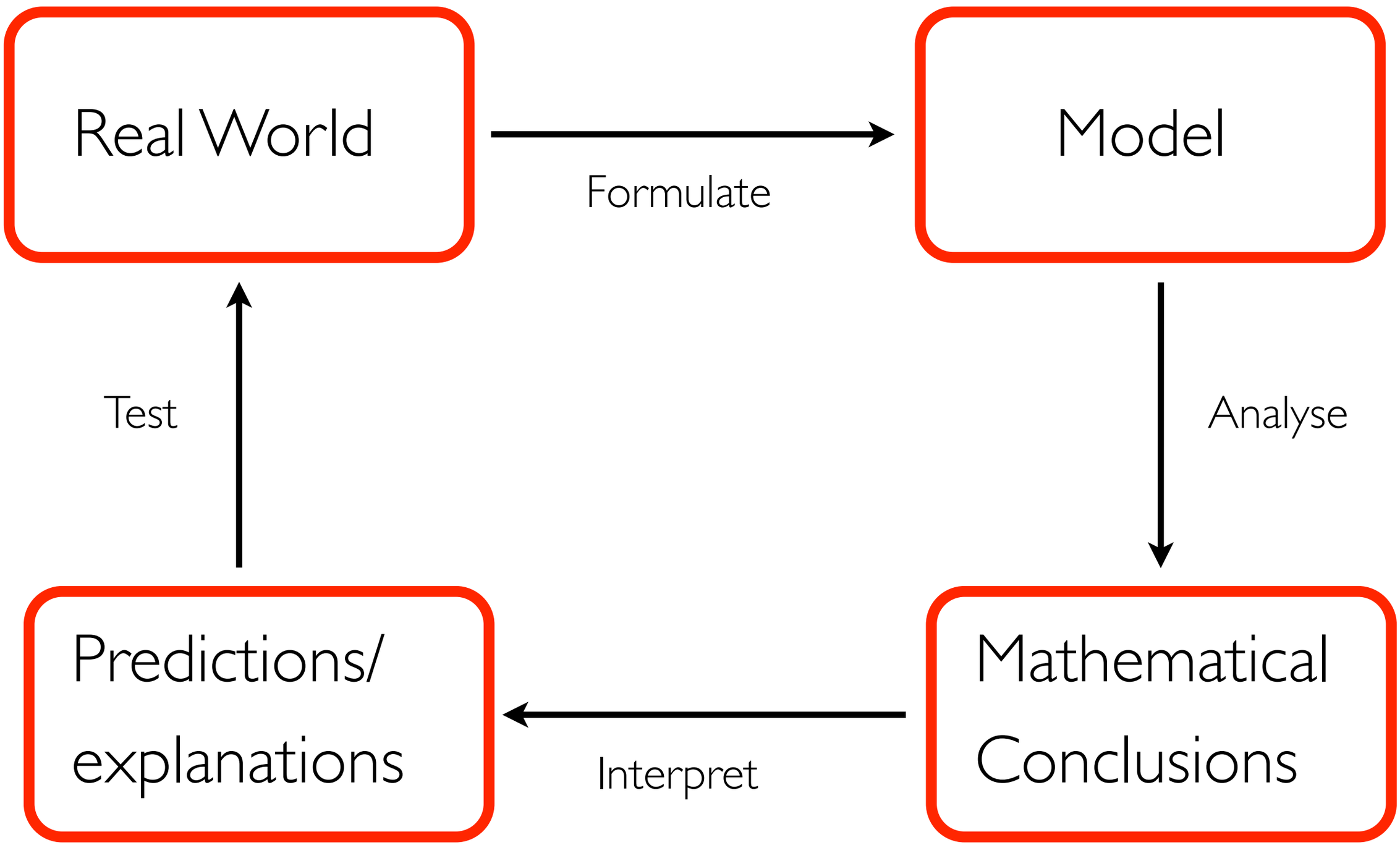
- Something on modelling humans
- (Quick) Modelling us in Sant’Antioco (here and now)
- (Deep) The problem of consensus
  - Simple conventions
  - Categories
- (Maybe) How we explore mental spaces

CHRIS ERSON MAGAZINE 06.23.08 12:00 PM

THE END OF THEORY: THE DATA DELUGE MAKES THE SCIENTIFIC METHOD OBSOLETE

ration: Marian Bantjes

"with enough data, the numbers speak for themselves"


Real World
Formulate
Model
Analyse
Mathematical Conclusions
Interpret
Predictions/ explanations
Test

model

/ˈmɒd(ə)l/

noun

noun: **model**; plural noun: **models**

1. a three-dimensional representation of a person or thing or of a proposed structure, typically on a smaller scale than the original.
   "a model of St Paul's Cathedral"
   synonyms: replica, copy, representation, mock-up, dummy, imitation, double, duplicate, lookalike, reproduction; More
   - (in sculpture) a figure or object made in clay or wax, to be reproduced in another more durable material.
     "wax models were used by sculptors in the lost wax method of bronze casting"

Etymology: 1570s, "likeness made to scale; architect's set of designs," from Middle French *modelle* (16c., Modern French modèle), from Italian *modello* "a model, mold," from Vulgar Latin **modellus*, from Latin *modulus* "a small measure, standard," diminutive of modus "manner, measure"

(from PIE root *med- "take appropriate measures").

calculations and predictions.
"a statistical model used for predicting the survival rates of endangered species"

4. a person employed to display clothes by wearing them.
   "Jane was too small to be a model"
   synonyms: fashion model, supermodel, mannequin; *informal* clothes horse
   "she was too small to be a top model"
   - a person employed to pose for an artist, photographer, or sculptor.
     "an artist's model"
     synonyms: sitter, poser, subject, artist's model, photographic model
     "he used his wife as a model for his pictures"

5. a particular design or version of a product.
   "the company revealed their latest model at the Motor Show"
   synonyms: version, type, design, mark, configuration, variety, kind, sort
   "he changes his car every year for the latest model"

MODELLING

"Consider first material models.

They start by being rough approximations, surrogates for the real facts studied.

Let the model approach asymptotically the complexity of the original situation.

It will tend to become identical with that original system. As a limit it will become that system itself.

That is, in a specific example, the best material model for a cat is another, *or preferably the same*, cat."

Arturo Rosenblueth and Norbert Wiener
"The Role of Models in Science"
Philosophy of Science, Vol. 12, No. 4 (Oct., 1945), pp. 316-321

MODELLING AS A PROBLEM OF MEASURE

Ockham's razor:
among competing hypotheses, the one with the fewest assumptions should be selected

A DEBATE IN THE SOCIAL SCIENCES

Symposium: "What is Good Theorizing?"

AMERICAN SOCIOLOGICAL ASSOCIATION

THE ‘HUMAN’ PROBLEM

- Impossibility of doing experiments (e.g., origin of decrease in crime rate in NYC in the ‘90s).
Not completely true. and what about astronomy?

- “Contingency”: random, unpredictable, facts affect history. (“Cleopatra’s nose” problem, Mark Antony fell in love..)
What about biology?

- Complexity of the human being. Human world is complicated because people are complicated.
Individuals are different, they react differently, they respond to the environment, they have free-will, etc.

RATIONALITY?

1. Rational individuals are predictable,
2. Everyone is identical.

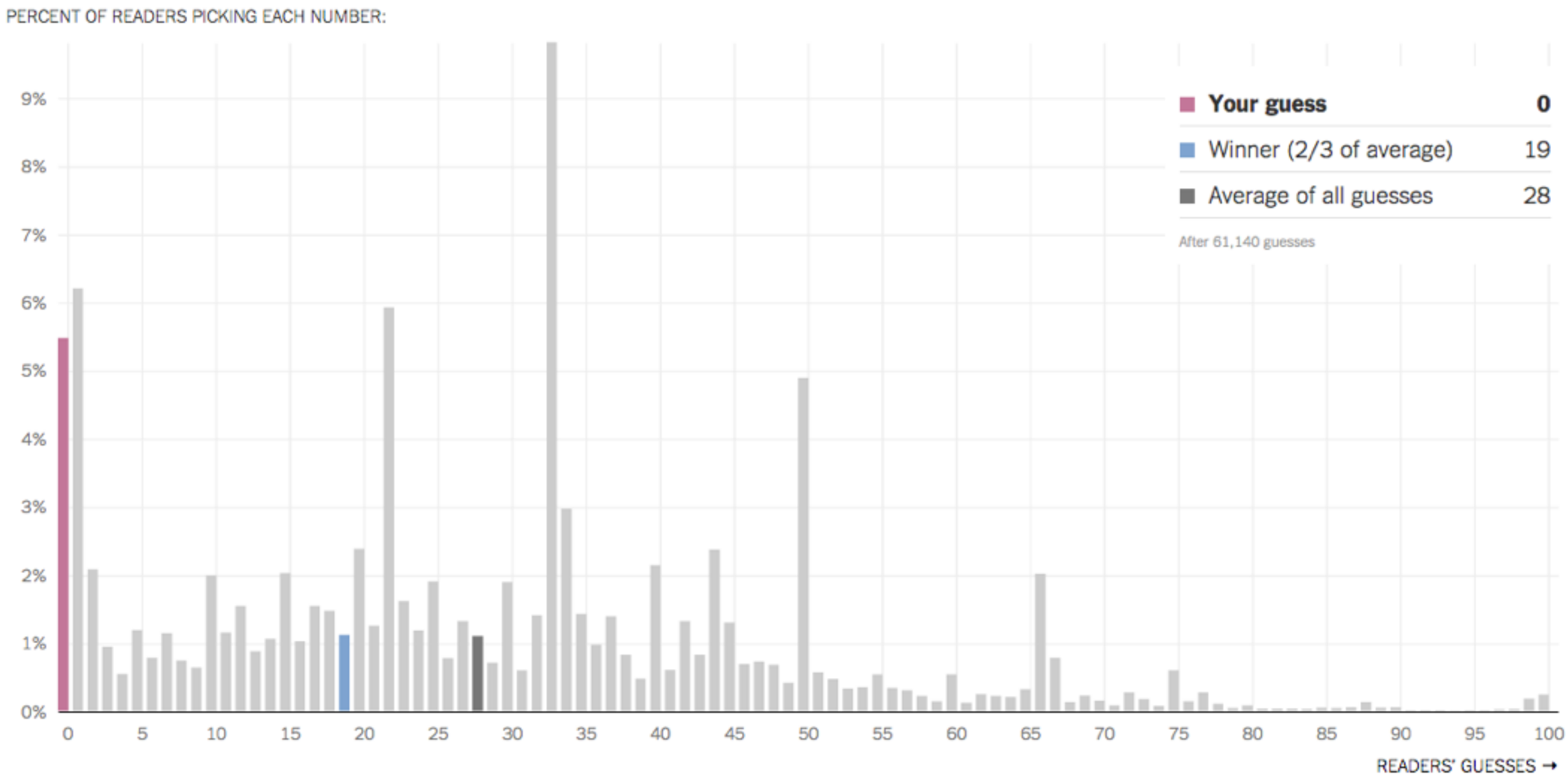
this has produced important results, but
often does not predict human behaviour.

Say a number between 0 and 100. The winner will be the one to be closer to 2/3 of the average of the chosen numbers. (Richard Thaler, 1987).

Replicated in todays NYT http://www.nytimes.com/interactive/2015/08/13/upshot/are-you-smarter-than-other-new-york-times-readers.html

Rationality: the average will be 50, so the winning number is 33. But everyone is rational, so the winning number is 22. But everyone notices this, so the winning number is 15.. The rational choice is 0.

The overall average was 18.9, and the winner said 13.

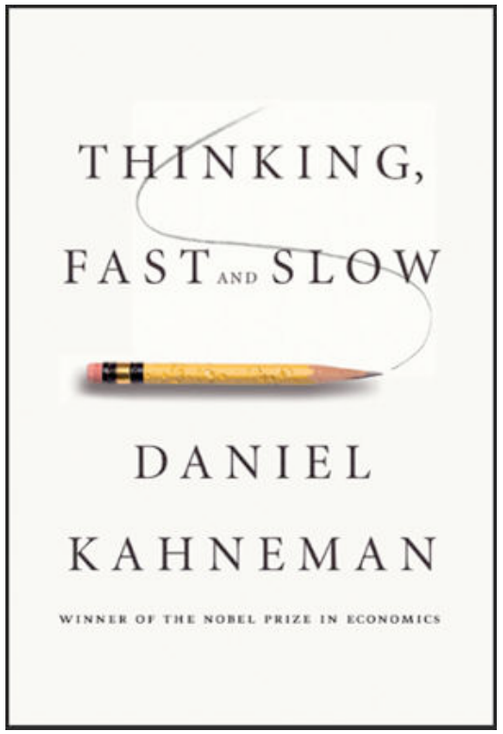

PERCENT OF READERS PICKING EACH NUMBER:
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
READERS' GUESSES →
Your guess 0
Winner (2/3 of average) 19
Average of all guesses 28
After 61,140 guesses

THINKING, FAST AND SLOW

Two systems:

1. Fast, instinctive and emotional
2. More rational system.

Both have biases. But both are shared.



A “social atom” is possible
(to be defined each time).

AGENT-BASED MODEL

Agent-based models consist of dynamically interacting rule-based agents.

Typically agents are situated in space, either a lattice a network or a physical space.

The modeller has to specify

1) the <u>architecture</u> of the agents (which can be heterogeneous),
2) the rules of their <u>interactions</u>.

ADAPTIVE AGENTS

Adaptive rather than rational agents. The individuals are assumed to follow simple rules [..]. These rules are not necessarily derivable from any principles of rational calculation based on costs and benefits or forward-looking strategic analysis typical of game theory. Instead, the agents simply adapt to their environment.

Robert Axelrod, J. Conflict. Resol. 2:203 (1997)

PROS AND CONS

- (Much) easier than deriving analytical results
- Flexible
- They allow to study out-of equilibrium systems, and dynamics in general
- They can be used to study the robustness, resilience, adaptivity of systems, etc.

- Complicated rules/agents can produce opaque results
- The modeller risks to put into the model the output she wants to find.
- Complex models which are closer to the system we want to model can be less explanatory than simpler models.

experiment

/ɪkˈspɛrɪm(ə)nt,ɛkˈspɛrɪm(ə)nt/

noun

noun: **experiment**; plural noun: **experiments**

1. a scientific procedure undertaken to make a discovery, test a hypothesis, or demonstrate a known fact.
   "a laboratory which carried out **experiments on** pigs"
   synonyms: test, investigation, trial, enquiry, demonstration; More
   - research, experimentation, observation, trial and error, analysis, testing

   antonyms: theory
- a course of action tentatively adopted without being sure of the outcome.
  "the previous **experiment in** liberal democracy had ended in disaster"

Etymology: from Latin *experimentum* "a trial, test, proof, experiment," noun of action from experiri "to try, test,"

from ex- "out of" (see ex-) + peritus "experienced, tested,"

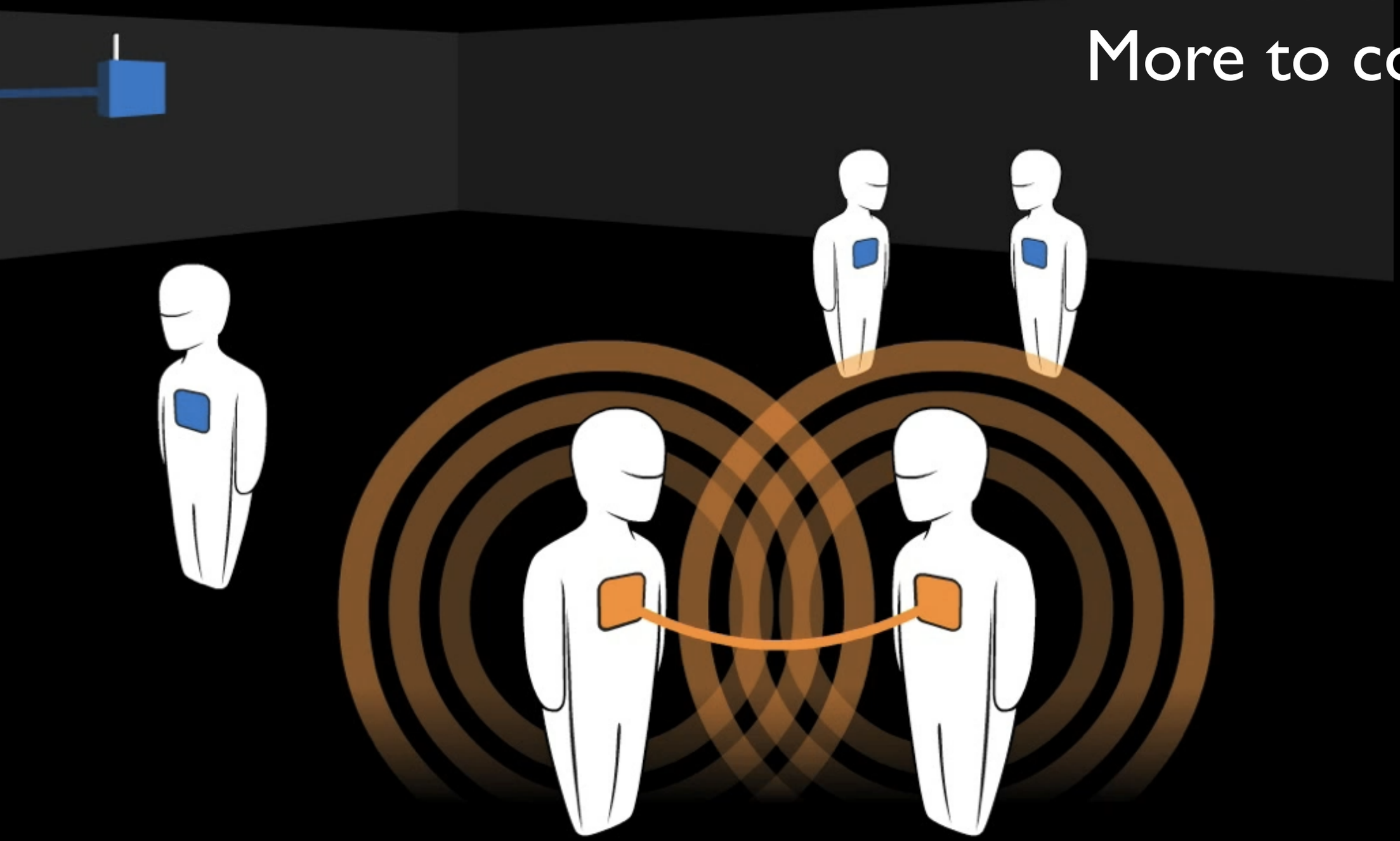
from PIE *per-yo-, suffixed form of root *per- (3) "to try, risk."

DYNAMICS OF F2F NETS

With M. Starnini and R. Pastor-Satorras

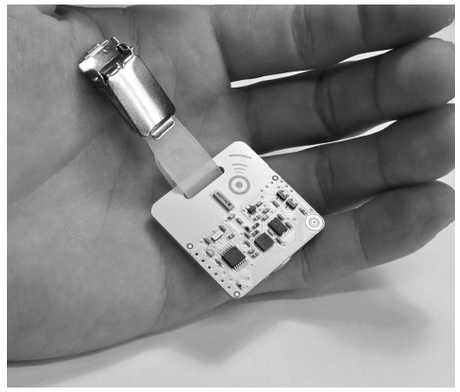
SocioPatterns

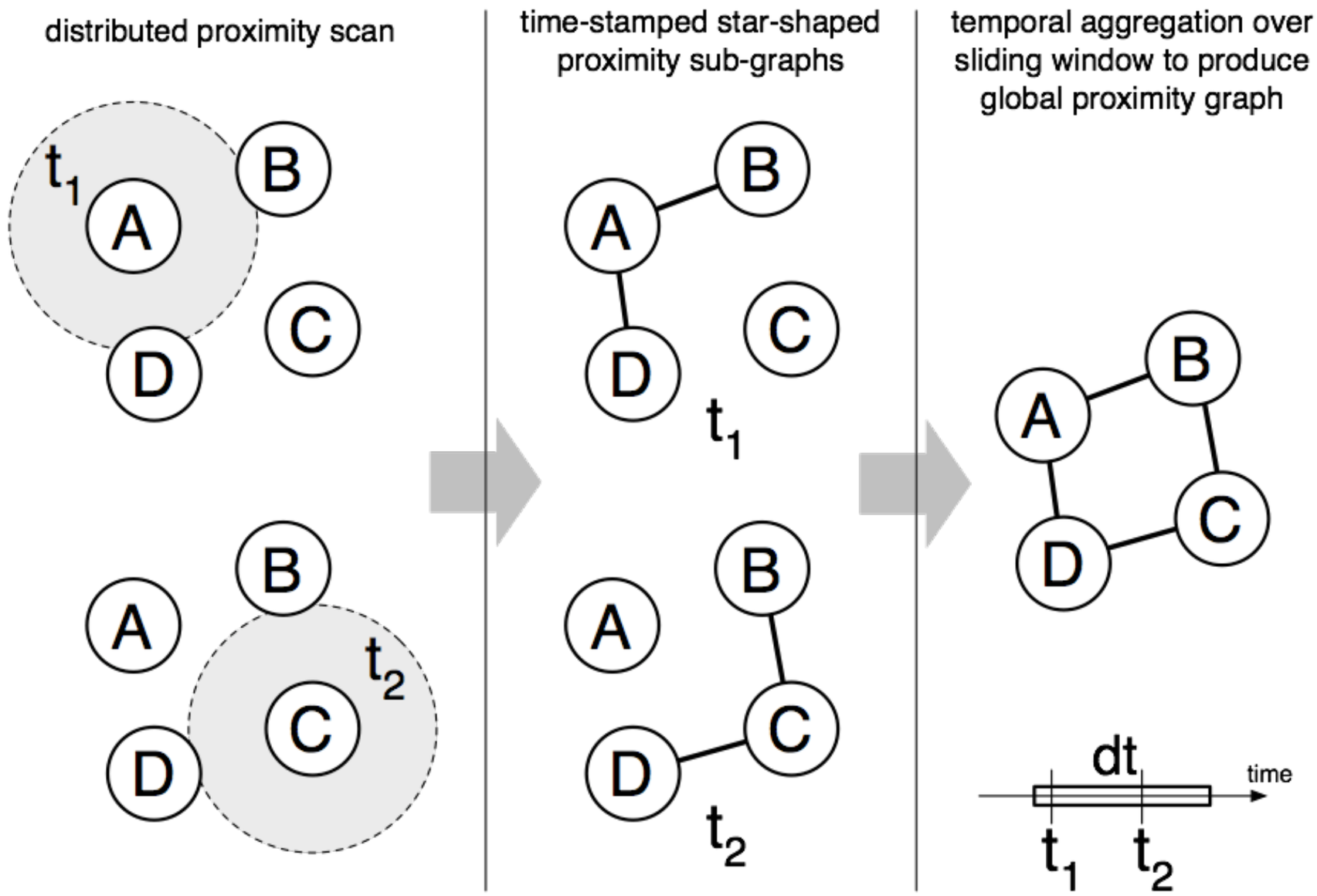
Conferences
Schools
Hospitals
Museum
More to come...



Empirical Networks

SocioPatterns

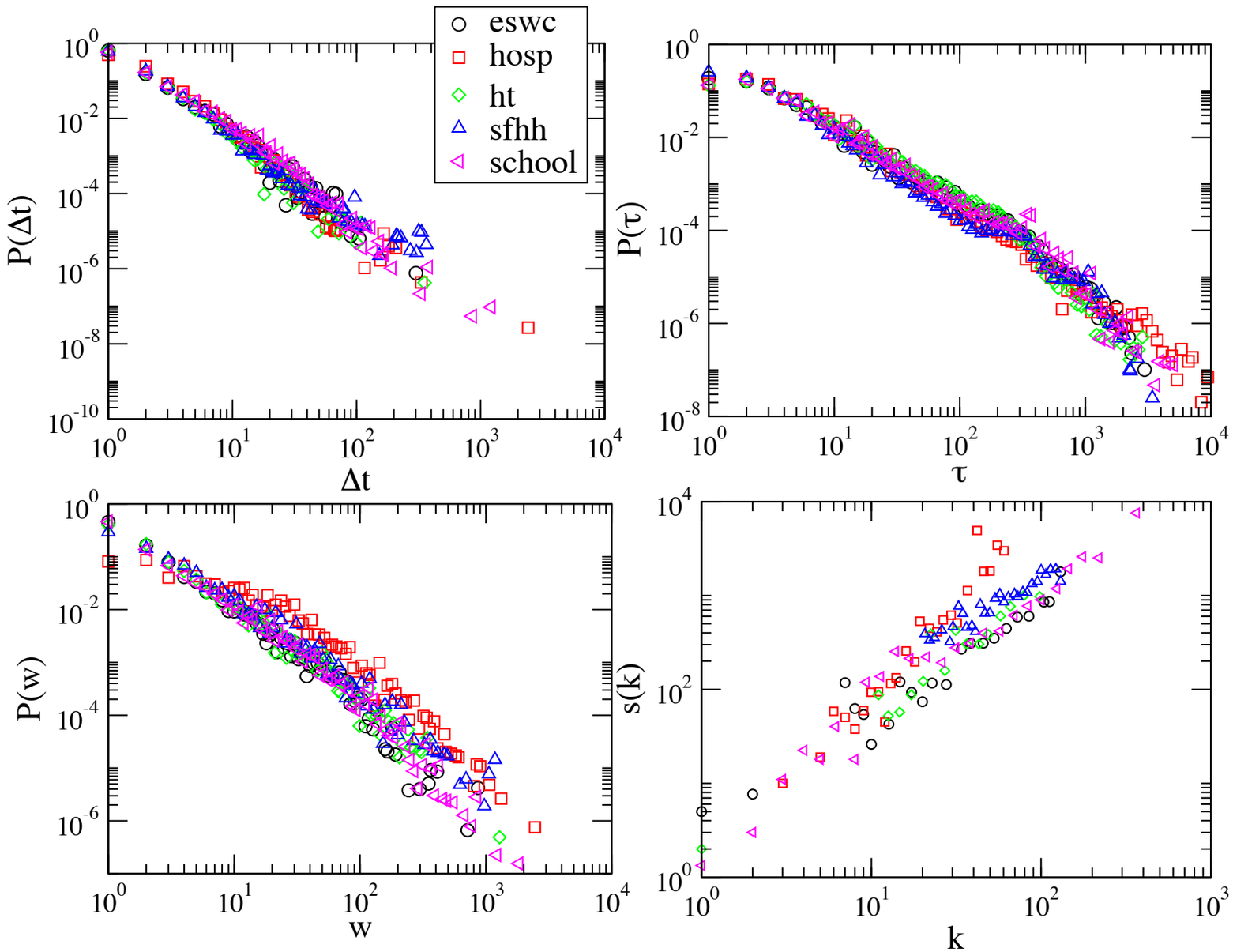




HETEROGENEITY AND BURSTINESS

Contact duration

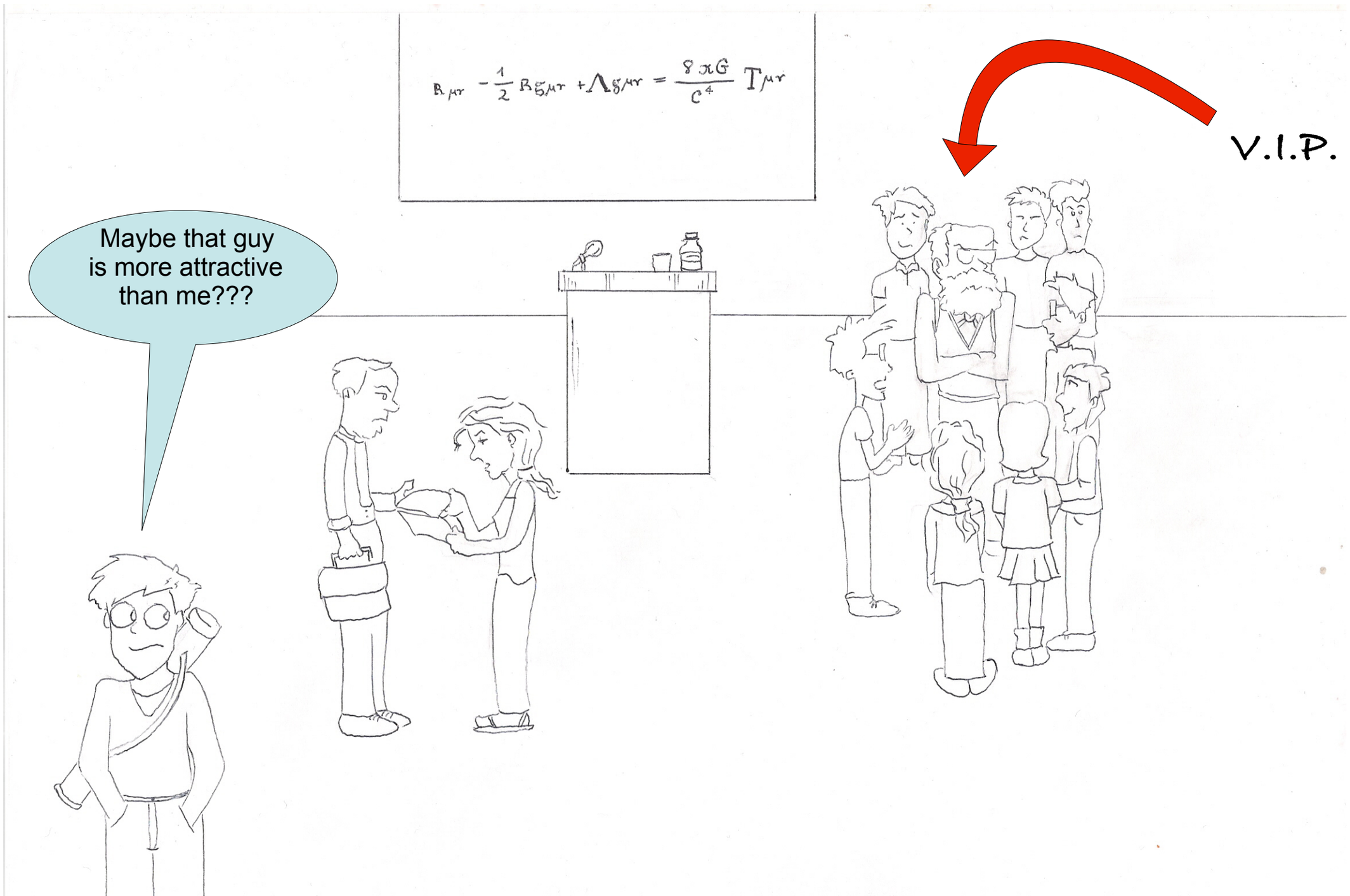
Inter-contact gap times



Total contact time between pairs

Strength vs Degree

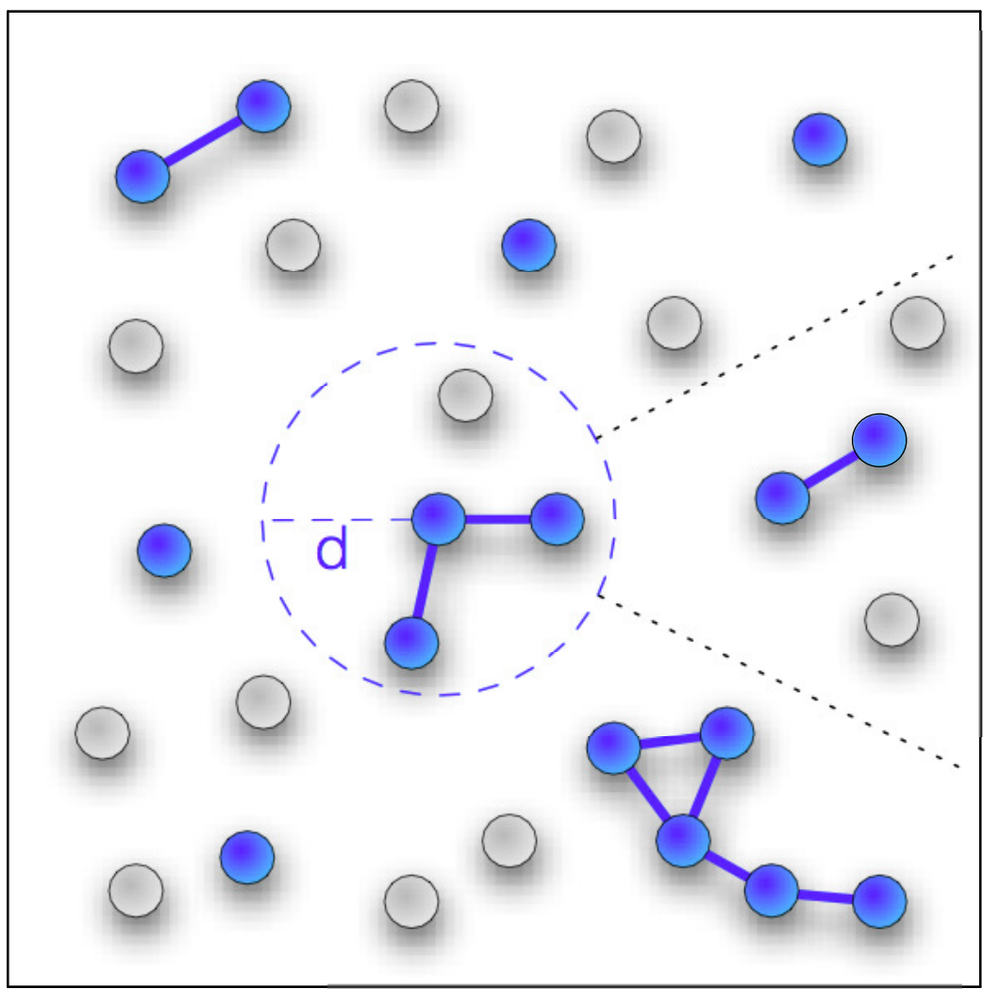
TYPICAL CONFERENCE



MODEL

N agents perform a biased random walk in a 2D space

When 2 agents meet within a distance d, they start to interact



Phys. Rev. Lett. 2013, Social Networks 2016

MODELLING FACE-TO-FACE INTERACTIONS

Biased random walk

Interaction within radius *d*

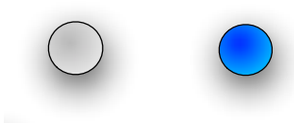
Each agent has a given attractiveness
(extracted from a uniform distribution)

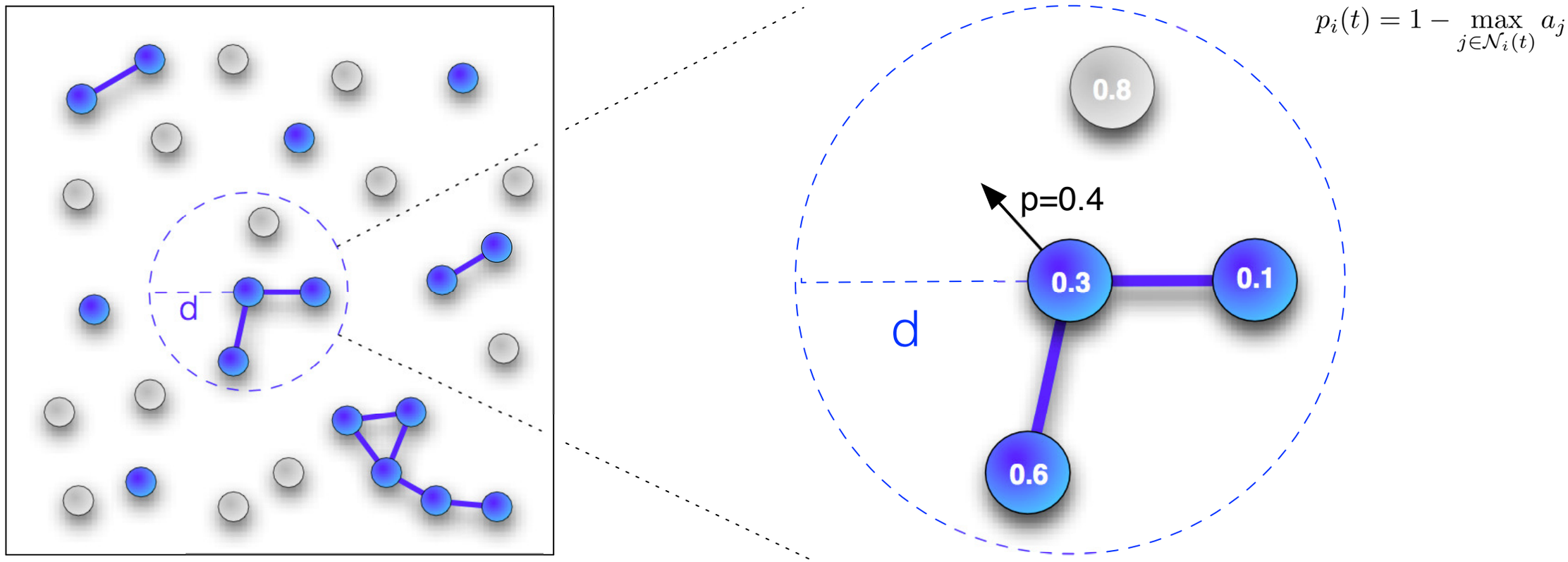
$$a_i \in [0, 1)$$

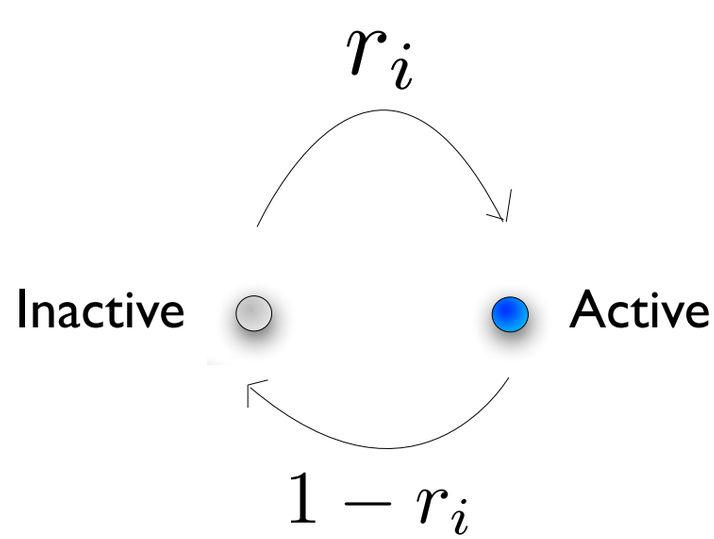
Agents stop by attractive individuals

$$p_i(t) = 1 - \max_{j \in \mathcal{N}_i(t)} a_j$$

Agents can be active or inactive

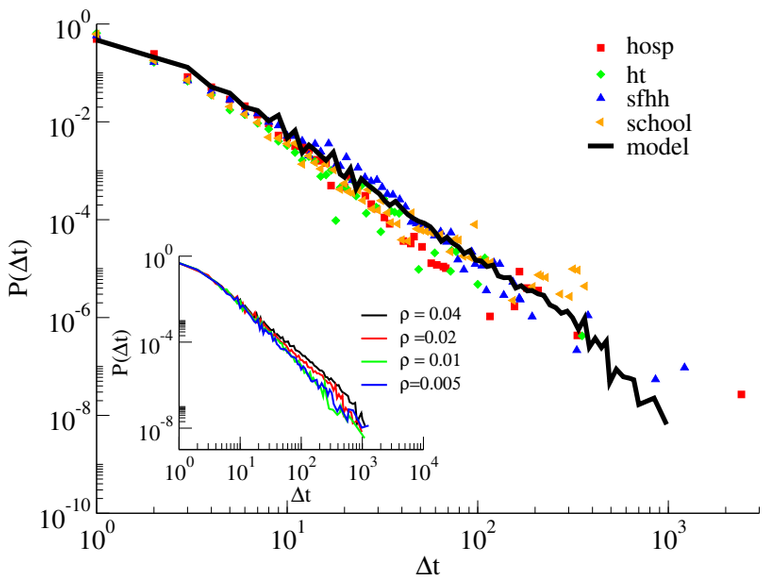



$p_i(t) = 1 - \max_{j \in \mathcal{N}_i(t)} a_j$
d
0.8
p=0.4
0.3
0.1
d
0.6

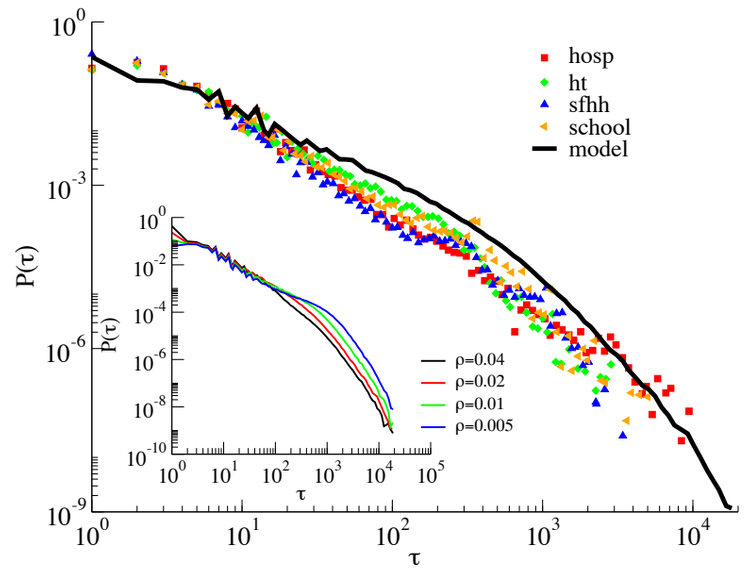

r_i
Inactive
Active
$1 - r_i$

MODEL REPRODUCES DATA

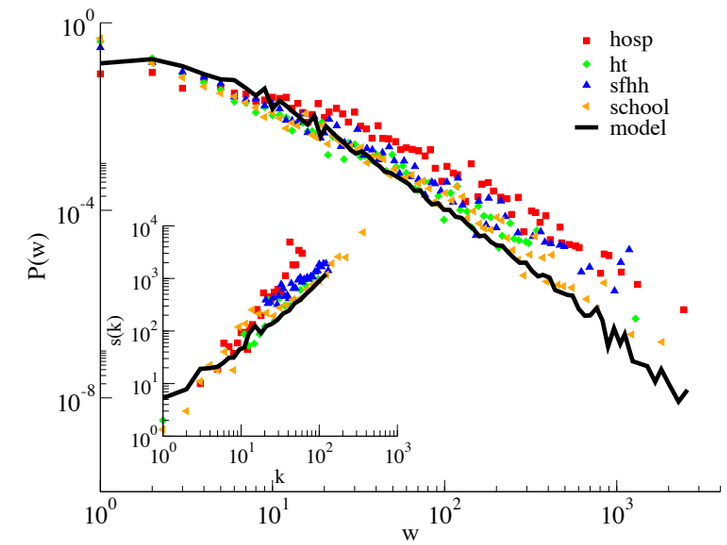
Contact duration



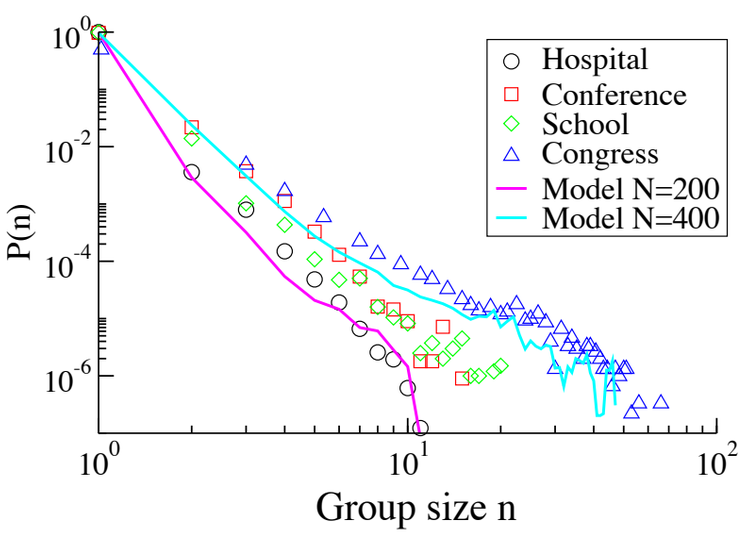
Inter-contact gap times



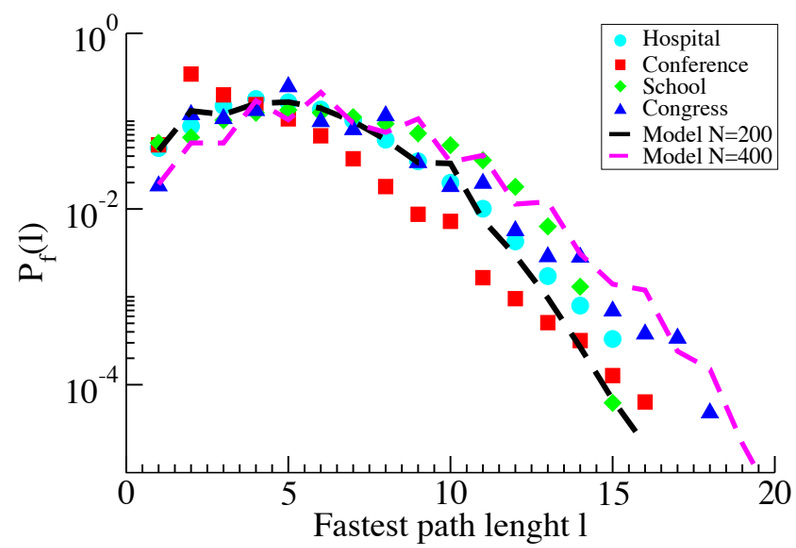
Strength in aggregated net.



Group sizes



Fastest path



M. Starnini, A. Baronchelli and R. Pastor-Satorras
Modeling human dynamics of face-to-face interaction networks
Phys. Rev. Lett. 110, 168701 (2013)

Model reproduces individual, group and collective dynamics of human contact networks
Social Networks 47, 130 (2016)

WHAT'S ATTRACTIVENESS?

A proxy for many things.

At IC2S2 in Cologne (July 2017) and here participants to a Sociopatterns experiment where given a questionnaire about

- self-perceived scientific attractiveness
- self-perceived social attractiveness
- range of google scholar citations
- range of participants already known

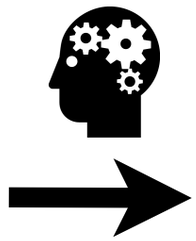
THE EMERGENCE OF CONSENSUS

With A. Barrat, D. Centola, L. Dall'Asta, V. Loreto, A. Puglisi, L. Steels

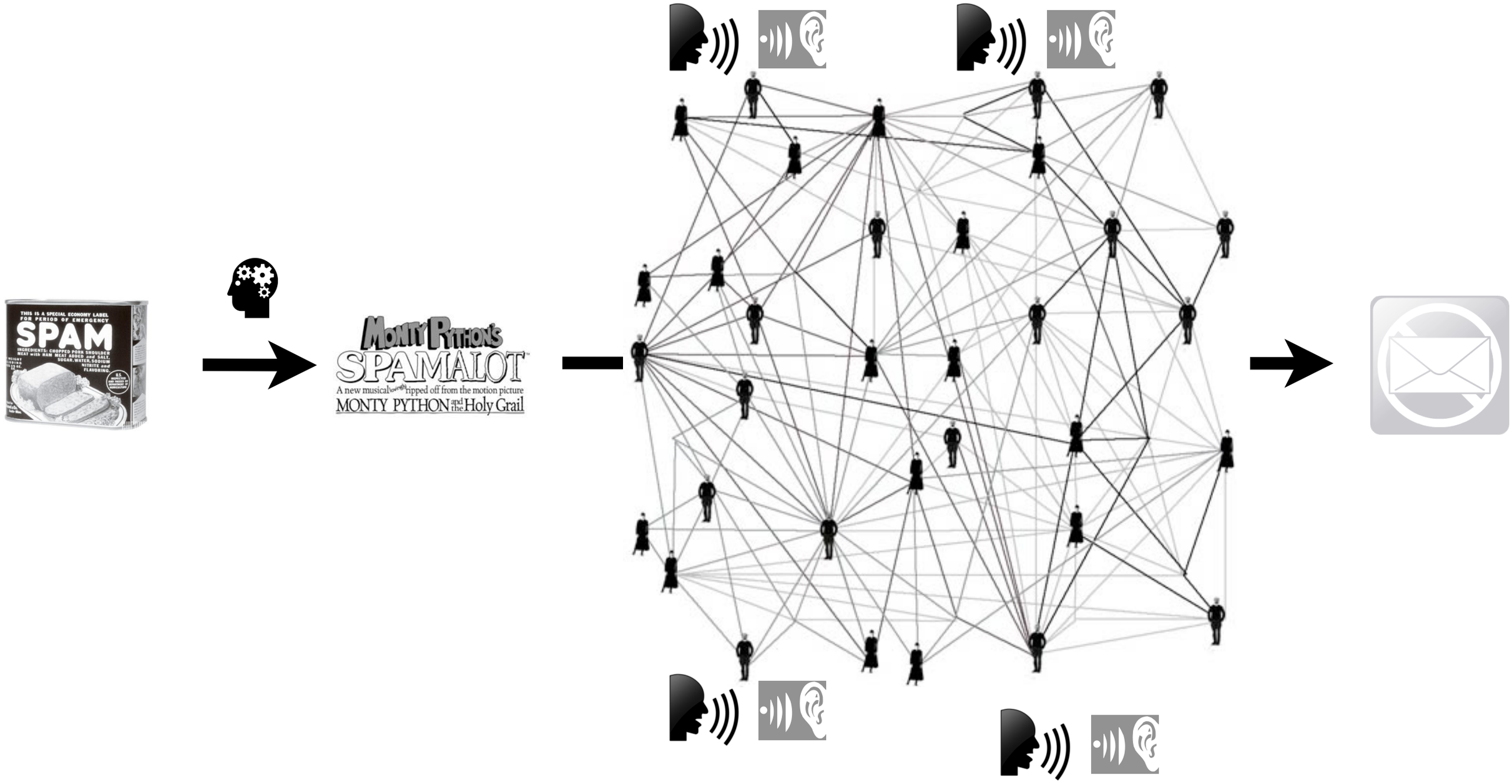
I. CONVENTIONS


MERRIAM WEBSTER DICTIONARY (2017)
SPAM
Unsolicited usually commercial e-mail sent to a large number of addresses
Monty Python (1974)


THIS IS A SPECIAL ECONOMY LABEL
FOR PERIOD OF EMERGENCY
SPAM
INGREDIENTS: CHOPPED PORK SHOULDER
MEAT with HAM MEAT ADDED and SALT,
SUGAR, WATER, SODIUM
NITRITE and
FLAVORING.
U.S.
INSPECTED
AND PASSED BY
DEPARTMENT OF
AGRICULTURE




MONTY PYTHON'S
SPAMALOT
A new musical ripped off from the motion picture
MONTY PYTHON and the Holy Grail


THIS IS A SPECIAL ECONOMY LABEL FOR PERIOD OF EMERGENCY
SPAM
MONTY PYTHON'S
SPAMALOT
A new musical ripped off from the motion picture
MONTY PYTHON and the Holy Grail

CONSENSUS IS NEEDED FOR, E.G.,

- Money
- Language
- Politeness
- Standards of dress and decorum
- Notions of fairness
- Conceptions of right and wrong
- Etc.

AS NOTED A LONG TIME AGO

No one is able to persuade me that the correctness of ***names*** *is determined by anything besides* ***convention****…*

Plato, Cratylus (384c-d)

Money *has become by* ***convention*** *a sort of representative of demand [..] and it is in our power to change it*

Aristotle, Nicomachean Ethics (V.5.II33a)

THE PROTOTYPICAL EXAMPLE: NAMES

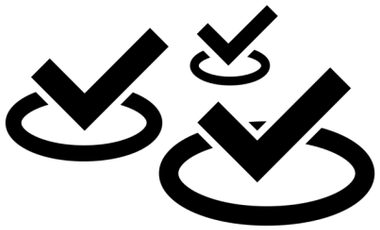
"What's in a name? That which we call a rose by any other name would smell as sweet"

W. Shakespeare

SOCIAL CONVENTION

unwritten custom **shared** throughout a community

selected from among two or more alternatives

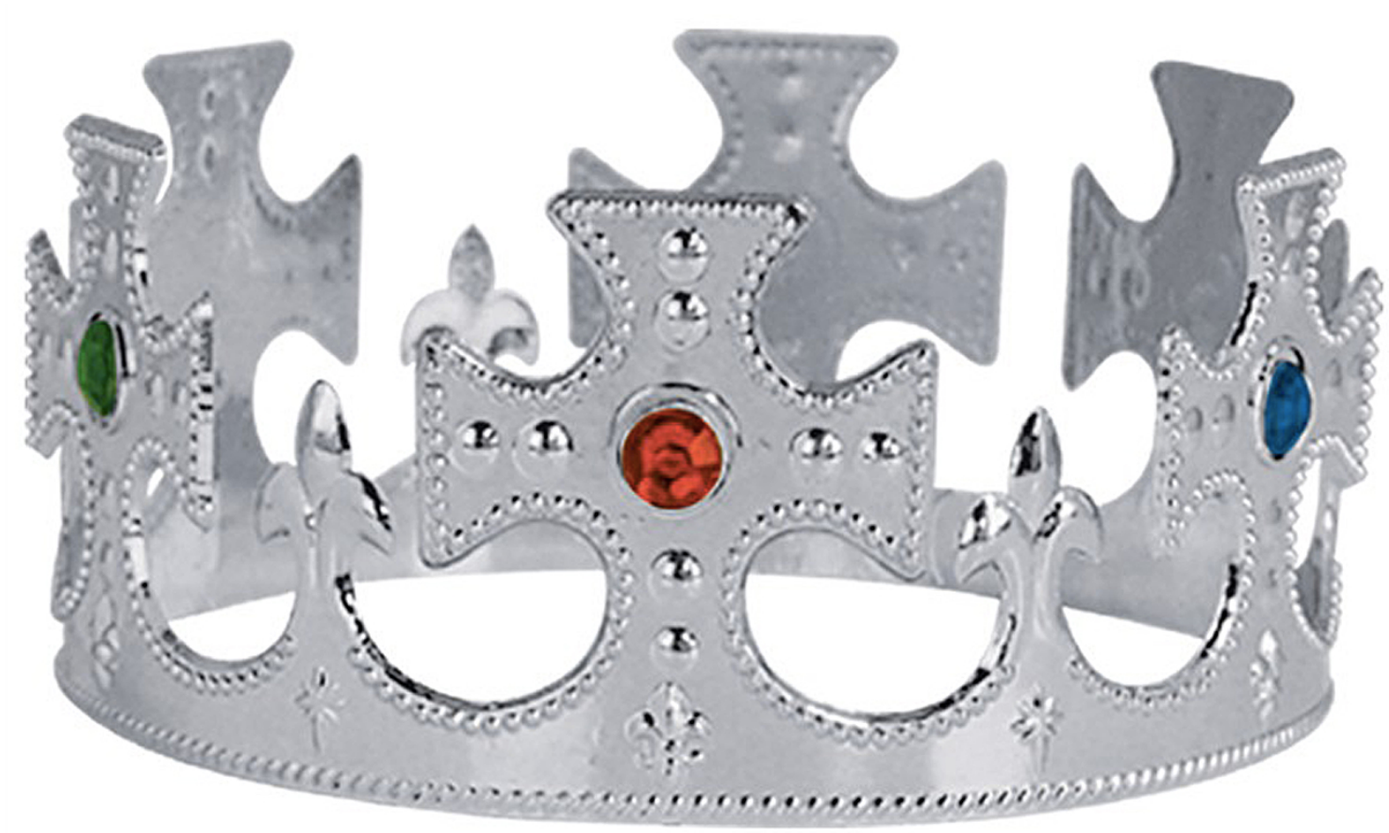


THE “FOUNDATION OF SOCIAL ORDER”

- Norms determine our expectations on how others will act (Bicchieri 2006)
- Once established, norms appear natural - as if other alternatives did not exist (Berger, 1977; Ridgeway 1991)
- Norms are not always desirable or beneficial (Skyrms 1996)

WHERE DOES THIS CONSENSUS COME FROM?

CENTRALISED AUTHORITY



- Formal authority (Tisak et al. 2005)
- Social leadership (Young, 1971)
- Informational feedback (Merton, 1951)
- Incentives for global coordination (Kearns, 2009)

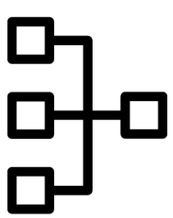
‘SPONTANEOUS’ EMERGENCE?

global consensus is the **unintended** consequence of individuals’ efforts to coordinate **locally** with one another

MECHANISMS OF SPONTANEOUS EMERGENCE

Logical reflection on the strategic situation
e.g. payoff dominance (Harsanyi & Selten 1988)

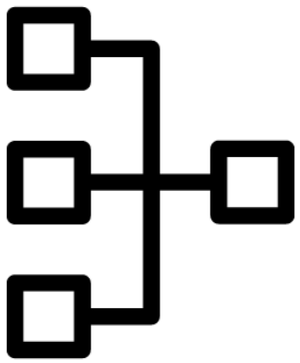
Psychological factors outside of rational analysis e.g. focal point (Shelling, 1960)



The **collective dynamics** selects the equilibrium
e.g. replicator dyn, naming game (Steels 1995; Skyrms 1996)

SPONTANEOUS EMERGENCE (STRICT DEFINITION)

+



Local interactions
Local information

All alternatives are equal
Dynamics selects equilibrium

TESTING SPONTANEOUS EMERGENCE

- Experiments (Garrod, 1994; Galantucci 2005; Selten & Warglien, 2007)
- Robot experiments (Steels et al, 1997)
- Modelling
- Data Science
- New Experiment

EXPERIMENTS WITH HUMAN SUBJECTS

Garrod & Doherty, 1994. *Conversation, co-ordination and convention: An empirical investigation of how groups establish linguistic convention.* Free dialogue, but focus on the choice between 4 categories of description.

N=2, N=10

Galantucci 2005. *An experimental study of the emergence of human communication systems.* Individuals have to coordinate on where to go in order to meet in a simple set of communicating room.

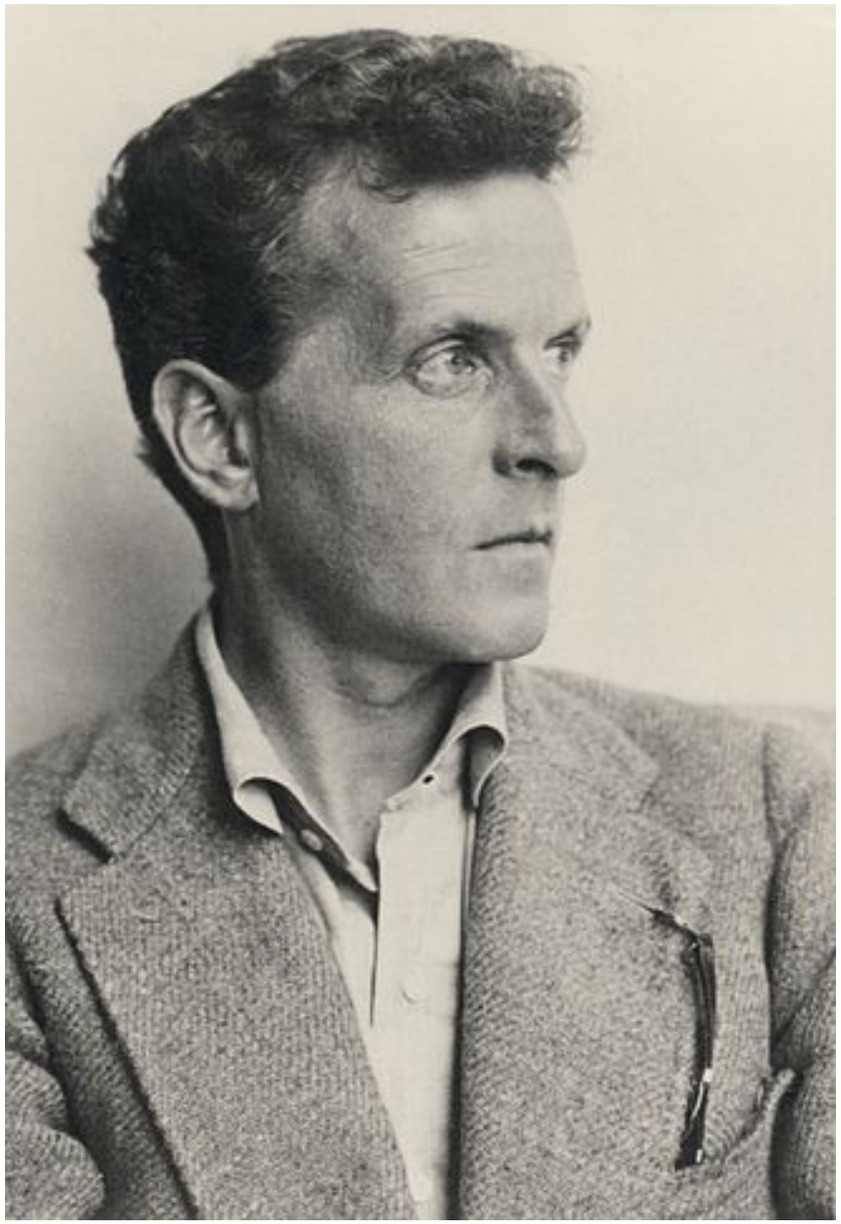
N=2

Selten & Warglien, 2007. *The emergence of simple languages in an experimental coordination game.* Language oriented analysis: emergence of compositionality, etc.

N=2

BUT MORE IS DIFFERENT! (?)

LANGUAGE GAMES



The language is meant to serve for communication between a builder A and an assistant B.

A is building with building-stones: there are blocks, pillars, slabs and beams. B has to pass the stones, in the order in which A needs them.

For this purpose they use a language consisting of the words "block", "pillar" "slab", "beam". A calls them out; — B brings the stone which he has learnt to bring at such-and-such a call.

Conceive this as a complete primitive language.

L. Wittgenstein, Philosophical Investigations, 1953

EXPERIMENTS WITH ROBOTS

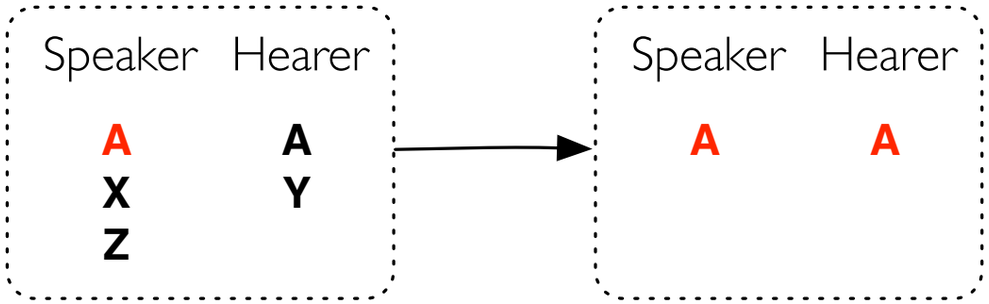
In the ‘Talking Heads’ experiment, group of robots managed to negotiate their ‘language’

BUT THEY ARE ROBOTS

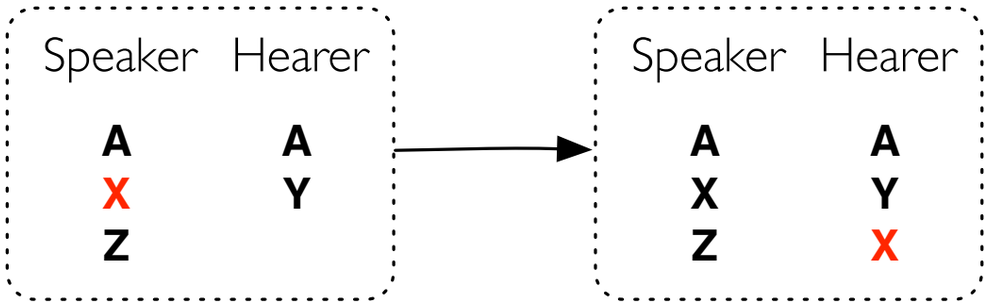
THE NAMING GAME MODEL

Memory and
Complex Contagion

Success



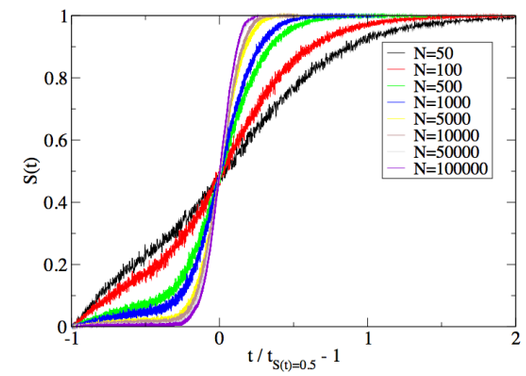
Failure



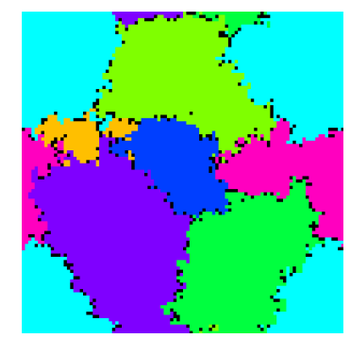
"Sharp Transition Towards Shared Vocabularies In Multi-Agent Systems" JSTAT 2006;
EPL 2006; PRE 2006, 2007, 2011,2012; PLOS ONE 2011; PNAS 2008, 2010; ETC. With V. Loreto, L.Steels, L. Dall'Asta, A. Barrat Et Al.

THE NAMING GAME MODEL

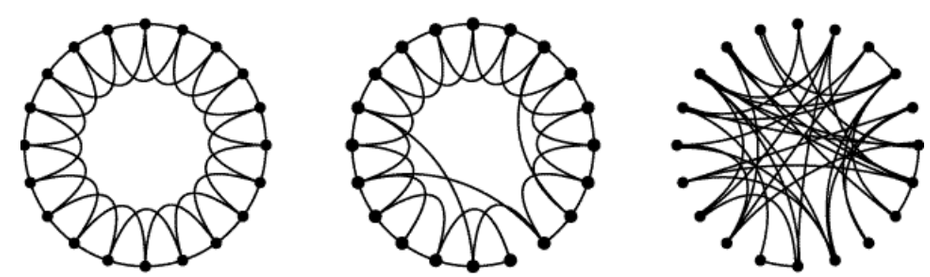
Mean-field: symmetry breaking in the space of names



Lattices: coarsening



Networks: Short-time coarsening, then mean-field behaviour

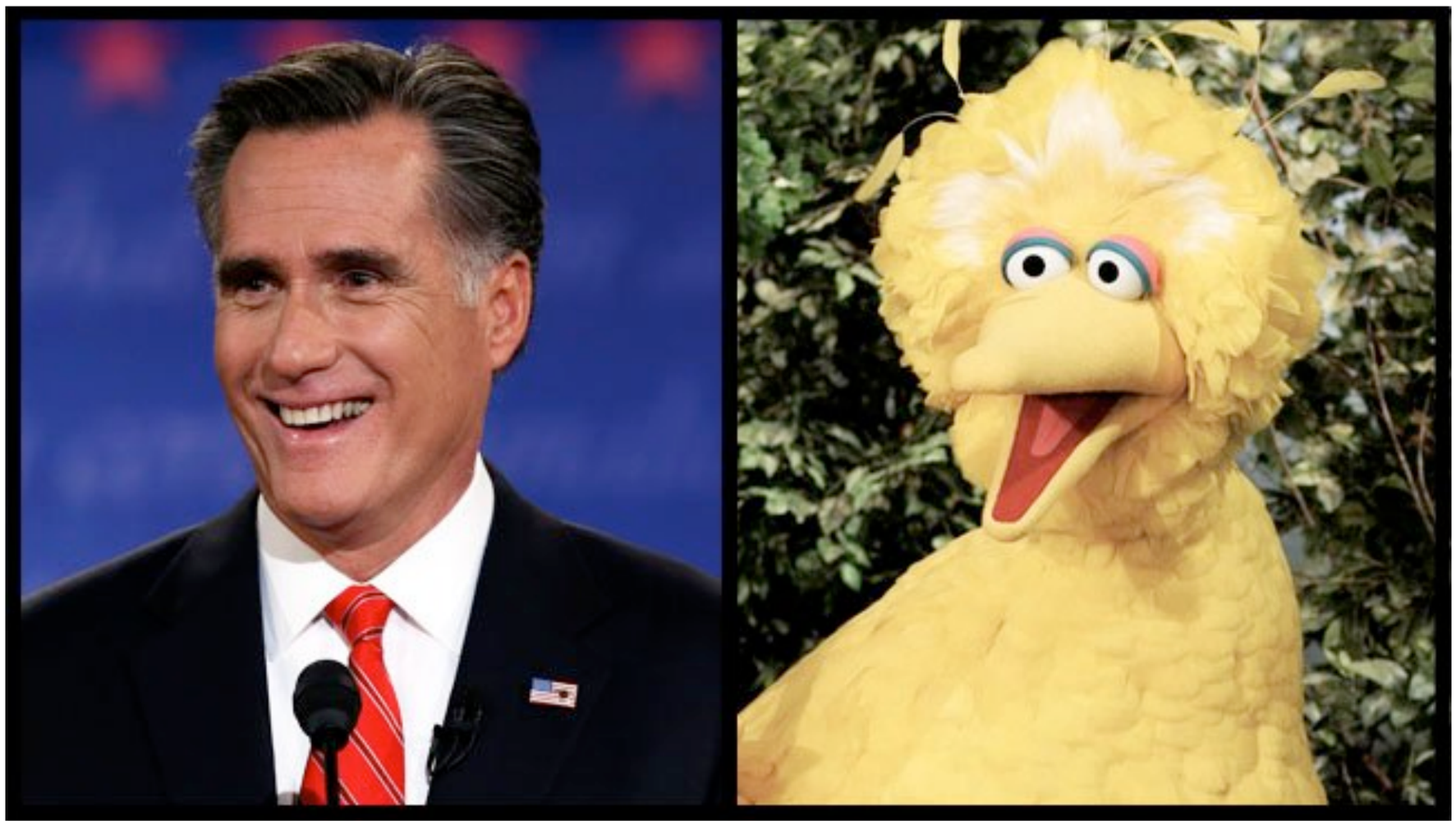


A MODEL IS GREAT (SYSTEM SIZE, TOPOLOGY, ETC.)

BUT WHAT ABOUT REAL DATA?

DATA SCIENCE

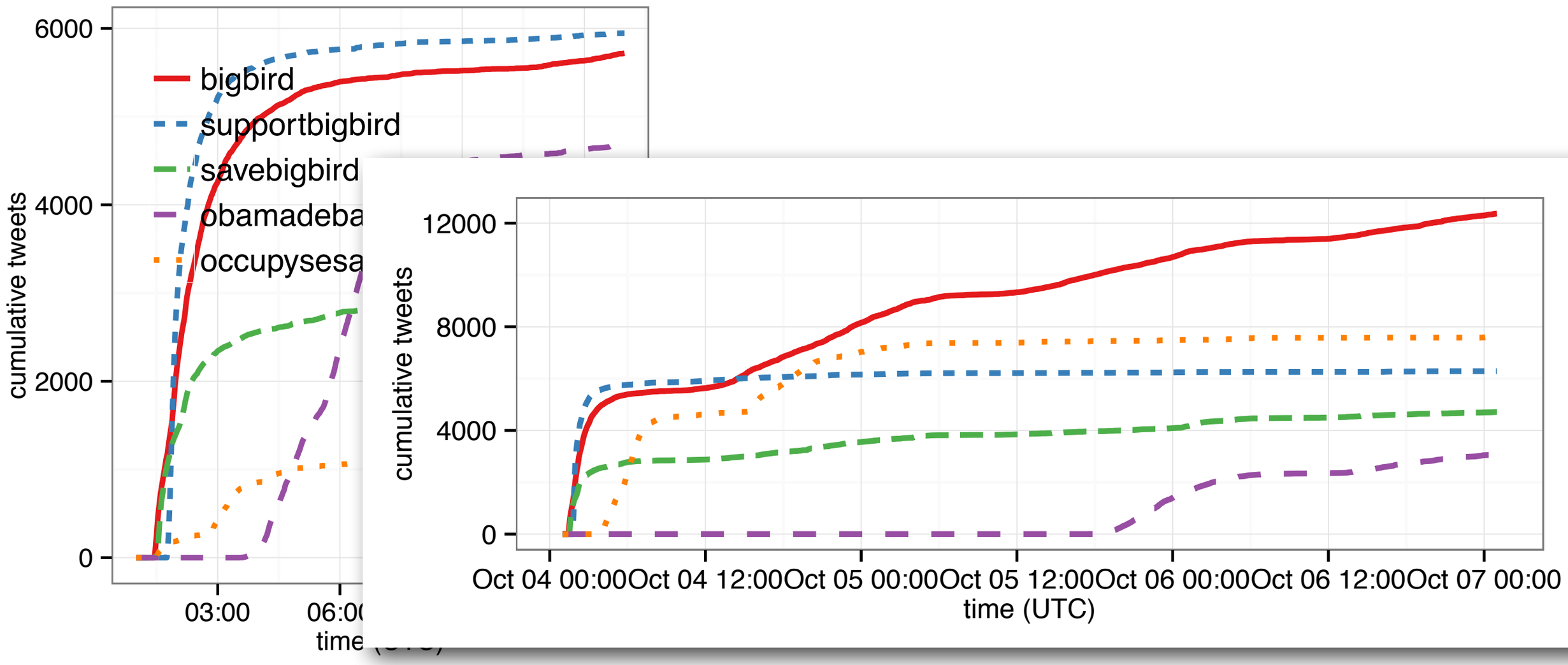
“I’m sorry Jim, I’m gonna stop the subsidy to PBS, I love Big Bird. I actually like you, too. But...”



123M TWEETS,
2.5M USERS

With Yr. Lin, D. Margolin, B. Keegan And D. Lazer, ICWSM 2013.

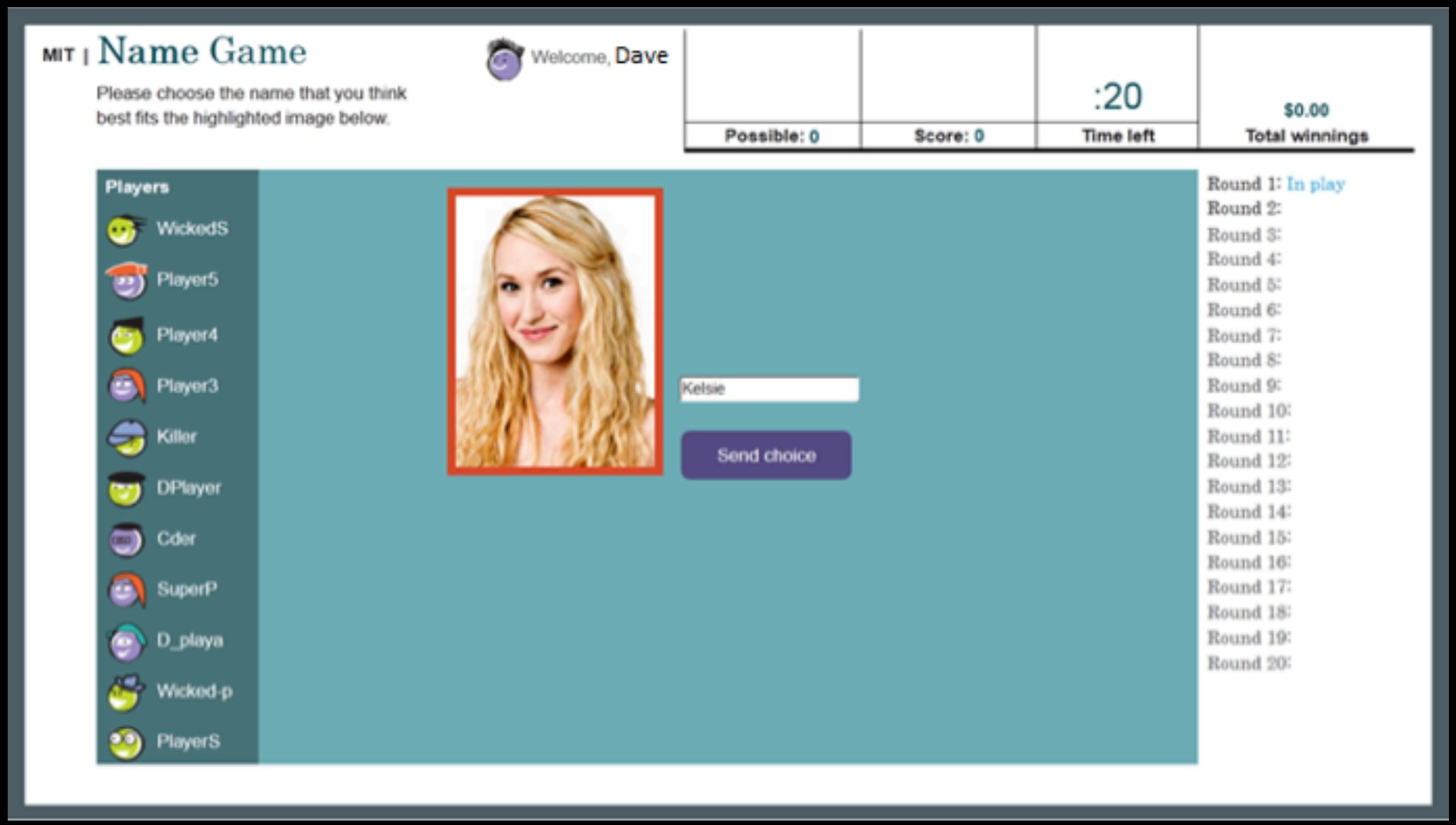
‘SYNONYMS’ ON TWITTER



DATA ARE OK. BUT TWITTER IS NOT A CLOSED SYSTEM

A NEW EXPERIMENT

with D. Centola. PNAS 112: 1989 (2015).


MIT | Name Game
Welcome, Dave
Please choose the name that you think best fits the highlighted image below.
Possible: 0
Score: 0
:20
Time left
$0.00
Total winnings
Players
WickedS
Player5
Player4
Player3
Killer
DPlayer
Cder
SuperP
D_playa
Wicked-p
PlayerS
Kelsie
Send choice
Round 1: In play
Round 2:
Round 3:
Round 4:
Round 5:
Round 6:
Round 7:
Round 8:
Round 9:
Round 10:
Round 11:
Round 12:
Round 13:
Round 14:
Round 15:
Round 16:
Round 17:
Round 18:
Round 19:
Round 20:

MIT | Name Game

Welcome, Dave

Possible: 1	Score: 0	Time left	$0.00 Total winnings

Players

- WickedS
- Player5
- Player4
- Player3
- Killer
- DPlayer
- Cder
- SuperP
- D_playa
- Wicked-p
- PlayerS

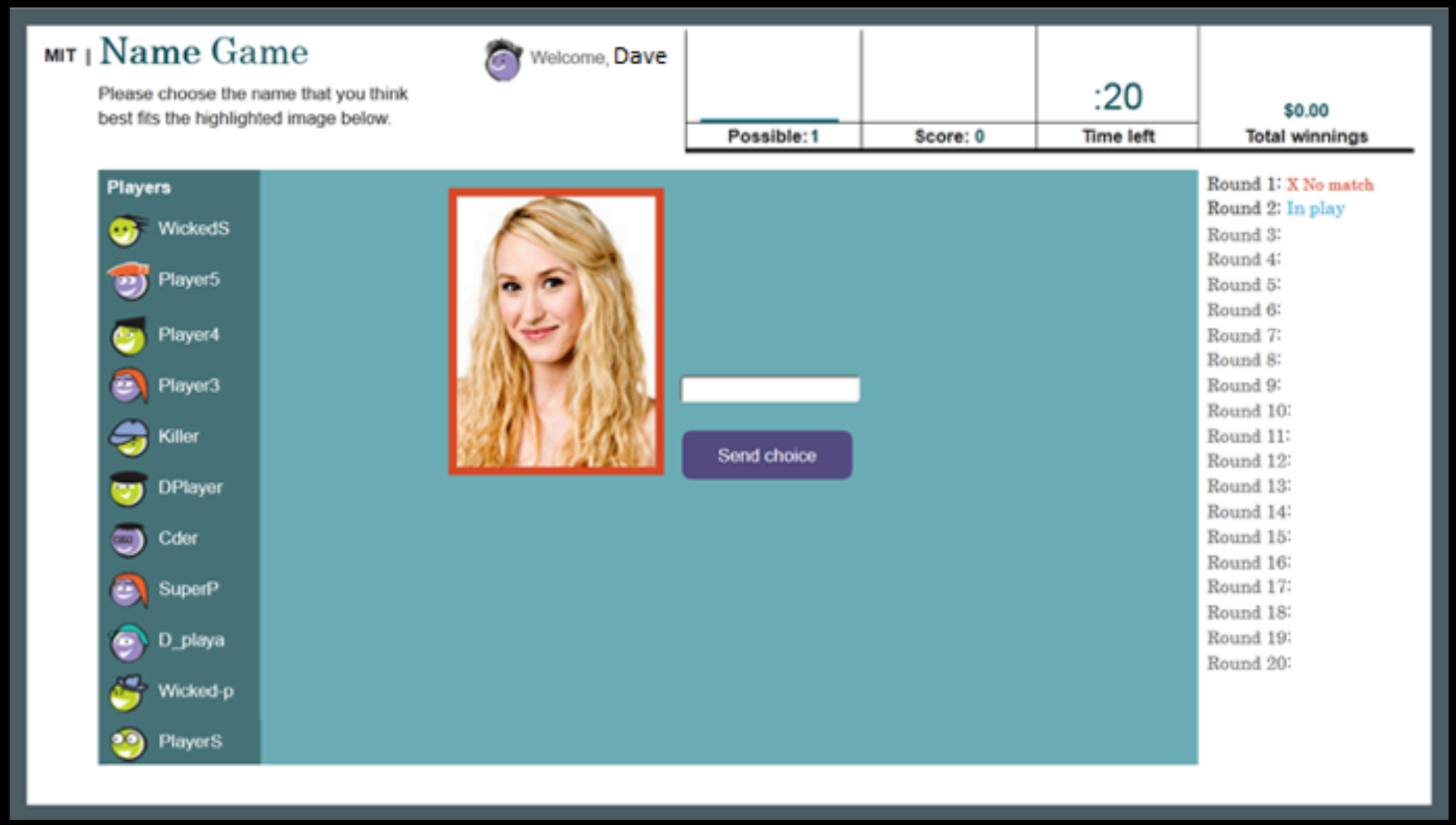
You: Kelsie

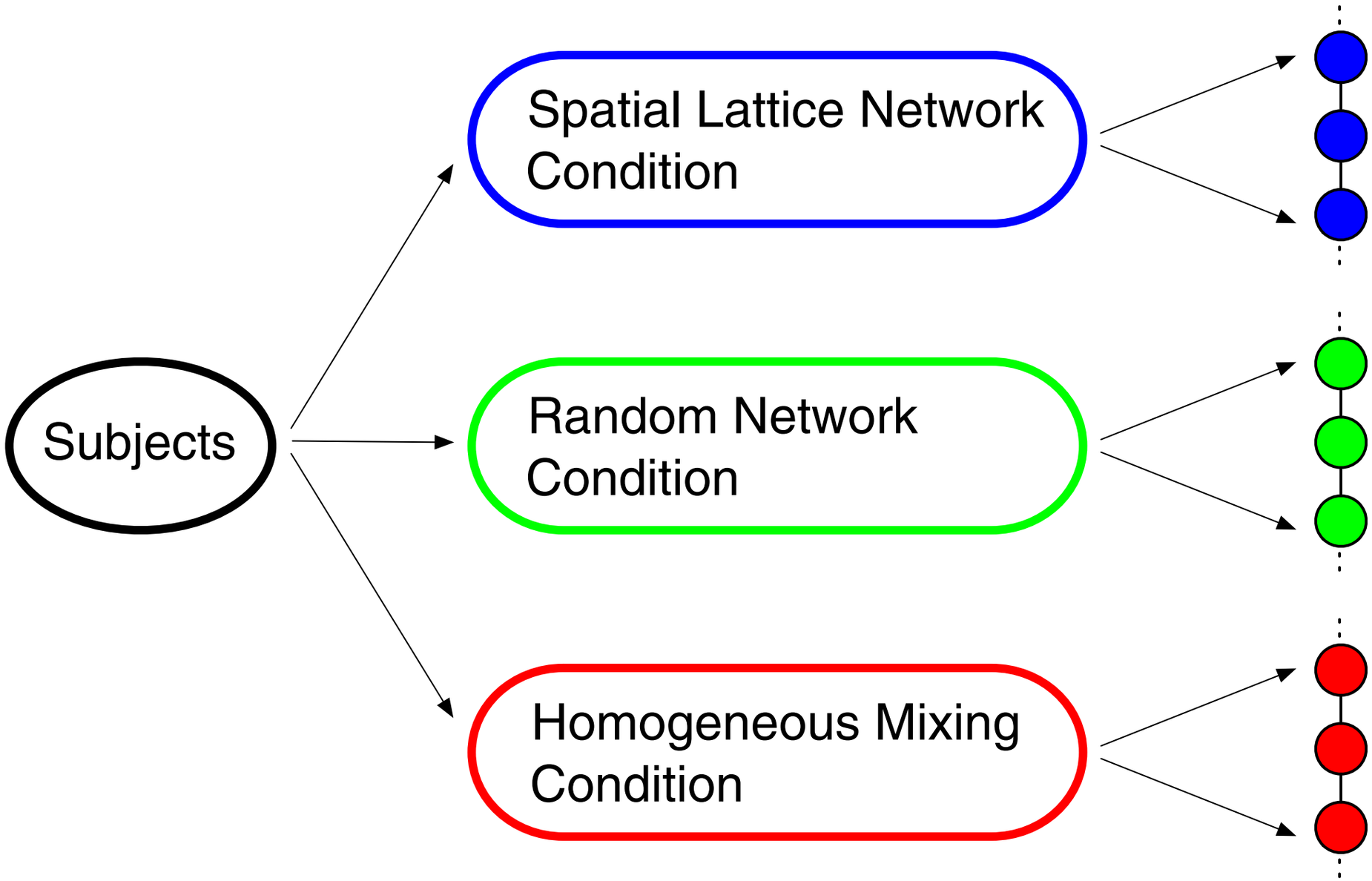
Your partner: Elizabeth

No match!

Next

Round 1: X No match
Round 2:
Round 3:
Round 4:
Round 5:
Round 6:
Round 7:
Round 8:
Round 9:
Round 10:
Round 11:
Round 12:
Round 13:
Round 14:
Round 15:
Round 16:
Round 17:
Round 18:
Round 19:
Round 20:


MIT | Name Game
Welcome, Dave
Please choose the name that you think best fits the highlighted image below.
Possible: 1
Score: 0
:20
Time left
$0.00
Total winnings
Players
WickedS
Player5
Player4
Player3
Killer
DPlayer
Cder
SuperP
D_playa
Wicked-p
PlayerS
Send choice
Round 1: X No match
Round 2: In play
Round 3:
Round 4:
Round 5:
Round 6:
Round 7:
Round 8:
Round 9:
Round 10:
Round 11:
Round 12:
Round 13:
Round 14:
Round 15:
Round 16:
Round 17:
Round 18:
Round 19:
Round 20:

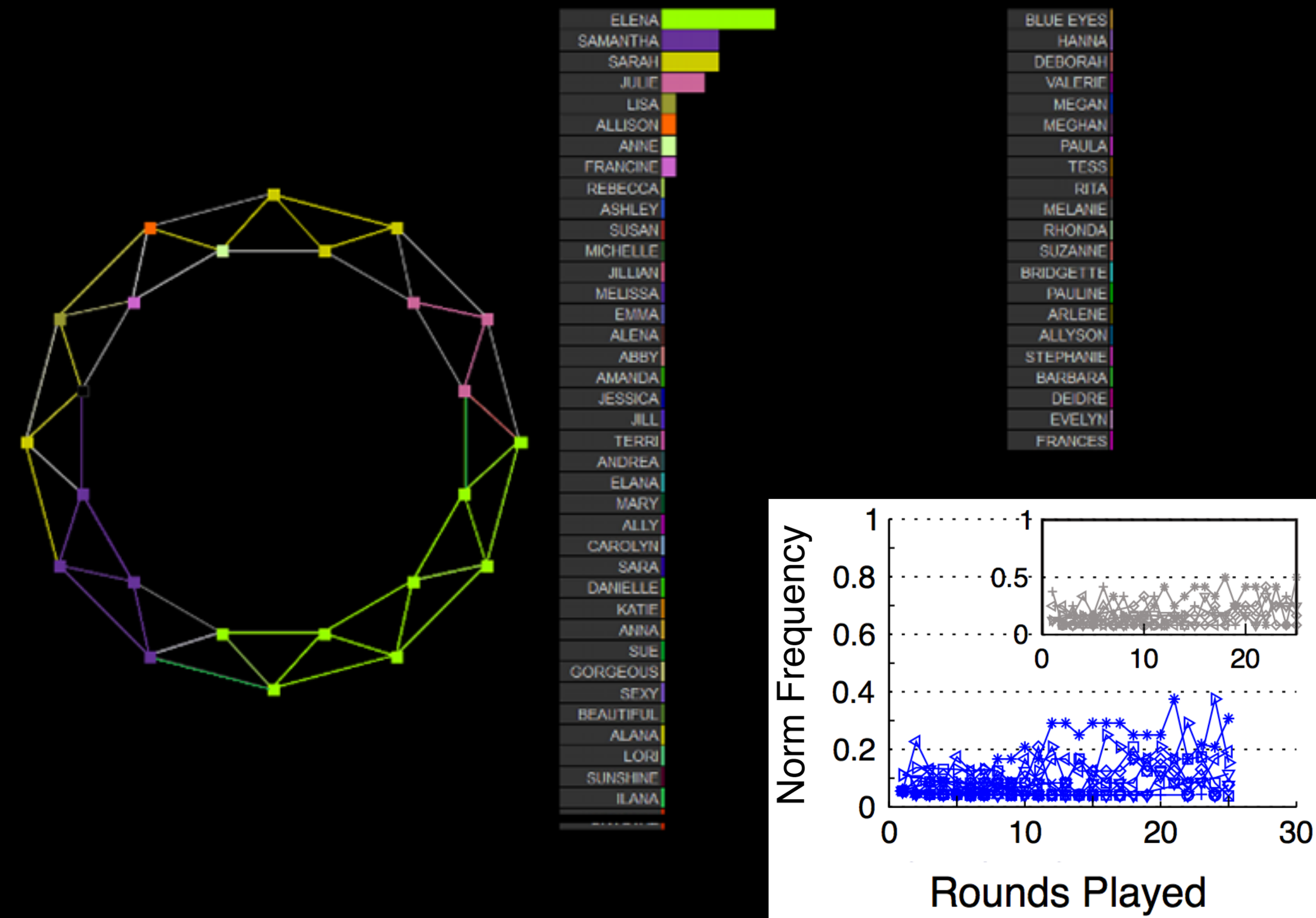

Subjects
Spatial Lattice Network Condition
Random Network Condition
Homogeneous Mixing Condition

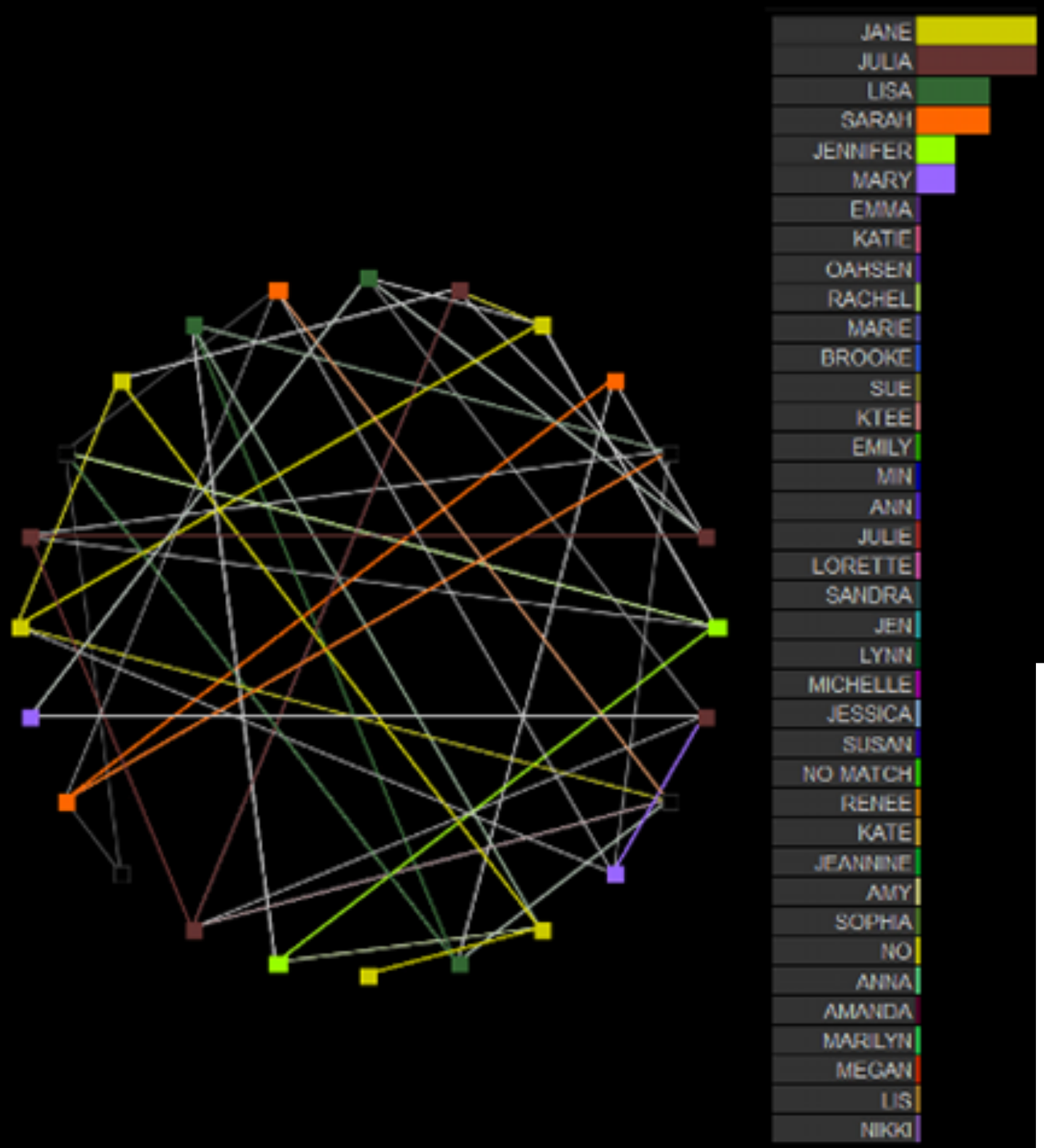
TESTING SPONTANEOUS EMERGENCE

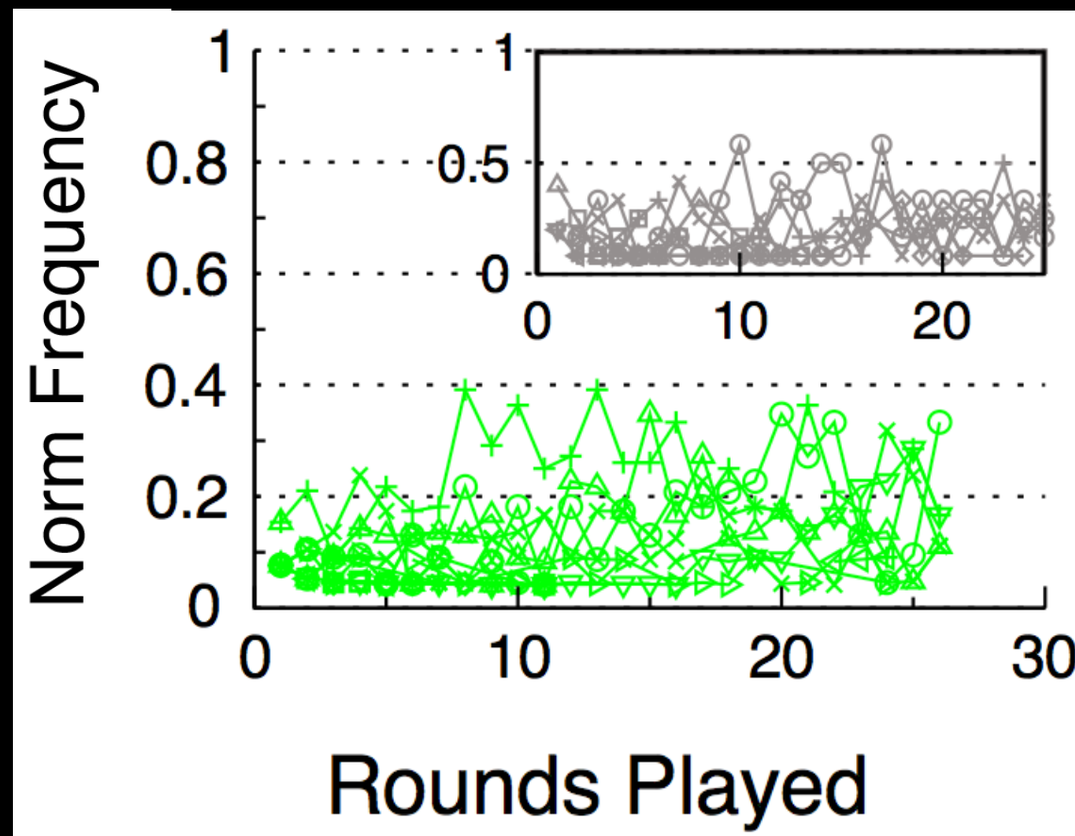
- ✓ Purely local coordination
- ✓ Equivalent alternatives
- ✓ Open-ended set of alternatives
- ✓ No info about the (existence of a) population
- ✓ No info about the identity of the partner

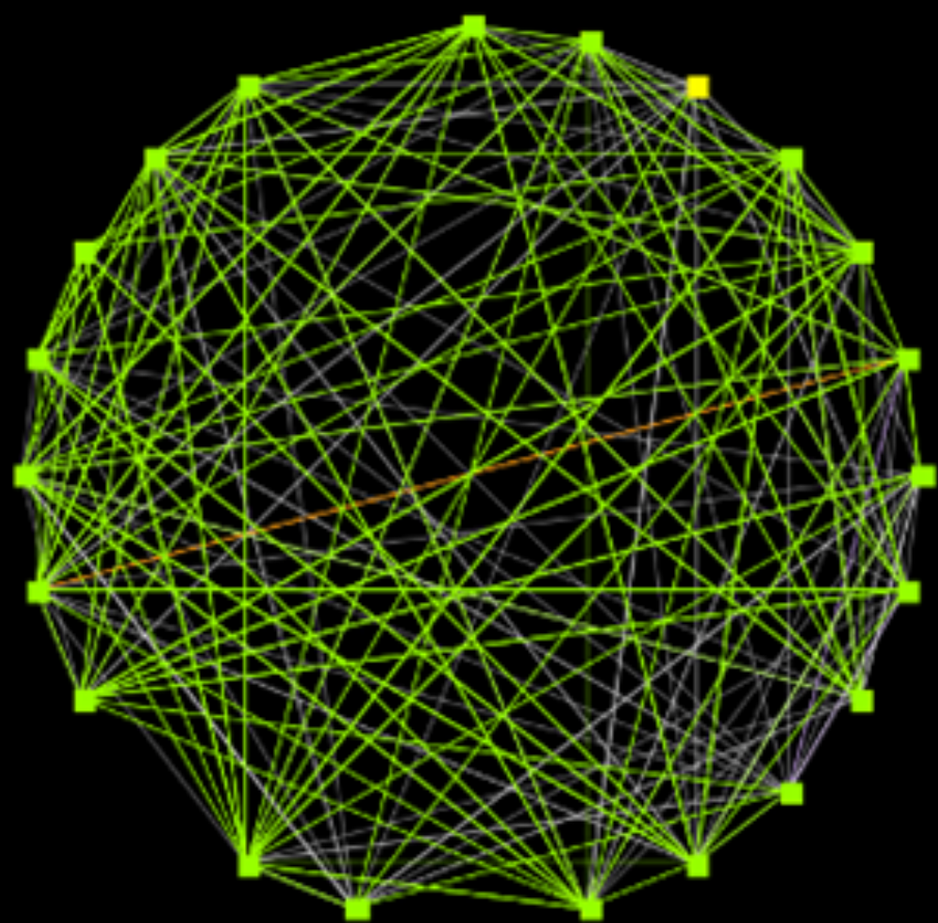
1. Do they reach a consensus?

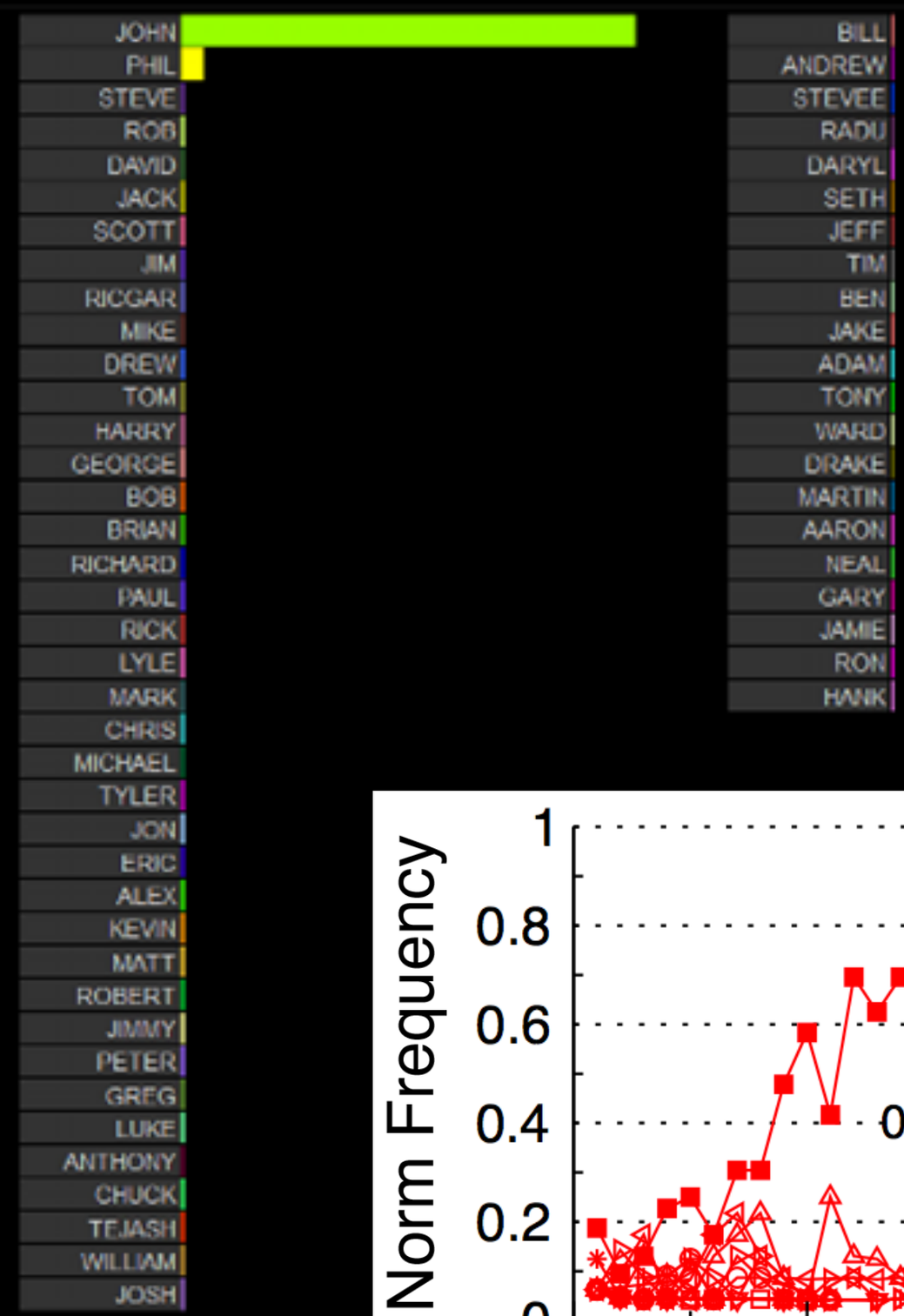
2. What role for the social network?

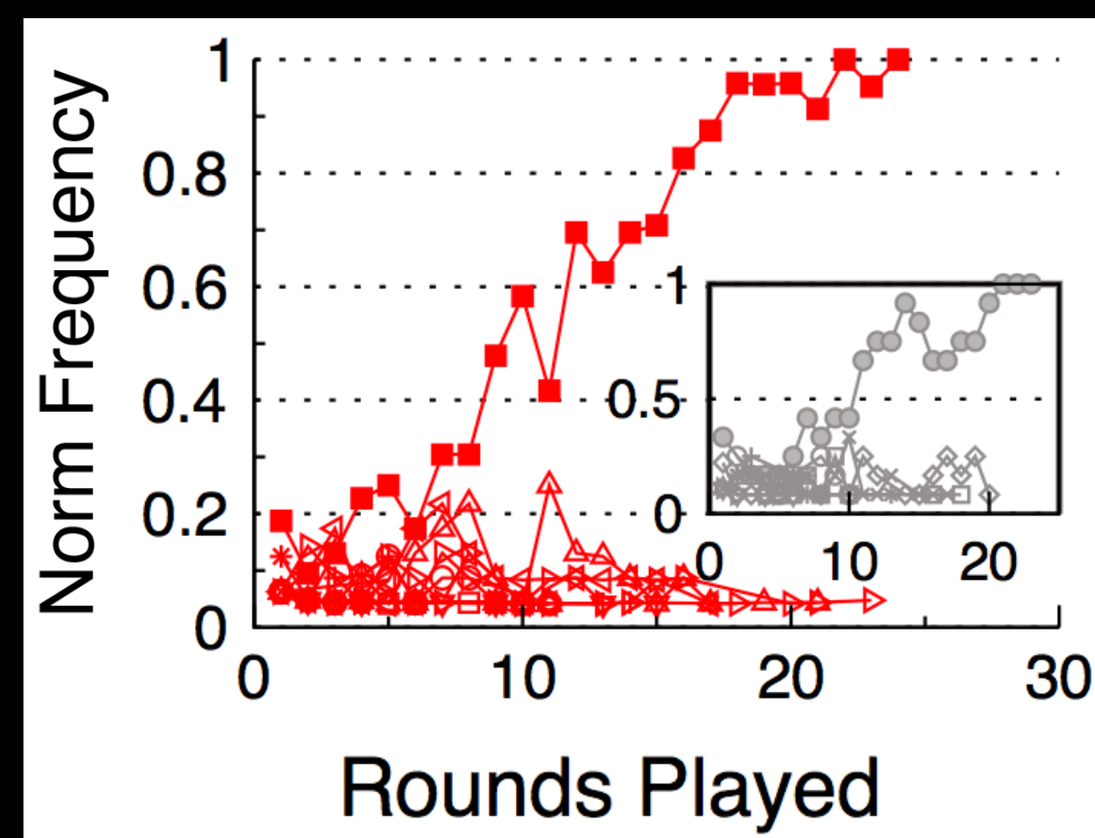

ELENA
SAMANTHA
SARAH
JULIE
LISA
ALLISON
ANNE
FRANCINE
REBECCA
ASHLEY
SUSAN
MICHELLE
JILLIAN
MELISSA
EMMA
ALENA
ABBY
AMANDA
JESSICA
JILL
TERRI
ANDREA
ELANA
MARY
ALLY
CAROLYN
SARA
DANIELLE
KATIE
ANNA
SUE
GORGEOUS
SEXY
BEAUTIFUL
ALANA
LORI
SUNSHINE
ILANA
BLUE EYES
HANNA
DEBORAH
VALERIE
MEGAN
MEGHAN
PAULA
TESS
RITA
MELANIE
RHONDA
SUZANNE
BRIDGETTE
PAULINE
ARLENE
ALLYSON
STEPHANIE
BARBARA
DEIDRE
EVELYN
FRANCES
Norm Frequency
Rounds Played
0
0.2
0.4
0.6
0.8
1
0
10
20
30
0.5


JANE
JULIA
LISA
SARAH
JENNIFER
MARY
EMMA
KATIE
OAHSEN
RACHEL
MARIE
BROOKE
SUE
KTEE
EMILY
MIN
ANN
JULIE
LORETTE
SANDRA
JEN
LYNN
MICHELLE
JESSICA
SUSAN
NO MATCH
RENEE
KATE
JEANNINE
AMY
SOPHIA
NO
ANNA
AMANDA
MARILYN
MEGAN
LIS
NIKKI

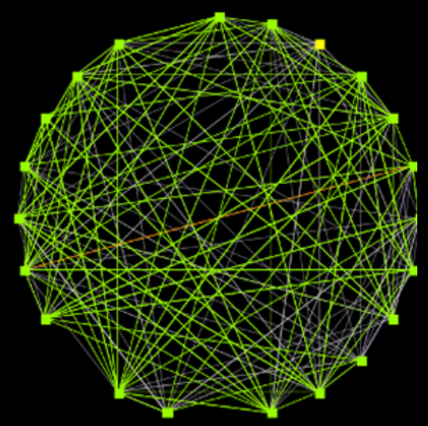

Norm Frequency
Rounds Played
0
0.2
0.4
0.6
0.8
1
0
10
20
30
0.5




JOHN
PHIL
STEVE
ROB
DAVID
JACK
SCOTT
JIM
RICGAR
MIKE
DREW
TOM
HARRY
GEORGE
BOB
BRIAN
RICHARD
PAUL
RICK
LYLE
MARK
CHRIS
MICHAEL
TYLER
JON
ERIC
ALEX
KEVIN
MATT
ROBERT
JIMMY
PETER
GREG
LUKE
ANTHONY
CHUCK
TEJASH
WILLIAM
JOSH
BILL
ANDREW
STEVEE
RADU
DARYL
SETH
JEFF
TIM
BEN
JAKE
ADAM
TONY
WARD
DRAKE
MARTIN
AARON
NEAL
GARY
JAMIE
RON
HANK


Norm Frequency
Rounds Played
0
0.2
0.4
0.6
0.8
1
0
10
20
30
0
0.5
1
0
10
20

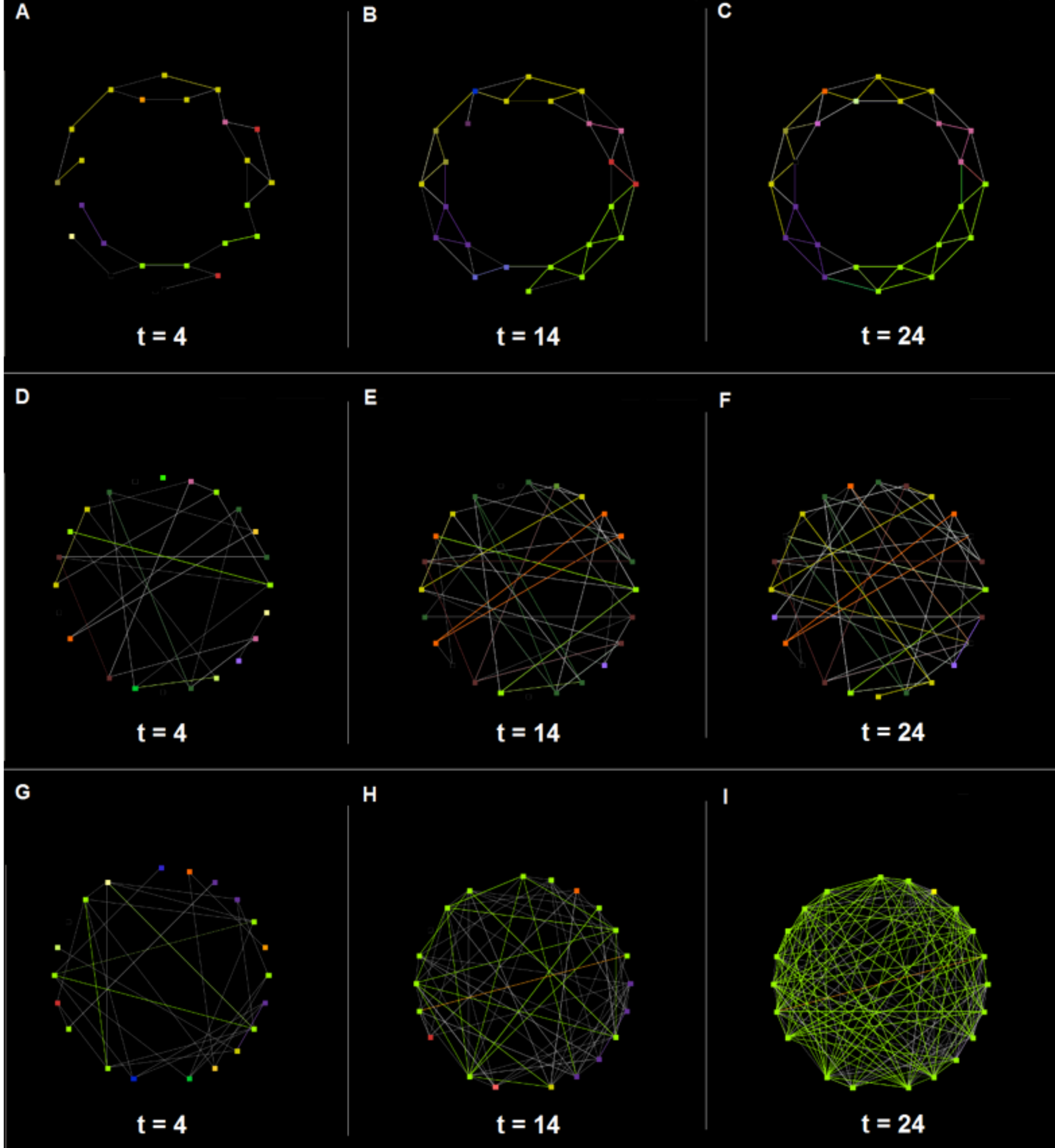
✓ SPONTANEOUS CONSENSUS



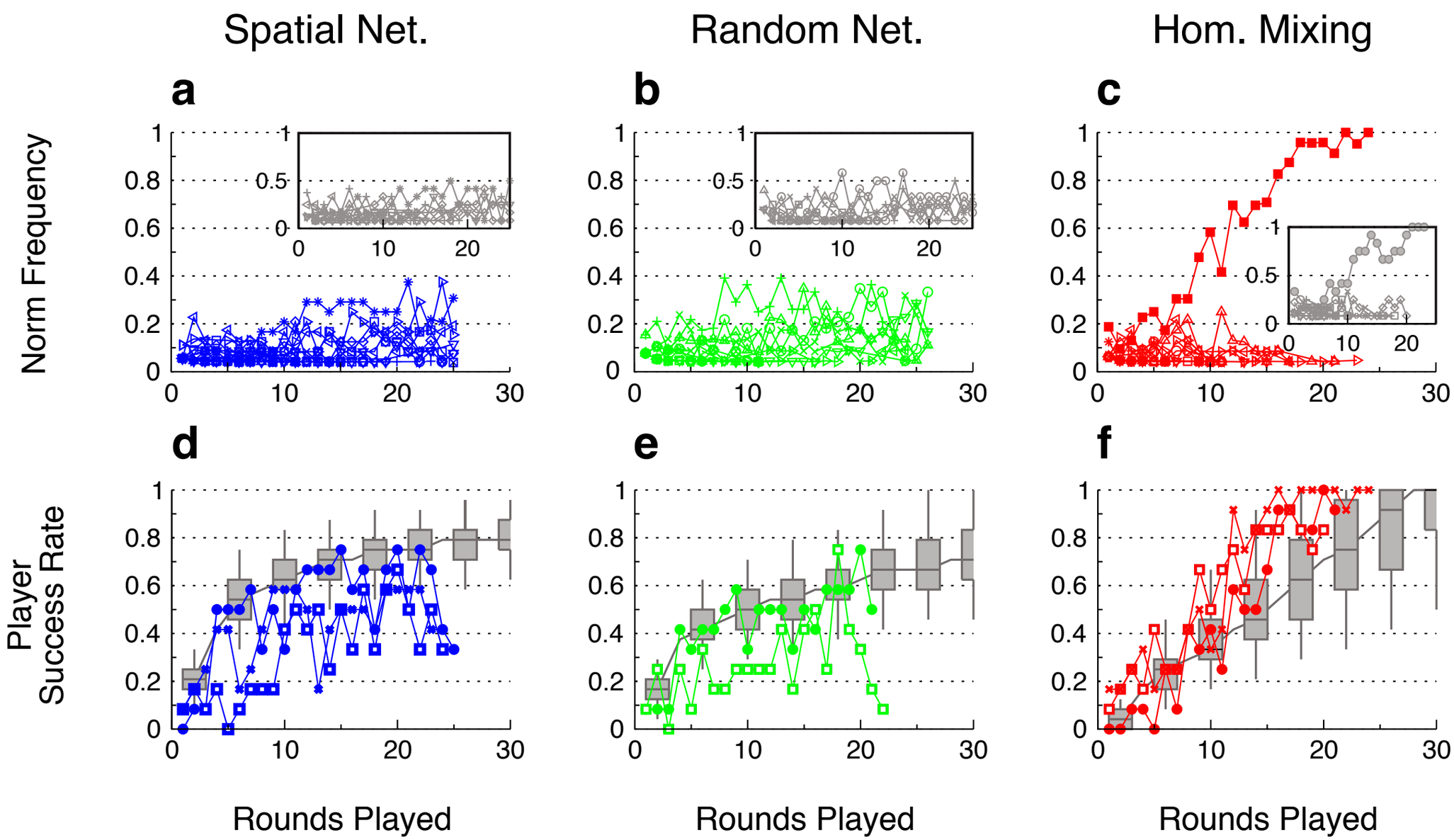
1d lattice
(fixed degree = 4)

random network
(fixed degree = 4)

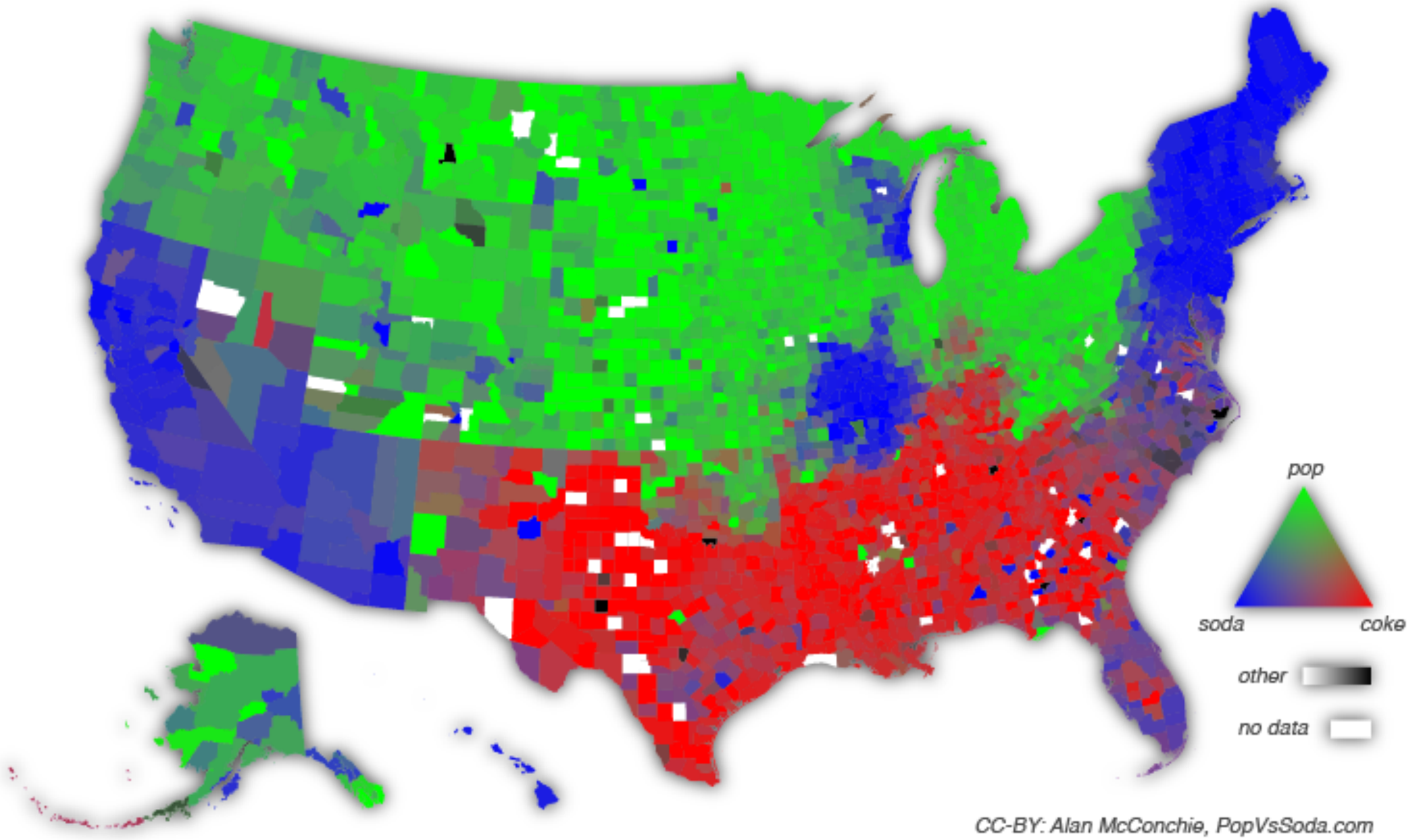
complete graph



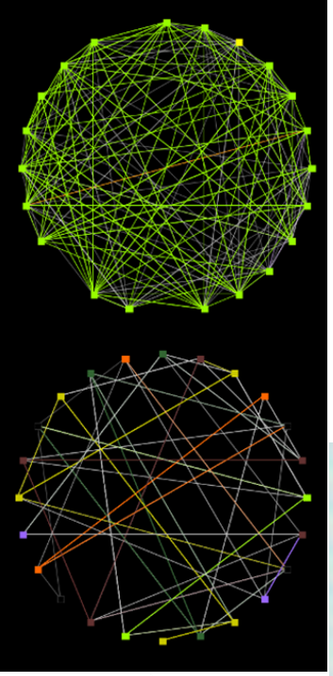
Competition in the space of norms is **coordination** in the space of individuals



REGIONAL NORMS COEXIST ON SPATIAL NETS



GLOBAL CONSENSUS IN CONNECTED GRAPHS



model predicts

TESTING THE EMERGENCE OF CONSENSUS

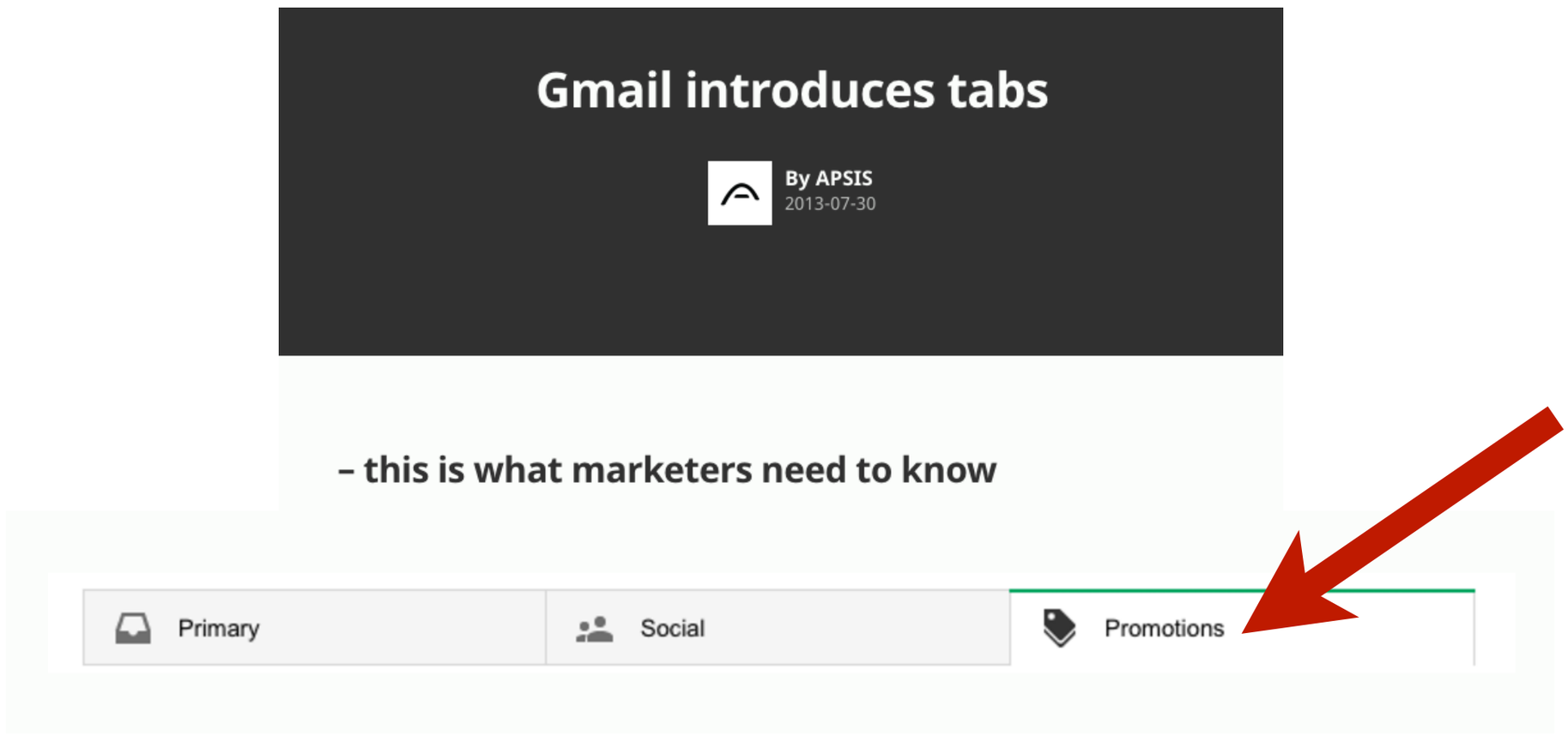
We observed convergence with N=24 in ~25 rounds.
What happens in larger populations?

N=24

N=48

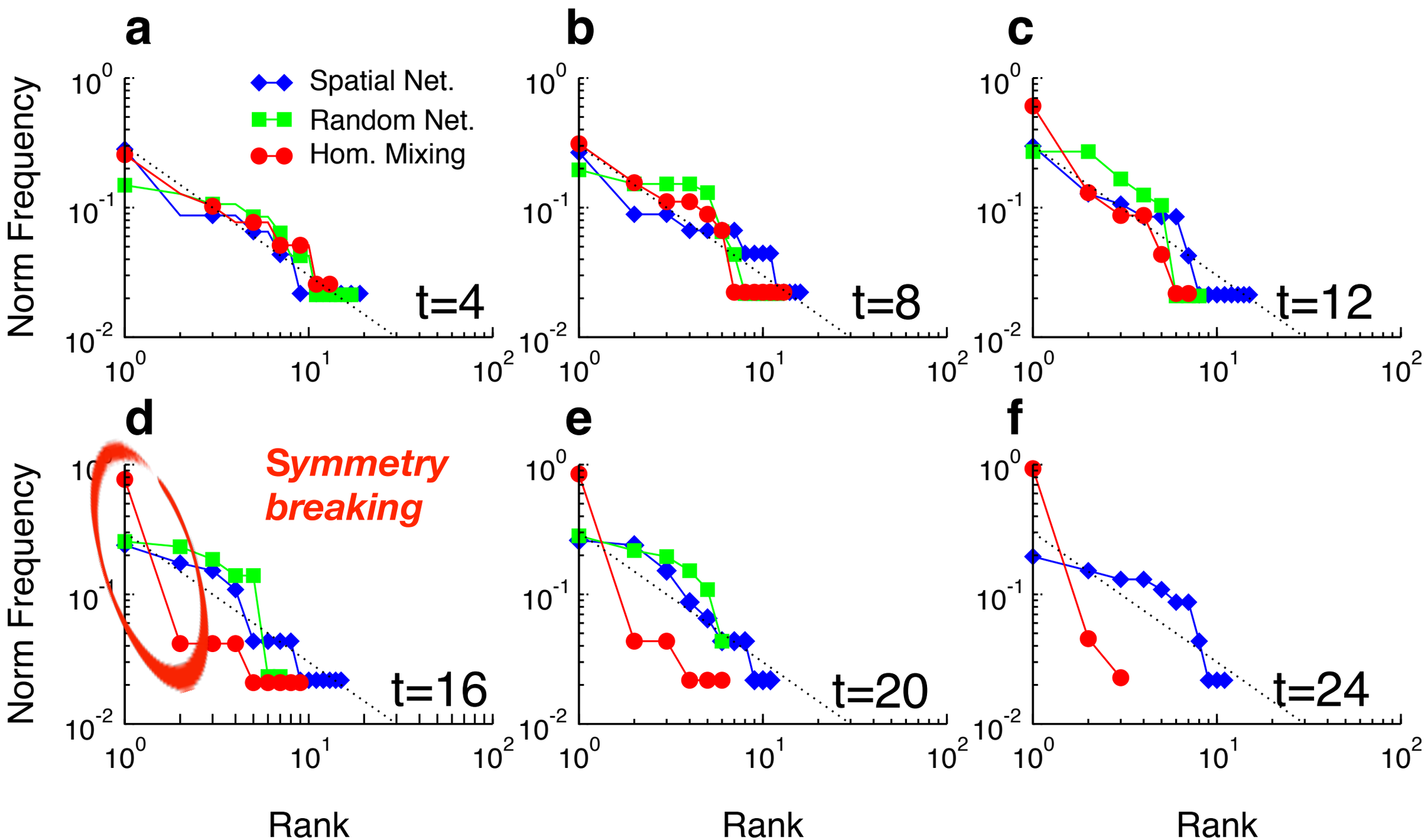
(A LITTLE EPIC FAIL)

We need to recruit more people.
We find a mailing list for the Boston area. And *pay* for it.
We spend time to discuss about text, time of the day etc.. and then we go.
And **nobody*** shows up.

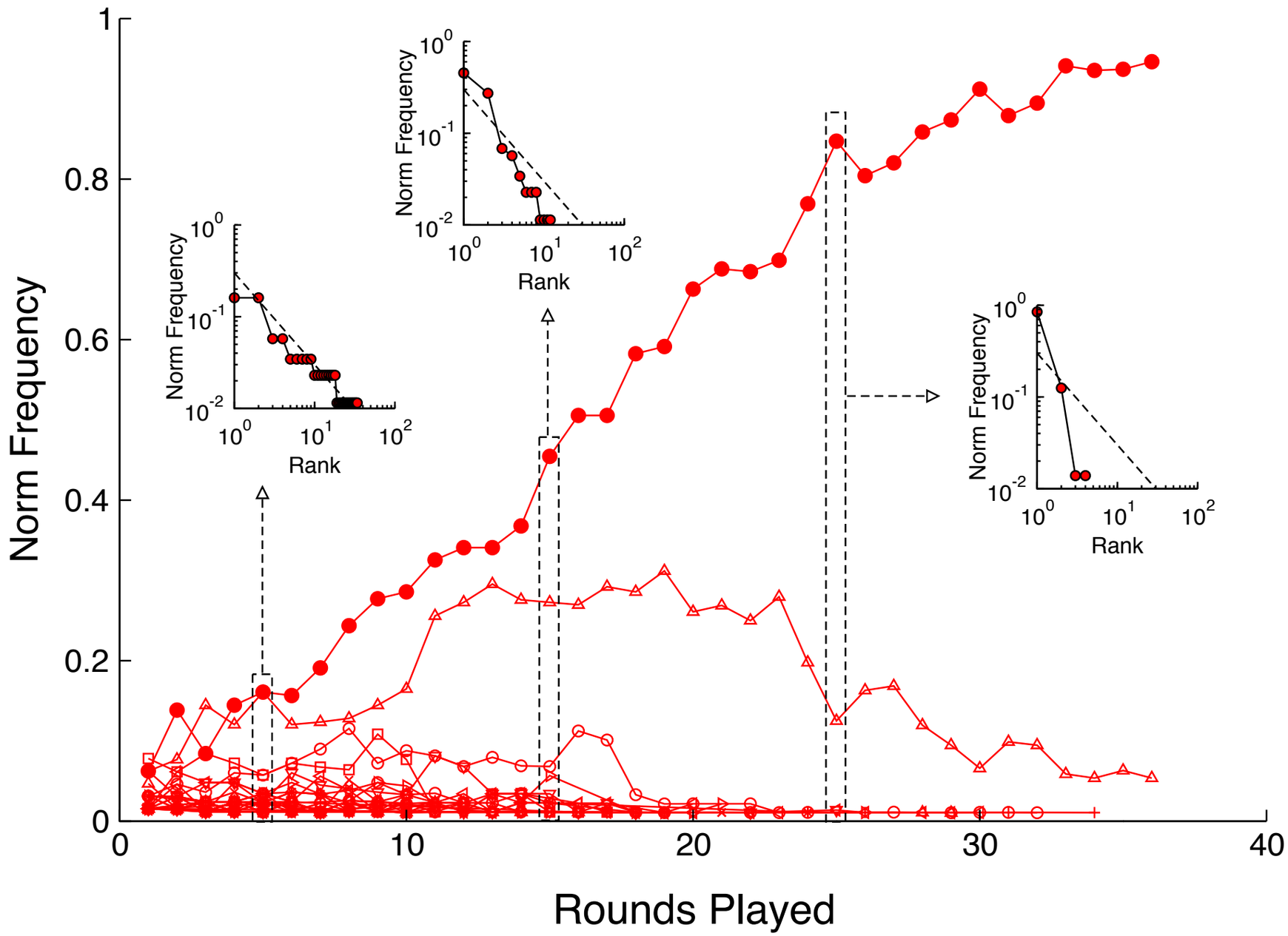


*This might be an over dramatisation.

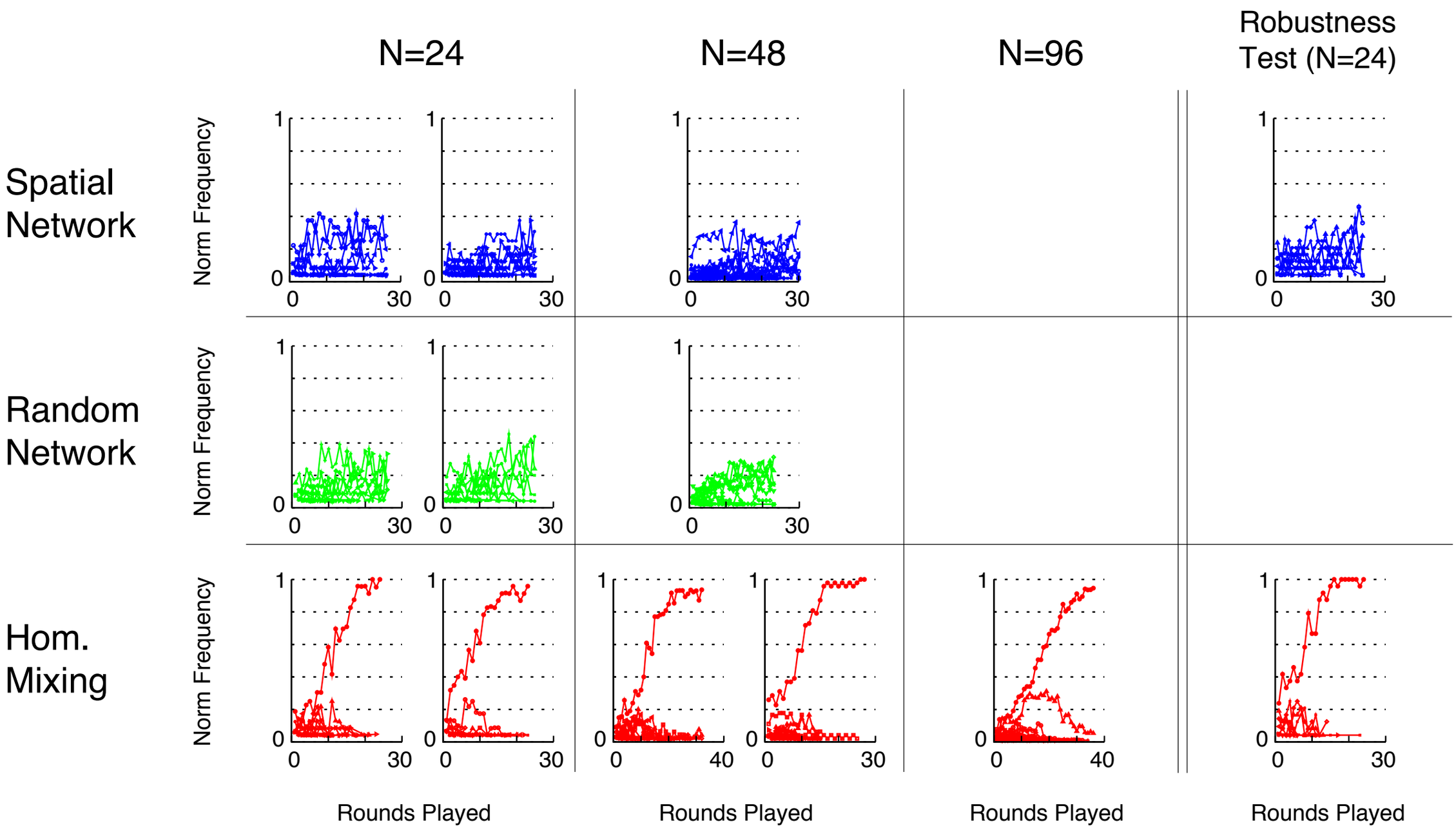
YES, CONSENSUS ALSO IN LARGE GROUPS



N=96

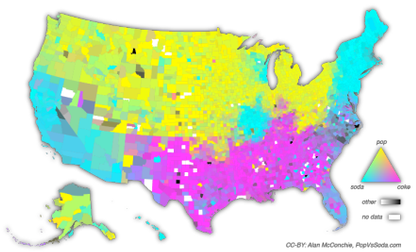

Norm Frequency
Rounds Played
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
Norm Frequency
Rank
10^0
10^{-1}
10^{-2}
10^1
10^2

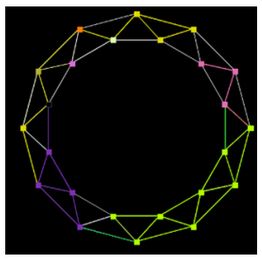
REPLICATIONS



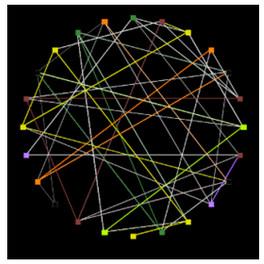
THE NETWORK CONTROLS THE GLOBAL BEHAVIOUR

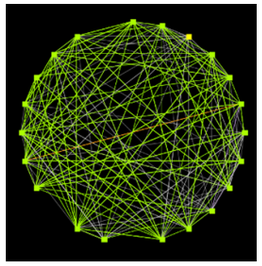
Coarsening on geographical structures



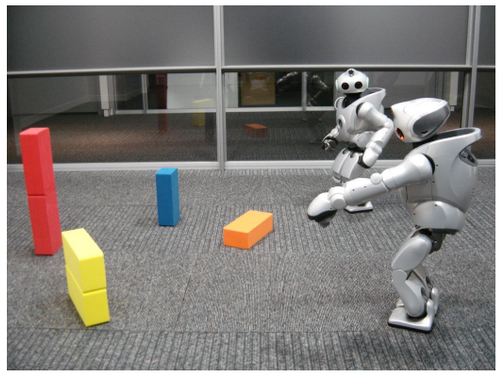


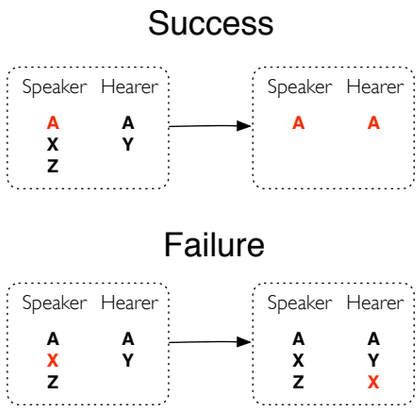
Symmetry breaking on small-world networks

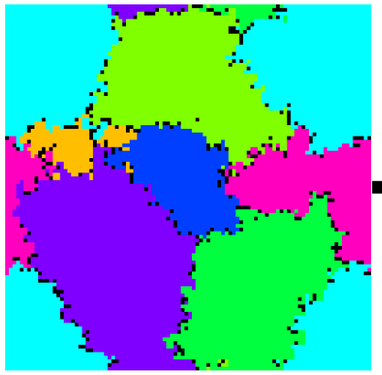


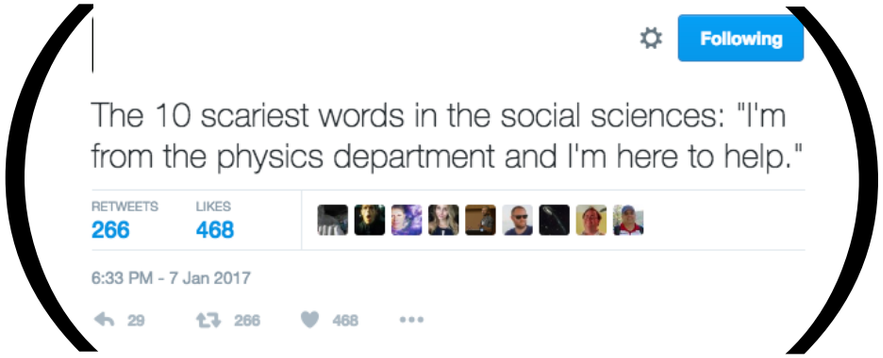


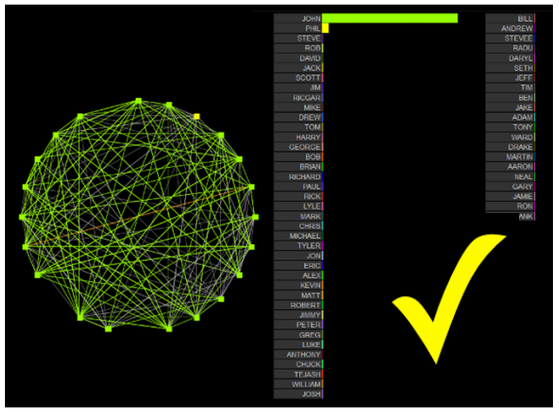
ON INTERDISCIPLINARY STUFF











The spontaneous emergence of conventions: An experimental study of cultural evolution

Damon Centola[a,b] and Andrea Baronchelli[c,1]

[a]Annenberg School of Communication, University of Pennsylvania, Philadelphia, PA 19106; [b]Center for Advanced Study in the Behavioral Sciences, Stanford University, Palo Alto, CA 94305; and [c]Department of Mathematics, City University London, London EC1V 0HB, United Kingdom

SOCIAL SCIENCES

APPLIED PHYSICAL SCIENCES

Stellar Seven 2015

AMERICAN SOCIOLOGICAL ASSOCIATION

CITAMS | Communication, Information Technologies, and Media Sociology

TAKE HOME (I)

Experimental evidence for the spontaneous emergence of social consensus. **PNAS 112: 1989 (2015)**

The **social network** controls the mechanisms of consensus formation (symmetry breaking - coarsening)

The **Naming Game** model captures the observed dynamics. **JSTAT P06014 (2006)**

The Emergence of Consensus

Andrea Baronchelli*

City, University of London

The origin of population-scale coordination has puzzled philosophers and scientists for centuries. Recently, game theory, evolutionary approaches and complex systems science have provided quantitative insights on the mechanisms of social consensus. This paper overviews the main dimensions over which the debate has unfolded and discusses some representative results, with a focus on those situations in which consensus emerges 'spontaneously' in absence of centralised institutions. Covered topics include the macroscopic consequences of the different microscopic rules of behavioural contagion, the role of social networks, and the mechanisms that prevent the formation of a consensus or alter it after it has emerged. Special attention is devoted to the recent wave of experiments on the emergence of consensus in social systems.

arXiv:1704.07767v1

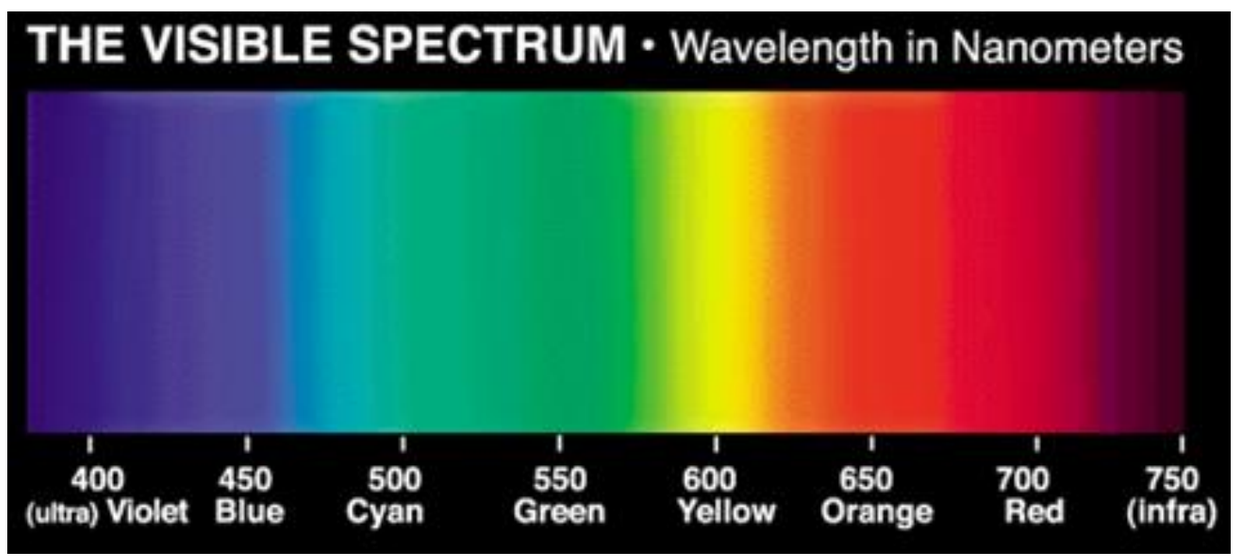
II. CATEGORIES

Colour categorisation

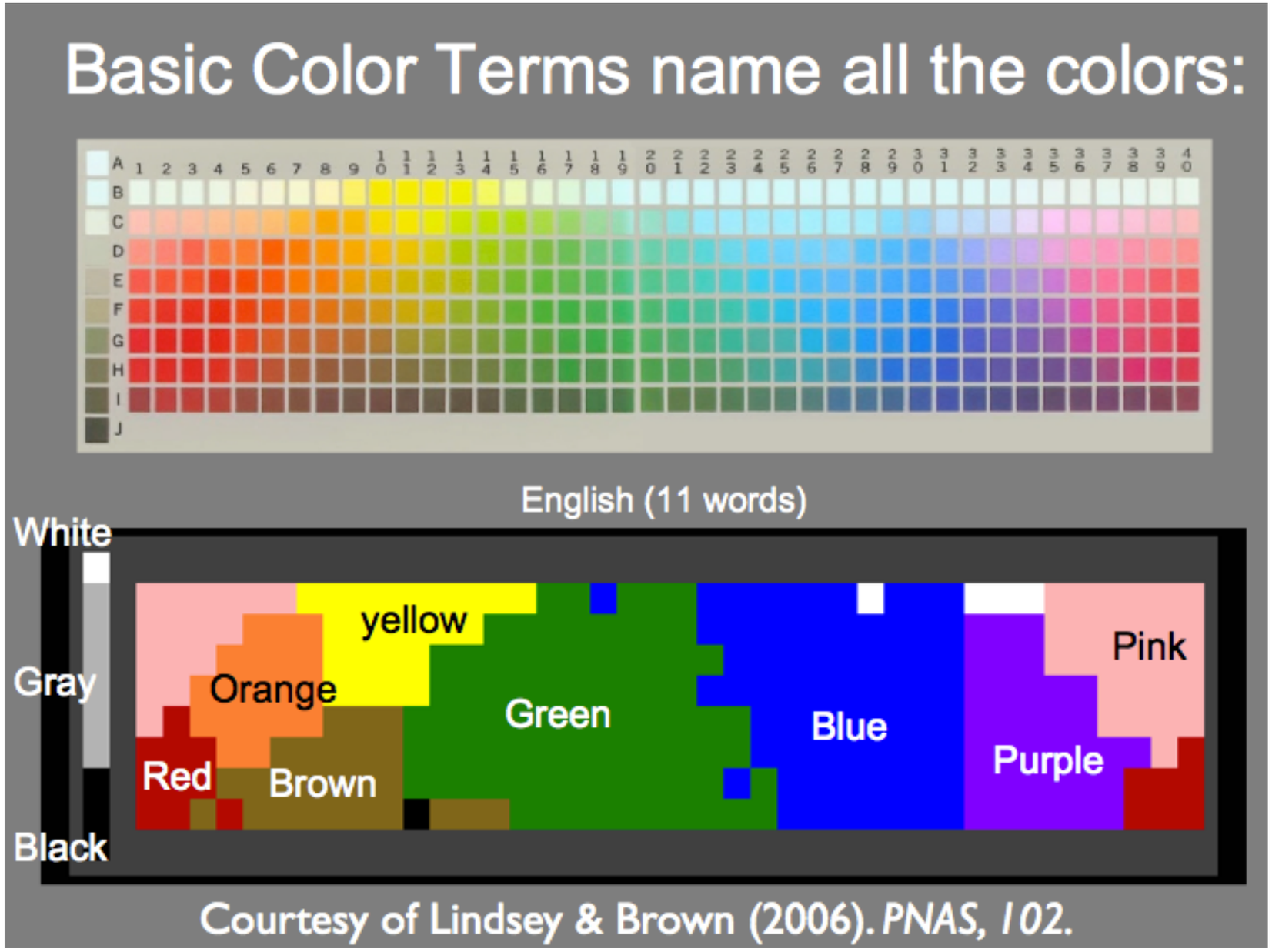
$\sim 10^7$ perceived colours

vs

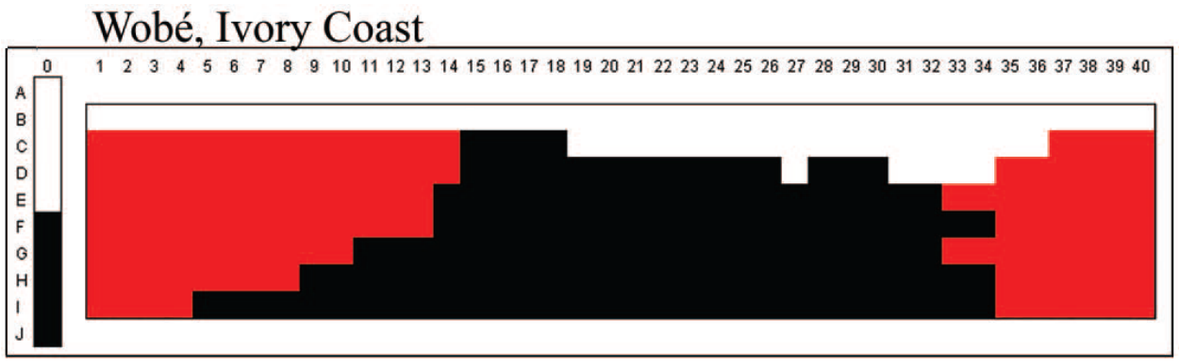
few names

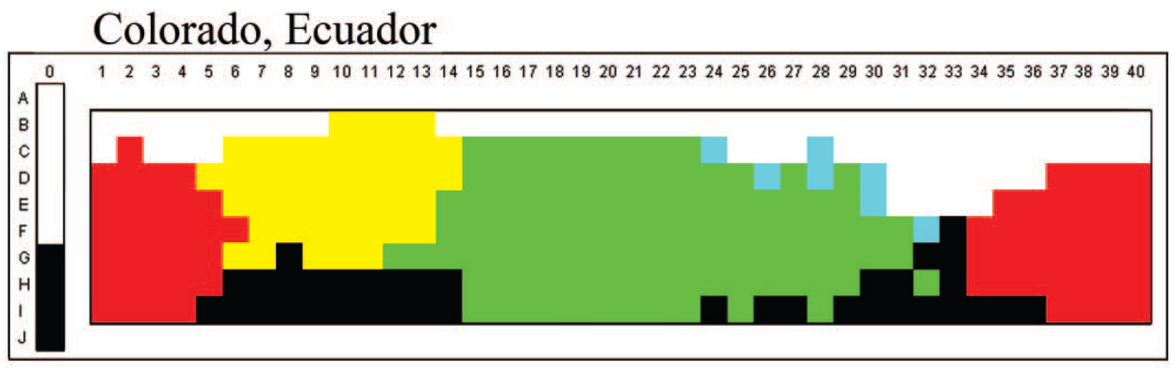


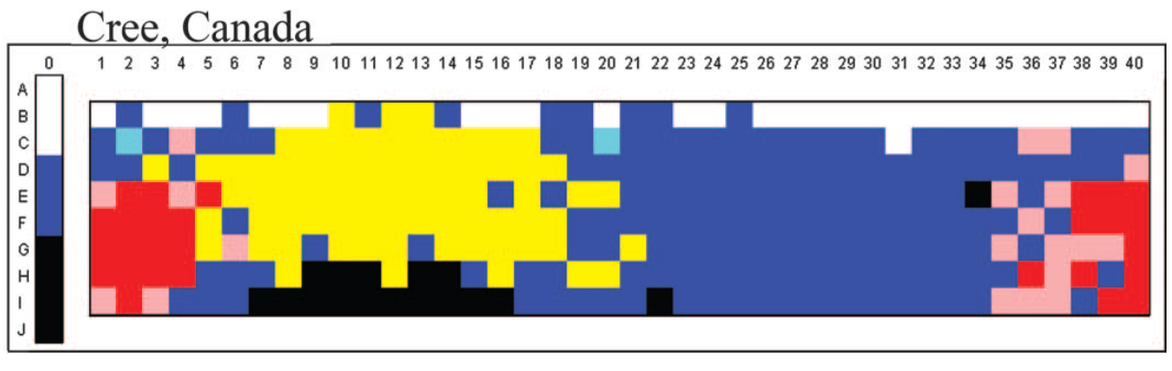
11 COLOUR NAMES IN ENGLISH



FROM 2 TO 11 BASIC COLOUR TERMS







Images from Regier, Kay and Khetarpal PNAS 104: 1436 (2007)

THREE APPROACHES

Nativism: All humans are born with the same categories. [1]

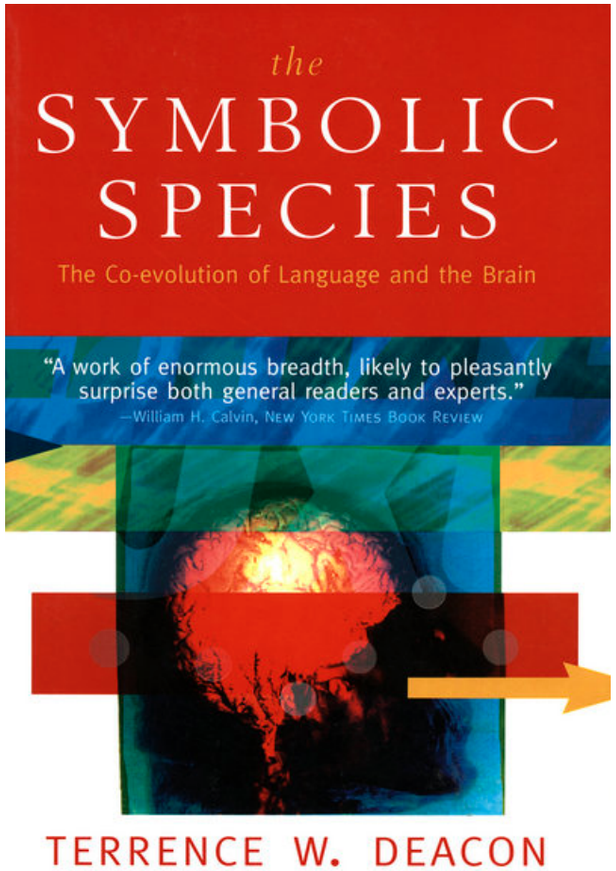
Empiricism: All humans share learning mechanisms and sensory-motor apparatu. They will arrive at the same categories reflecting the statistical structure of the real world. [2]

Culturalism: Categories are social conventions shared by a given group. They emerge spontaneously. [3]

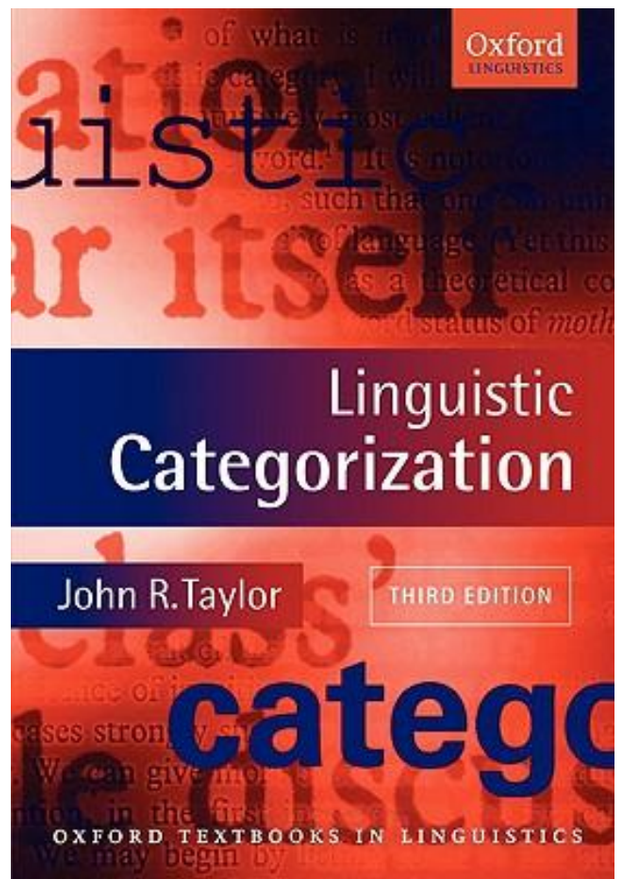
[1]Rationalism: Fodor1983; Evolutionary psychology: Pinker&Bloom 1990, etc
[2]Empiricist psychology: Elmann 1996; Inductive machine learning; Connectionism
[3]Cultural psychology: Tomasello 1999; Language as an adaptive system: Steels 1997.

Cfr Steels & Belpaeme: BBS 28, 469 (2005).

COLOUR IS THE EXAMPLE



"this is an ideal example"



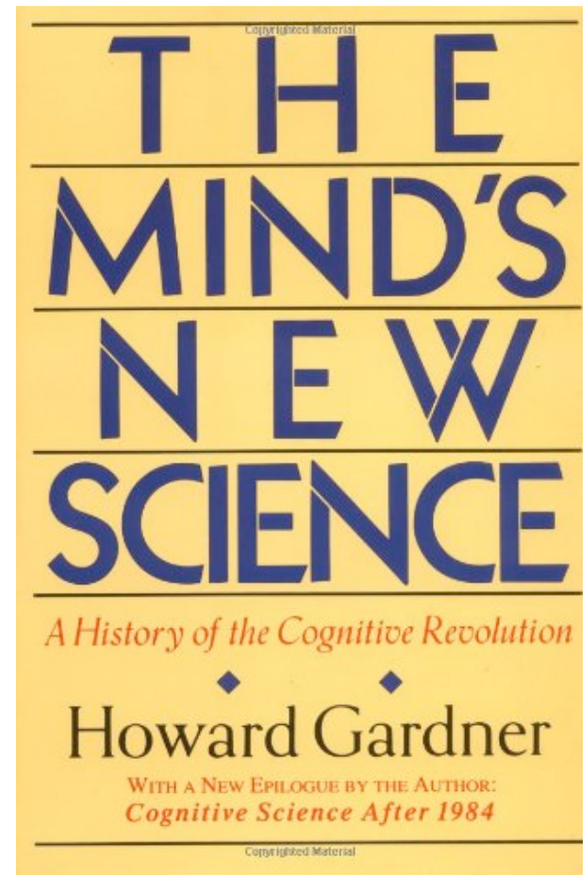
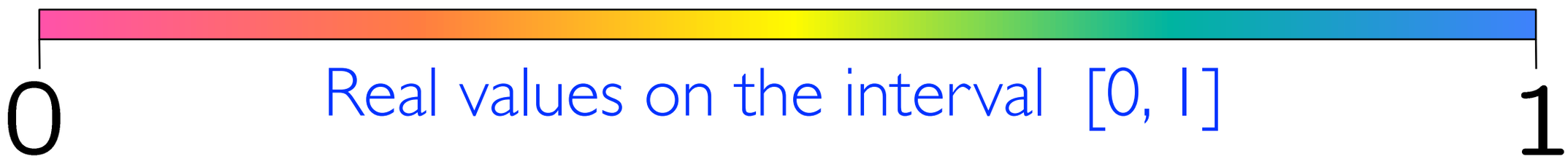


Table of Contents

Can we model the spontaneous emergence of categories?

THE CATEGORY GAME

Individuals: a low-dimensional input channel, 1d



Categories (perceptual): subsets of the interval

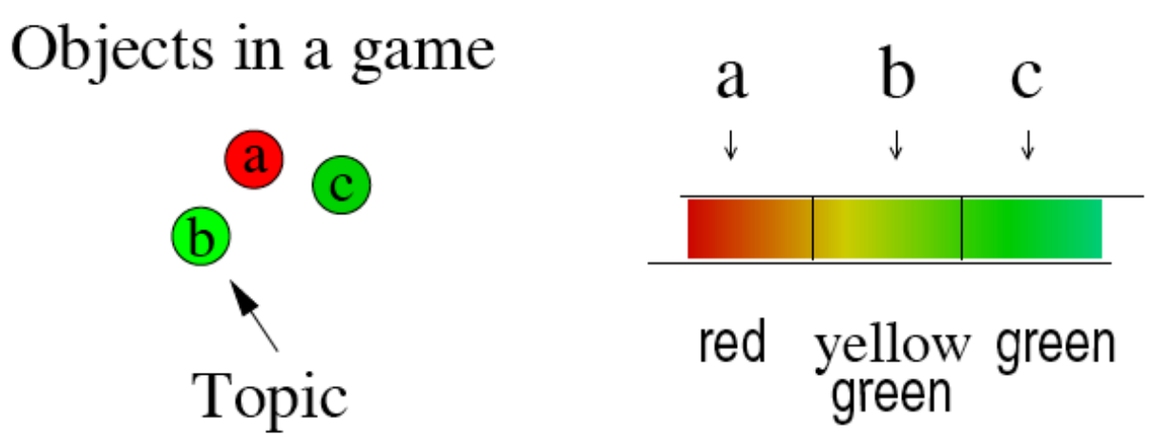
Just Noticeable Difference: objects not closer than d_{min}

with A. Puglisi e V. Loreto, PNAS 2008, 2010; PLoS ONE 2012, 2016

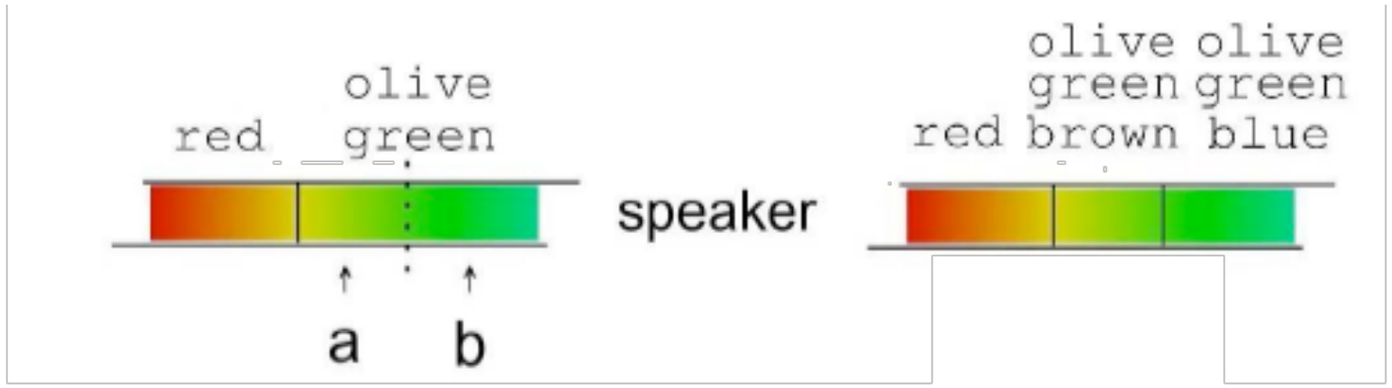
each agent has a set of non-overlapping categories; at the beginning only the category (0,1) exists

each category comes with an inventory of words;

the scene: M real numbers in (0,1) at a minimal distance d_{min} , one is the topic



the speaker discriminates the topic: possible creation of new boundaries; each new category inherits the words of the old category, plus a brand new one



the speaker says a word

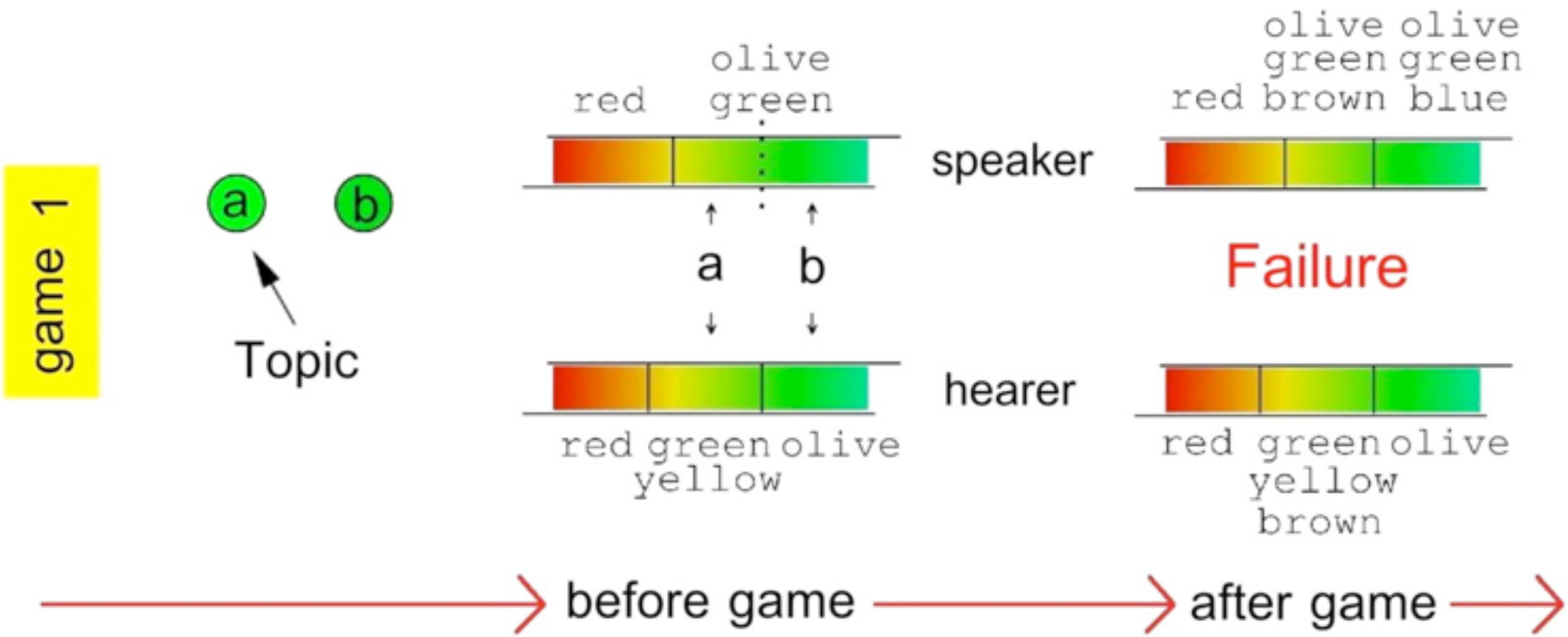
the hearer looks at her inventory for that word and builds a set of candidate categories (word + object), one of which is selected

failure

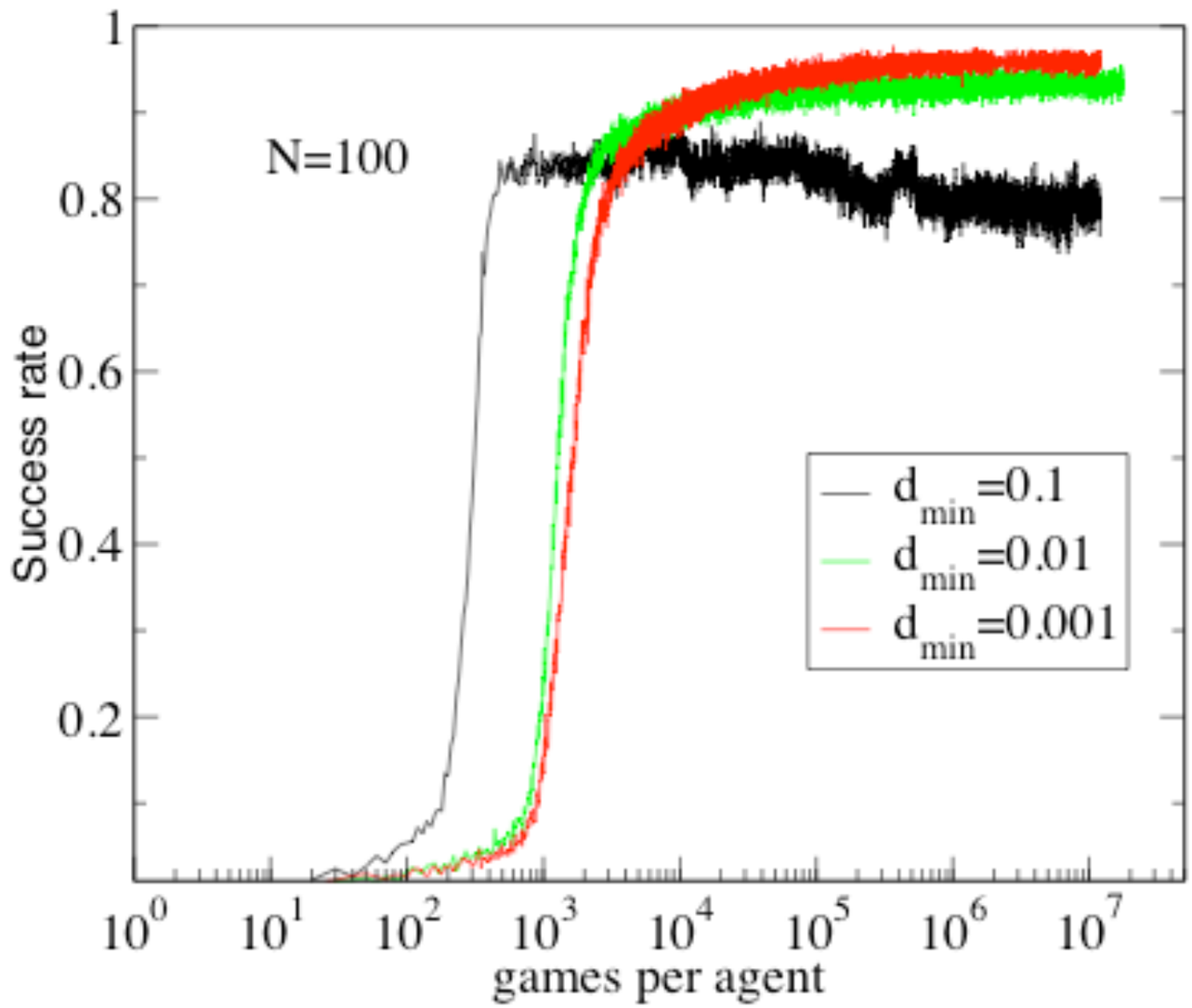
the hearer discriminates the object and adds the speaker's word to the correct category

success

both individuals reduce the inventory associated to the winning category to the winning word only


game 1
a
b
Topic
red
olive
green
speaker
a
b
hearer
red green olive
yellow
olive olive
green green
red brown blue
Failure
red green olive
yellow
brown
before game
after game

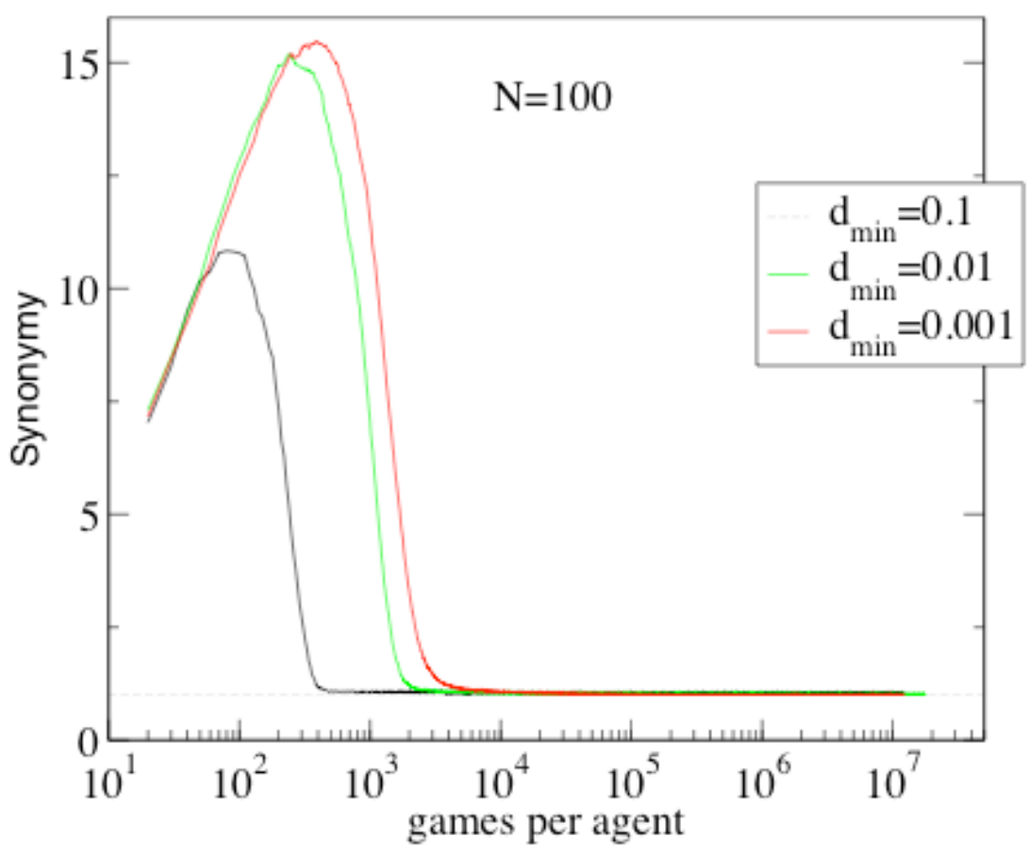
SPONTANEOUS EMERGENCE OF CONSENSUS

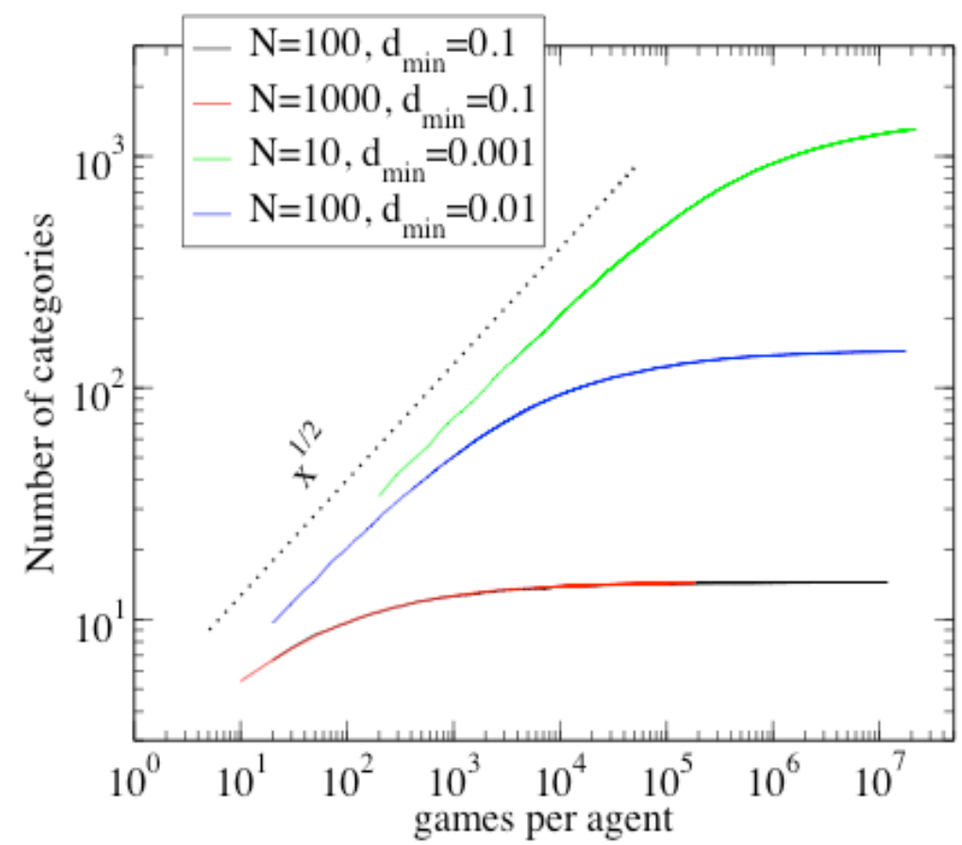


1. SYNONYMY + FREE CATEGORISATION

For each category: typical Naming Game synonymy curve

Number of categories grows and then saturates at $2/d_{min}$





2. SUCCESS

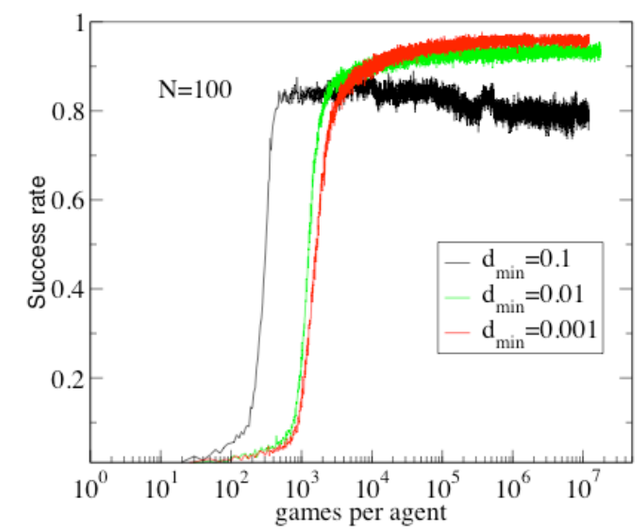
Success is high (~90%)

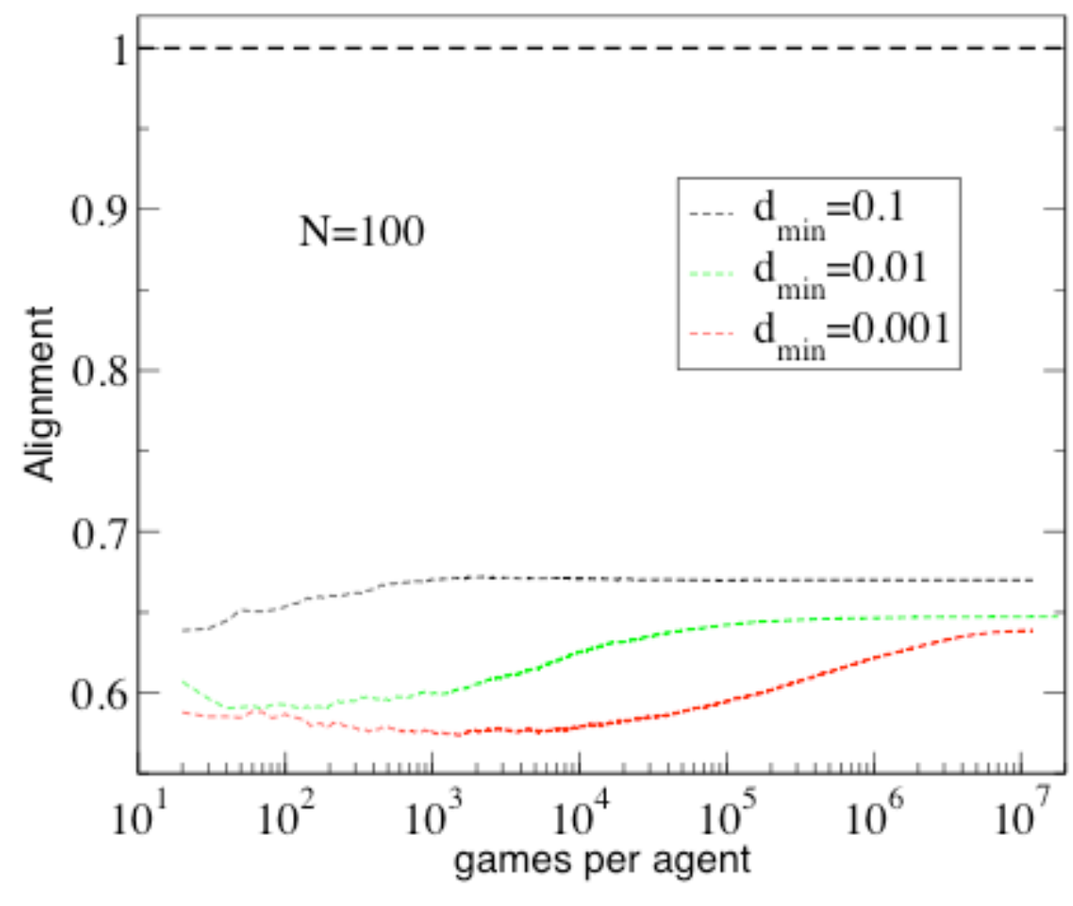
Synonymy is eliminated

Categories are still evolving (slow refinement)

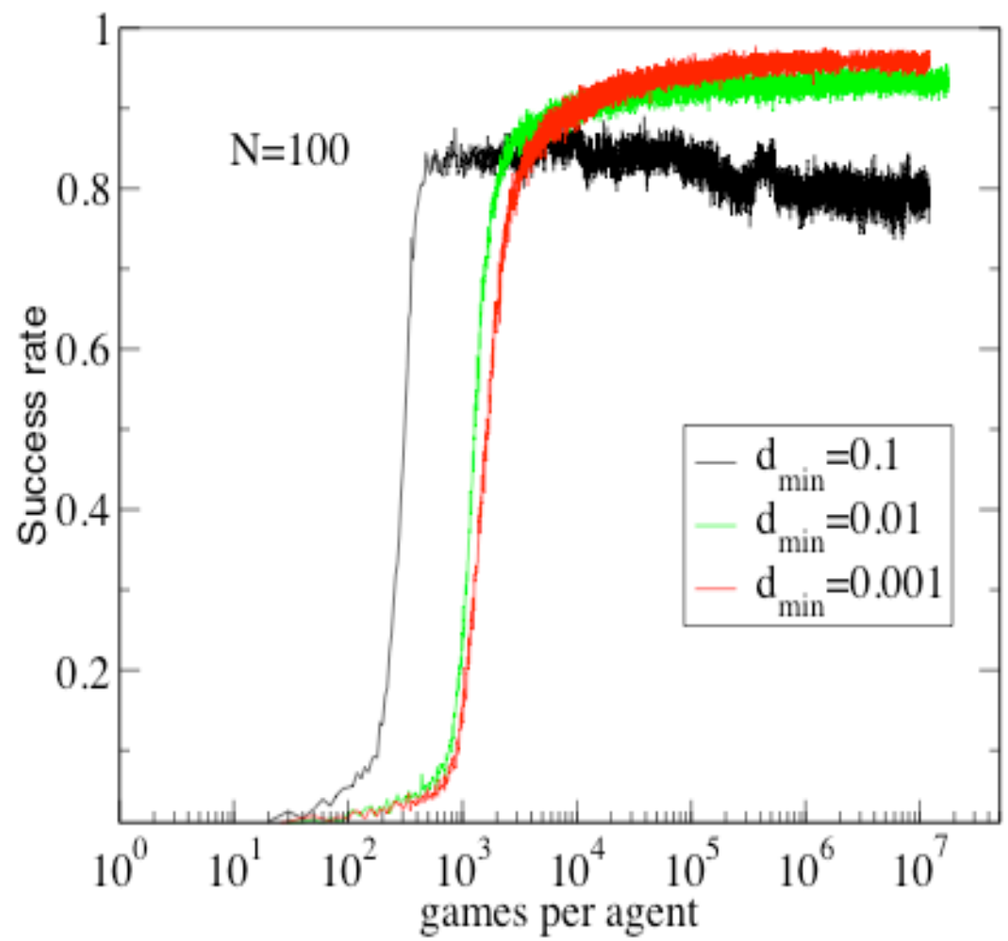
and are poorly aligned (!)

$$o_{ij} = \frac{2\sum_{c_i^j}(l_{c_i^j})^2}{\sum_{c_i}(l_{c_i})^2 + \sum_{c_j}(l_{c_j})^2}$$



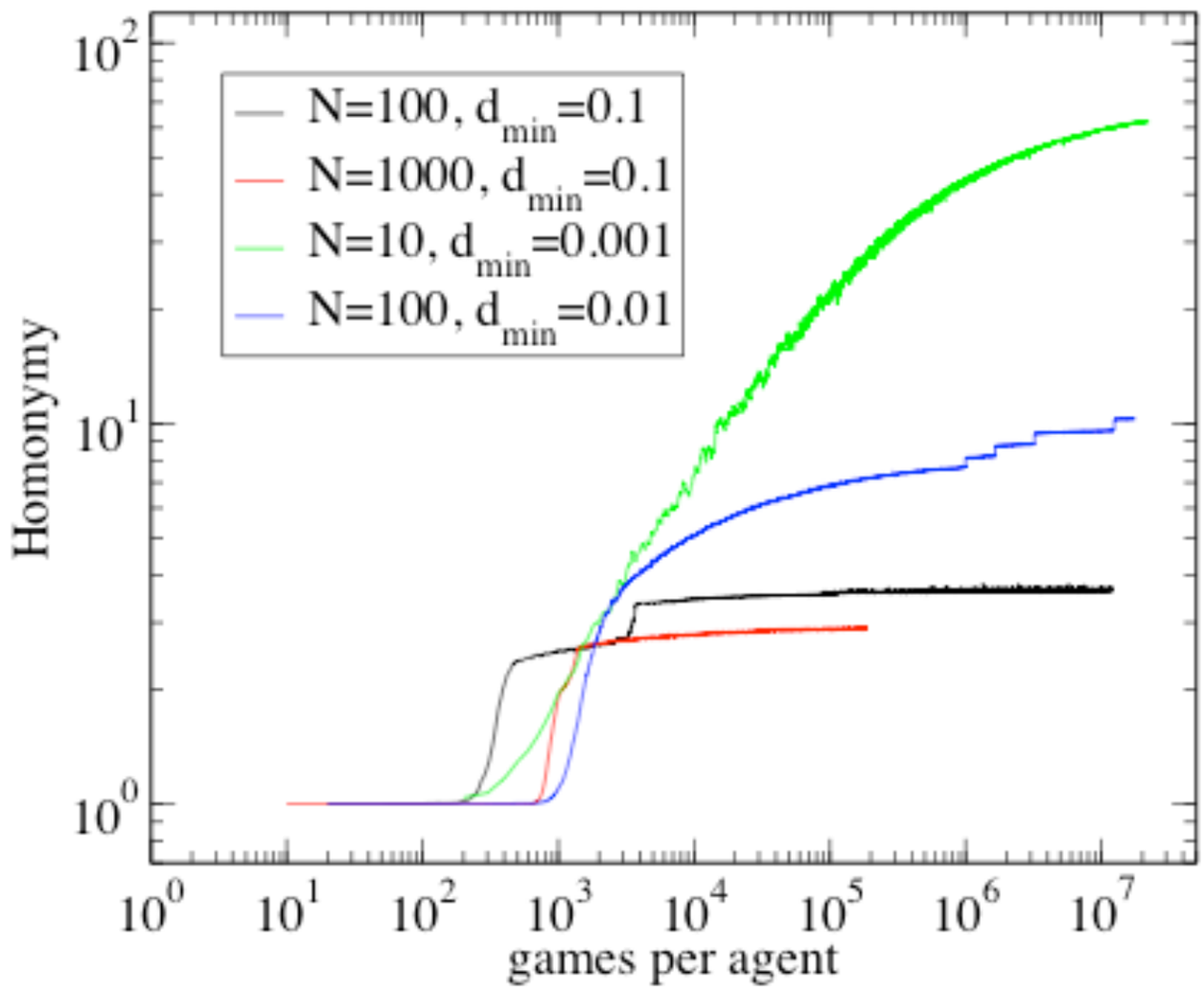


How can the success be so high?



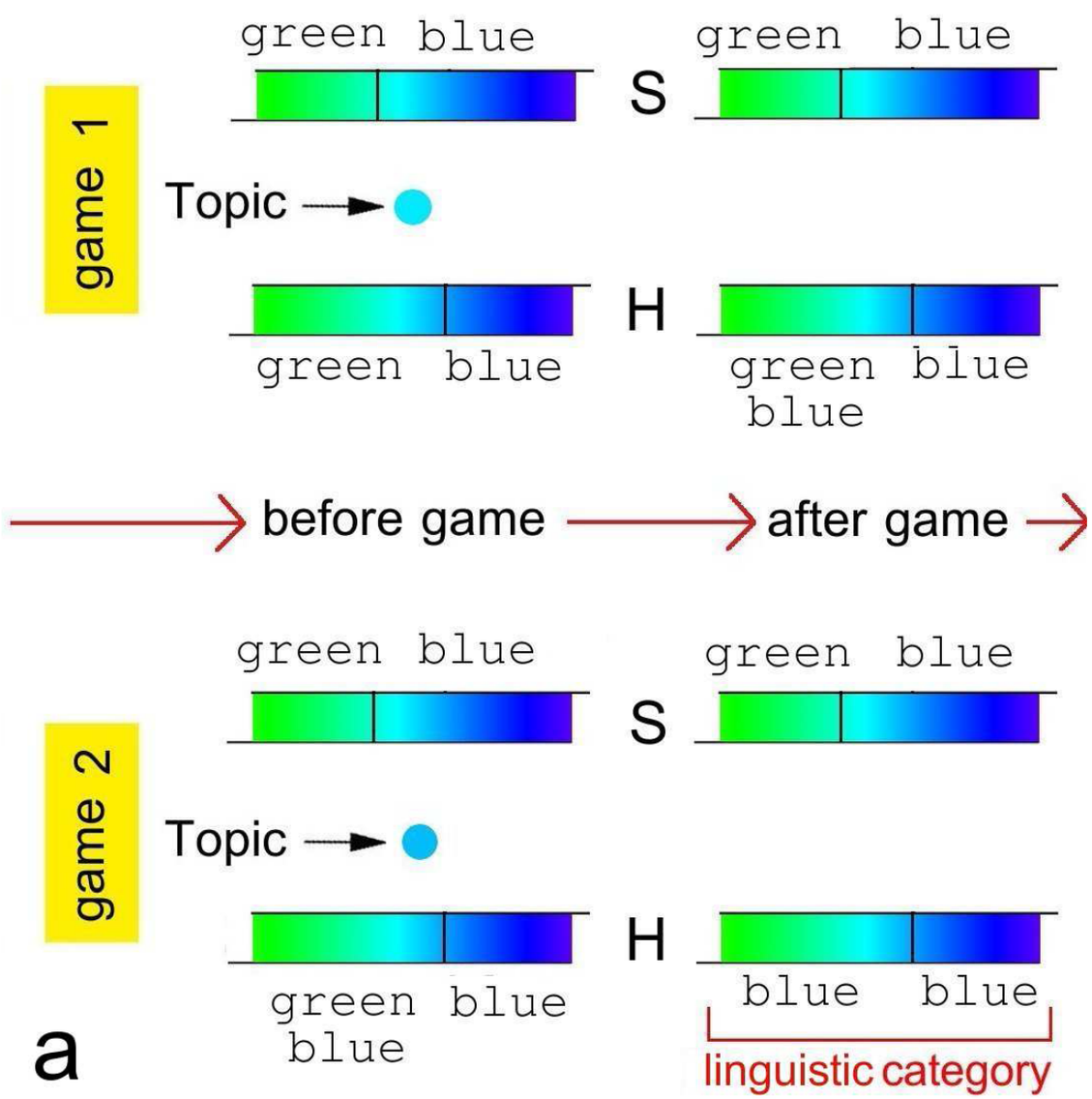
As synonymy disappears

homonymy is growing

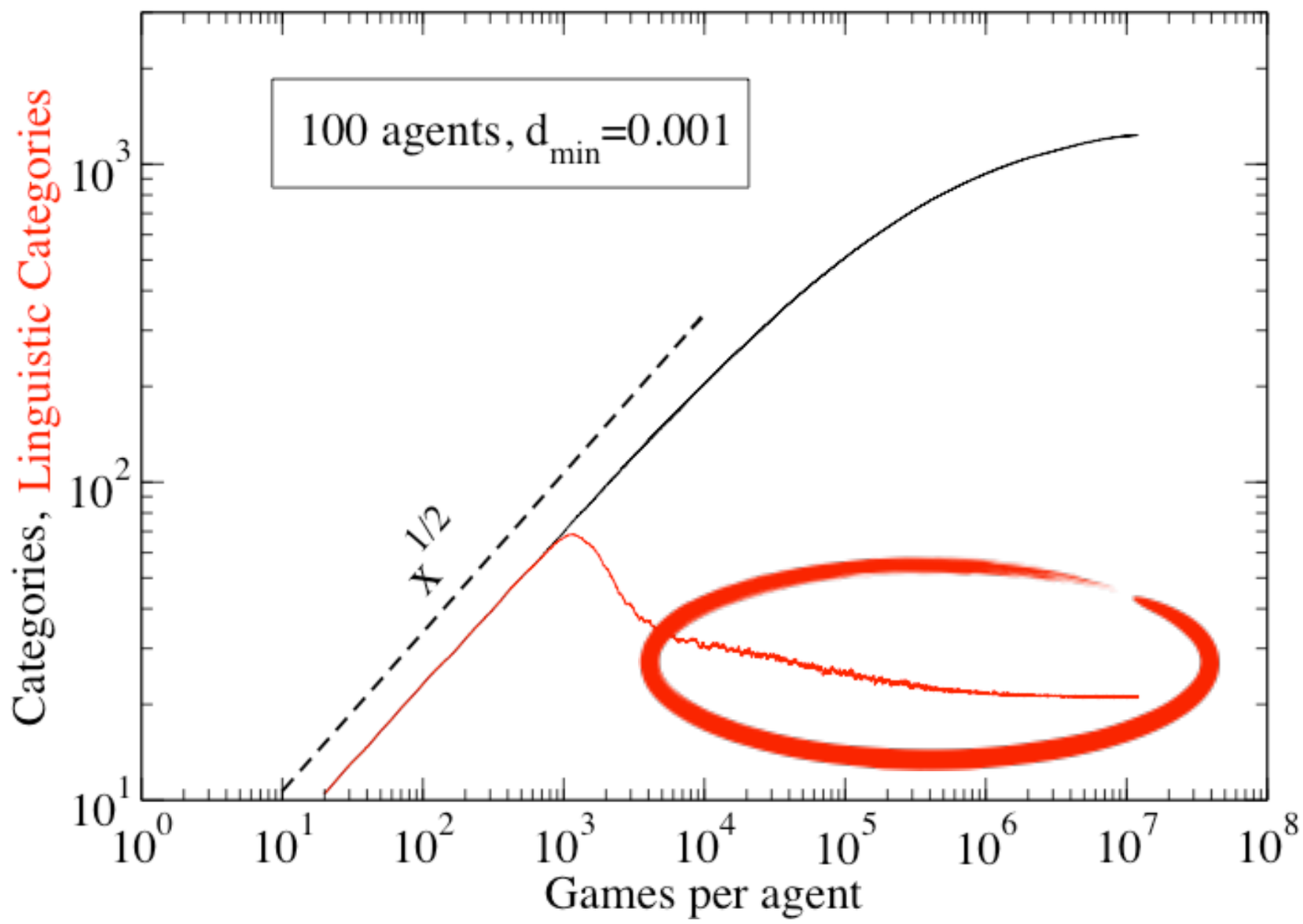


Number of categories associated to the same (unique) word

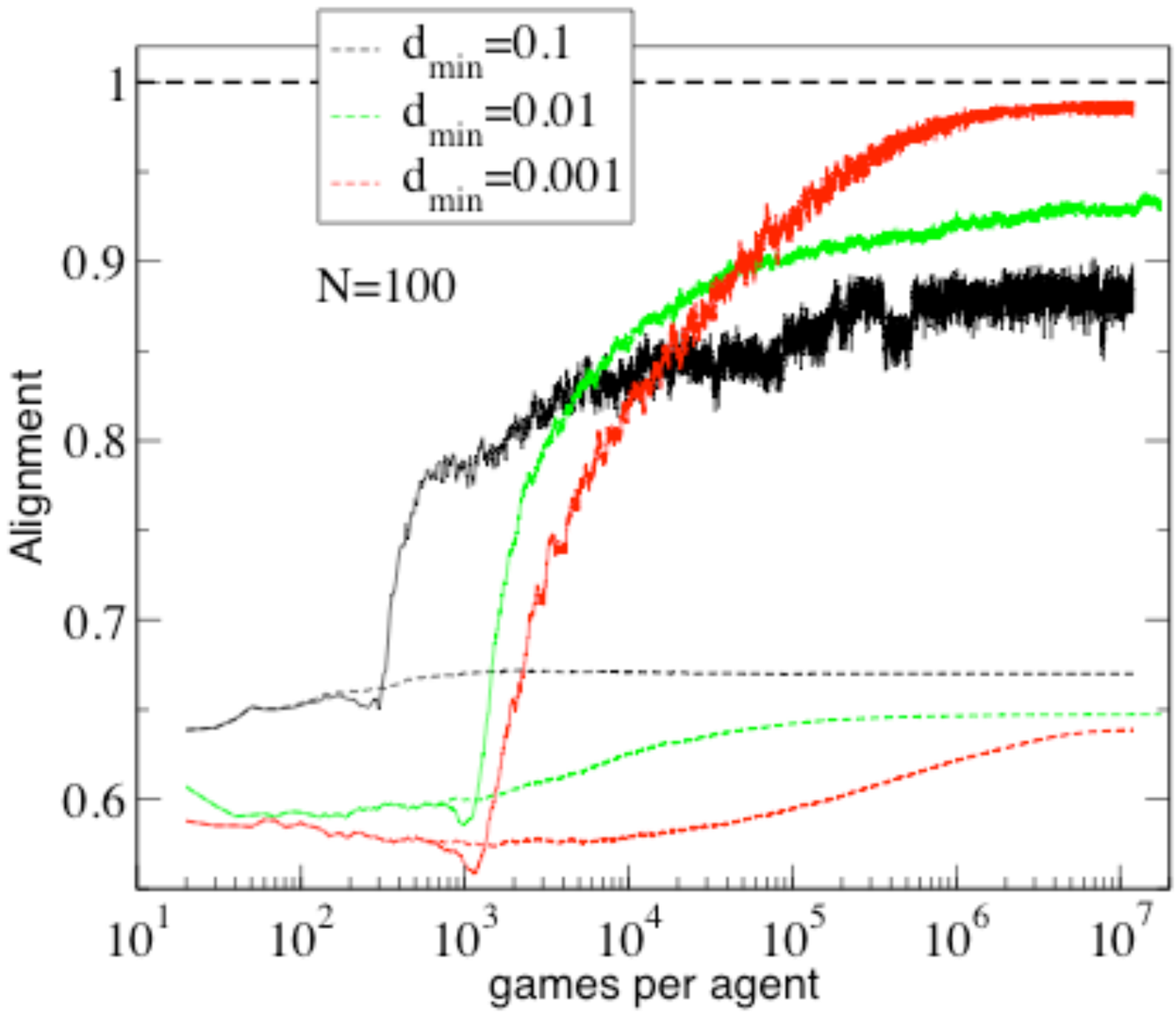
LINGUISTIC CATEGORIES EMERGE

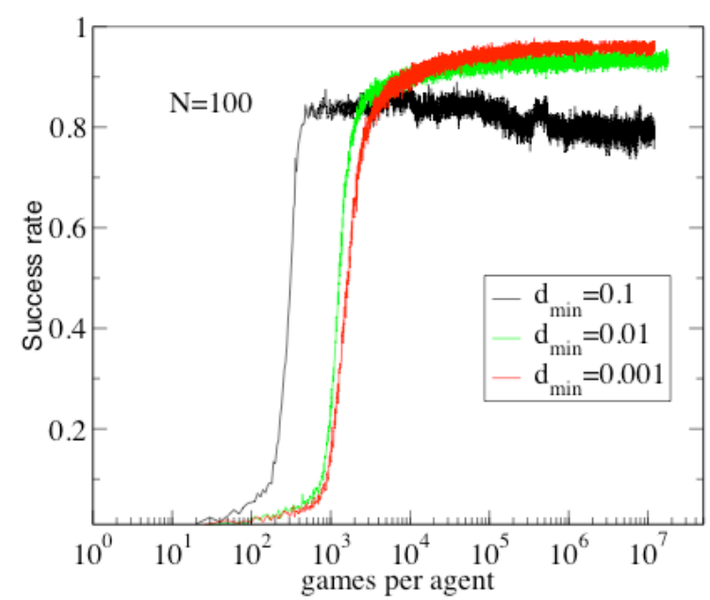


LING CAT ARE FEW (10-20)

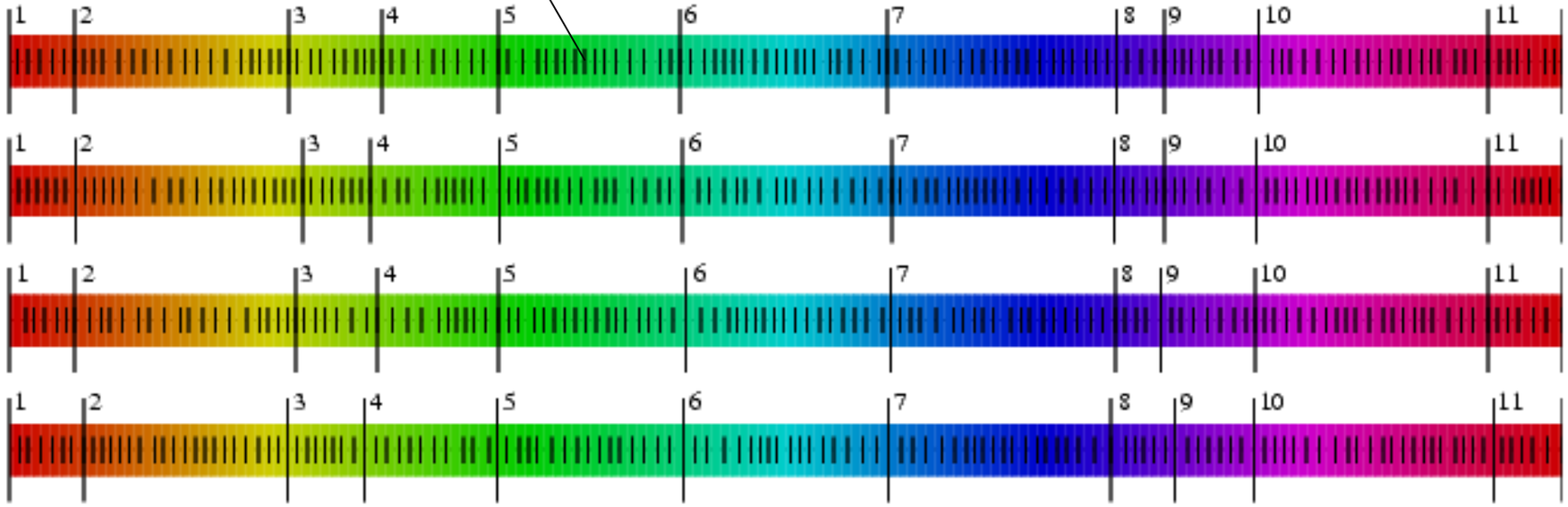


THEY ARE WELL ALIGNED



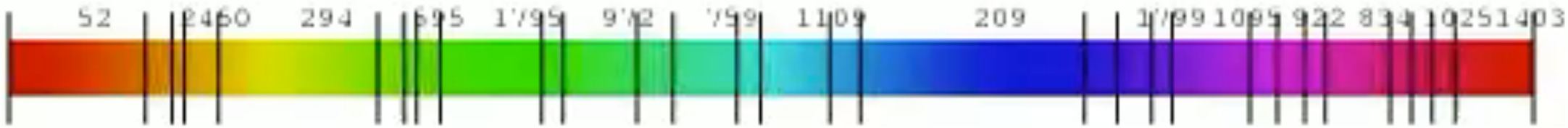


individual perceptual category

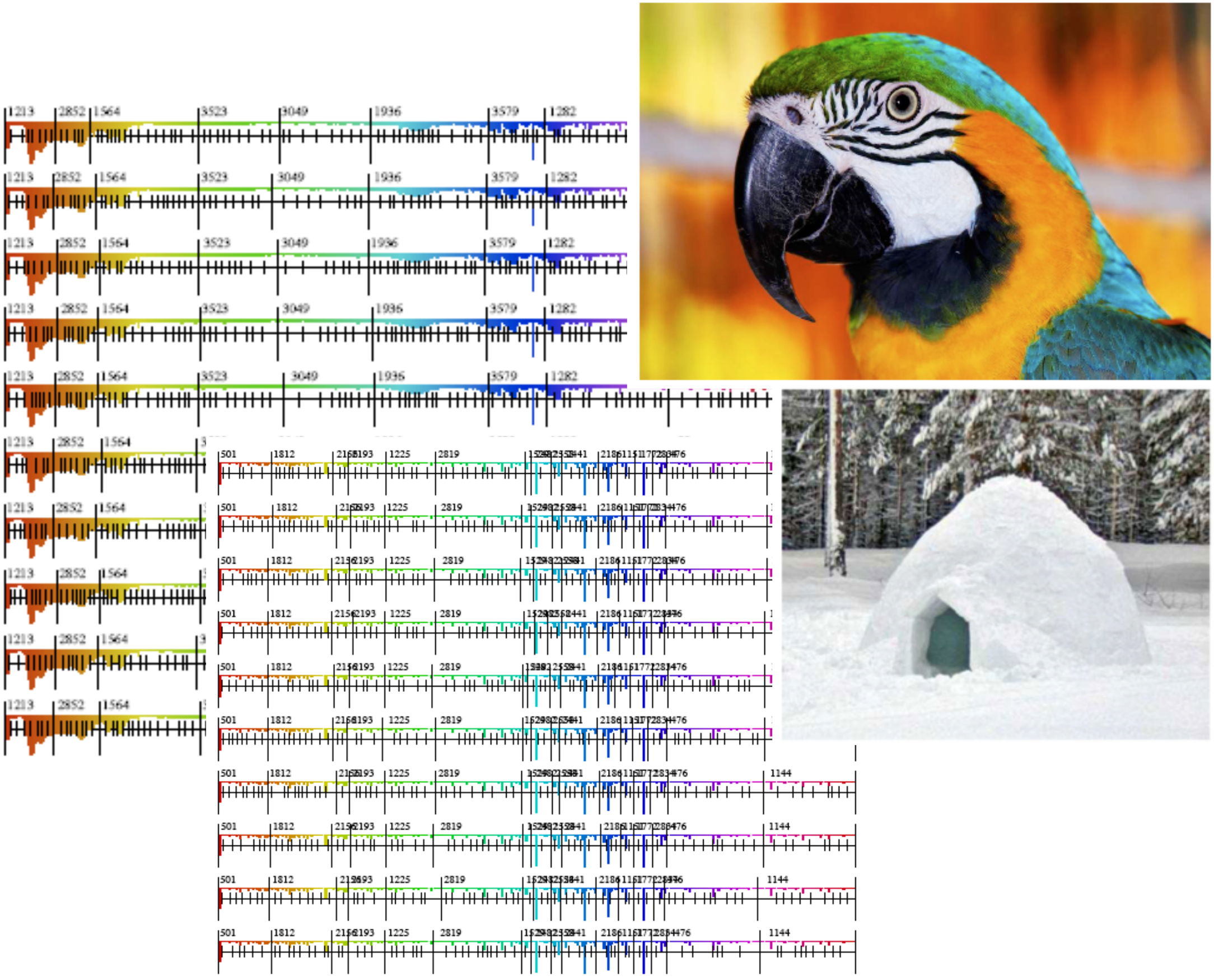


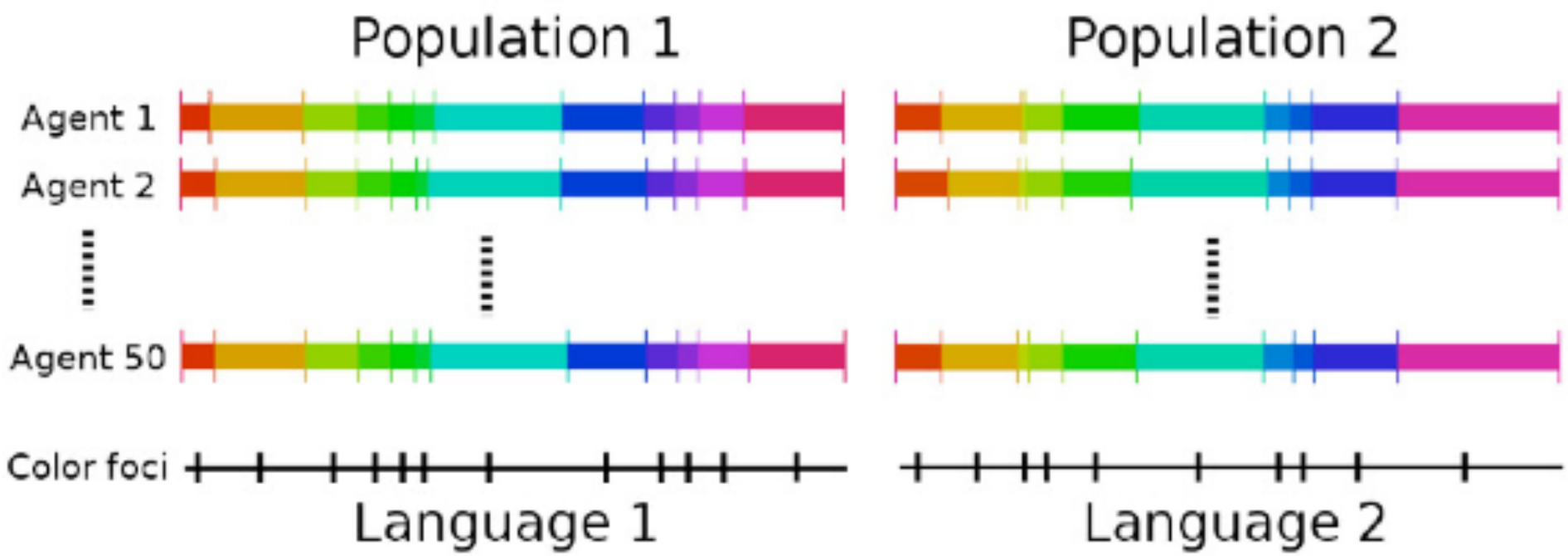
emerging collective linguistic category

Consensus

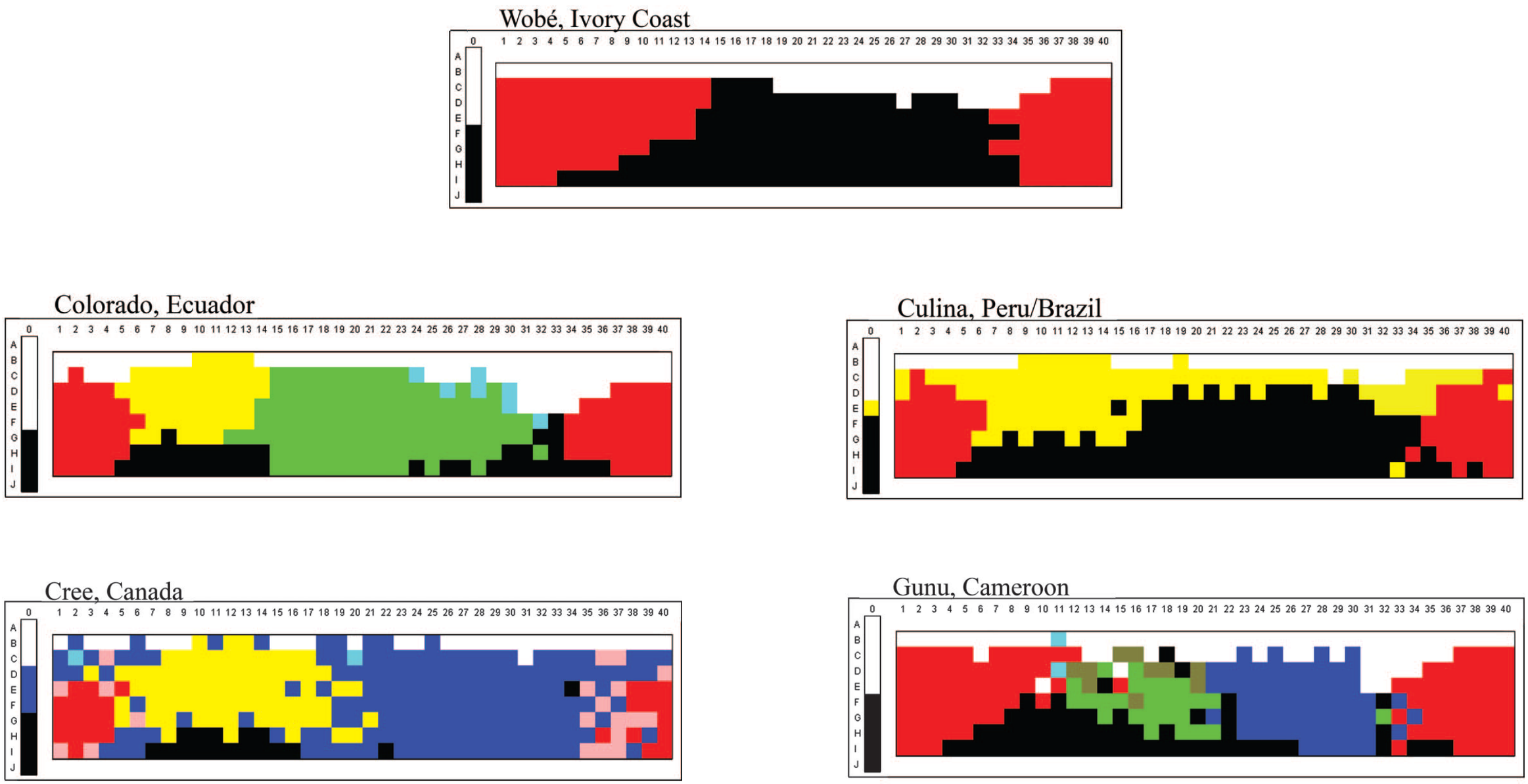


Misunderstanding


1213 2852 1564 3523 3049 1936 3579 1282
501 1812 2168 2193 1225 2819 1144


Population 1
Population 2
Agent 1
Agent 2
Agent 50
Color foci
Language 1
Language 2

RANDOM? UNIVERSAL PROPERTIES?



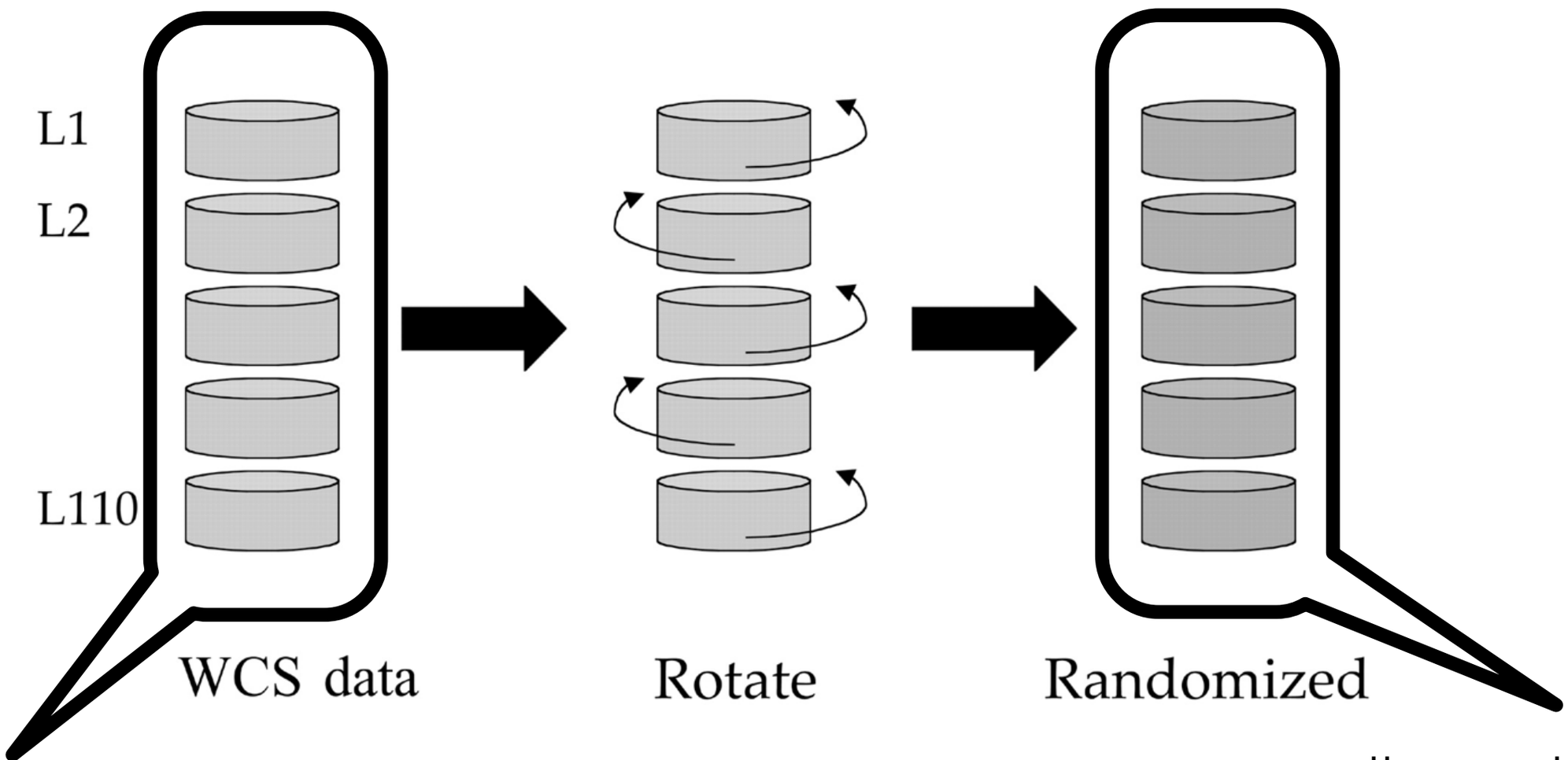
Images from Regier, Kay and Khetarpal PNAS 104: 1436 (2007)

Resolving the question of color naming universals

Paul Kay[†‡§] and Terry Regier[‡§¶]

[†]International Computer Science Institute, Berkeley, CA 94704; and [¶]Department of Psychology, University of Chicago, Chicago, IL 60637

PNAS | July 22, 2003 | vol. 100 | no. 15 | 9085–9089

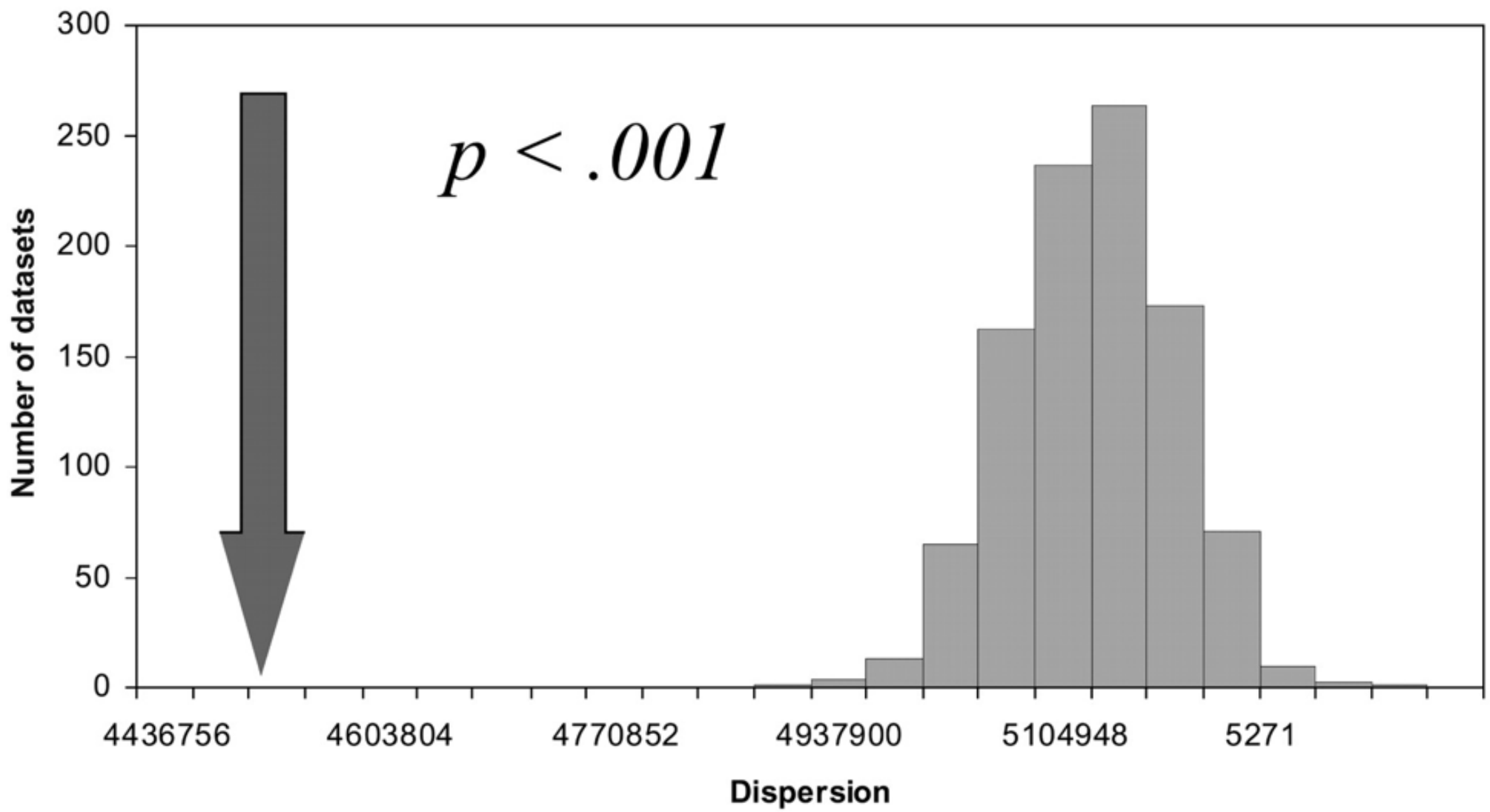


dispersion

dispersion

$$D_{S_0} = \sum_{l,l^* \in S_0} \sum_{c \in l} \min_{c^* \in l^*} \text{distance}(c, c^*)$$

COLOR NAMES ARE <u>NOT</u> RANDOM



WCS data are less dispersed than their randomised counterparts => universality

UNIVERSALITY:
the object of consensus is not completely random

A REVOLUTION

According to the Classical Theory of categorization, categories:

1. Are arbitrary;
2. Have defining or critical attributes (shared by members)
3. Have an extension (which items are member) defined by their intension (set of attributes). No internal structure.

Categories and thought

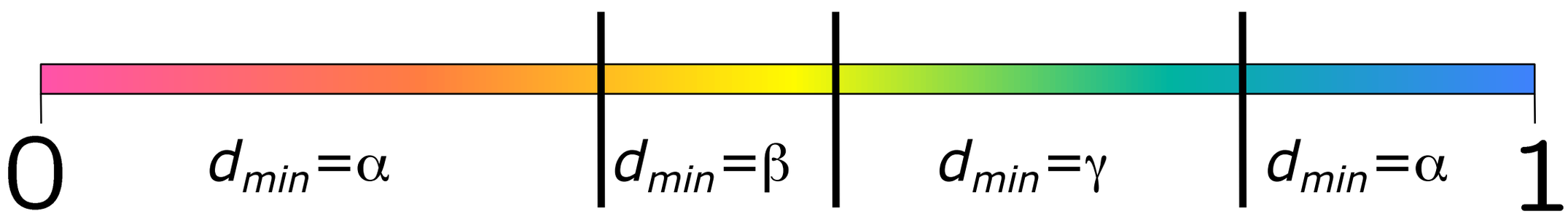
1. Are embodied;
2. Are imaginative (employ metaphor, metonymy, etc);
3. Have gestalt properties;
4. Have an internal structure, aka ecological properties.

Lakoff. ‘Women Fire, and dangerous things’

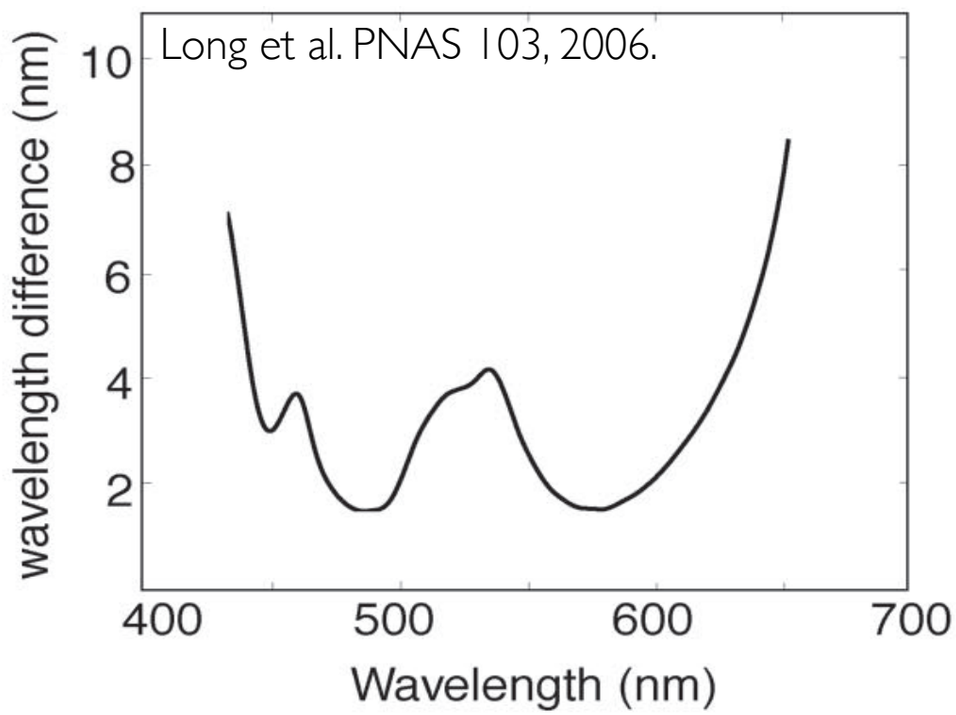
Where does the observed <u>statistical</u> universality come from?

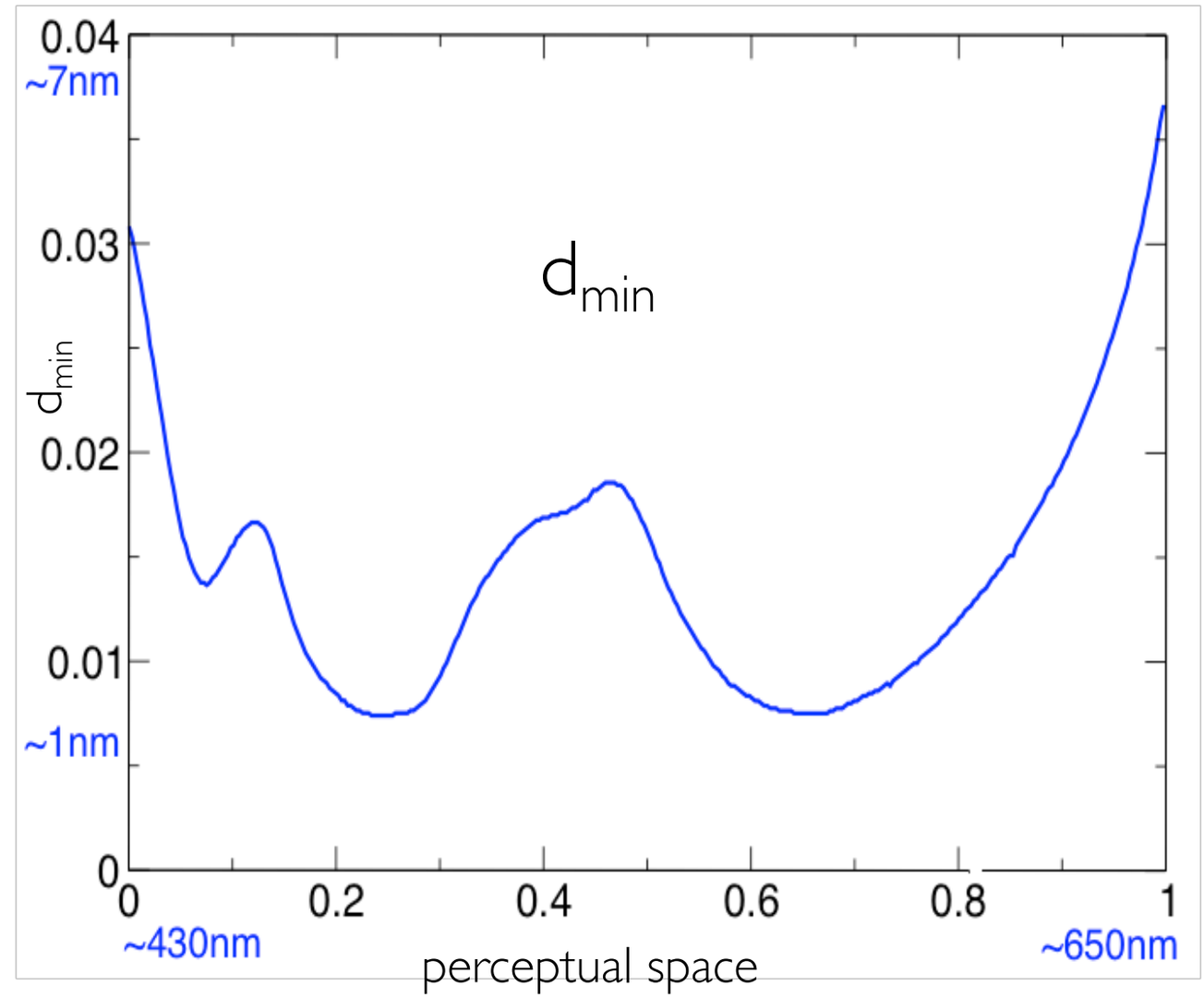
d_{min} 'FILTERS' THE ENVIRONMENT

In principle it can vary on the [0,1] axis:
different resolution power for different stimuli

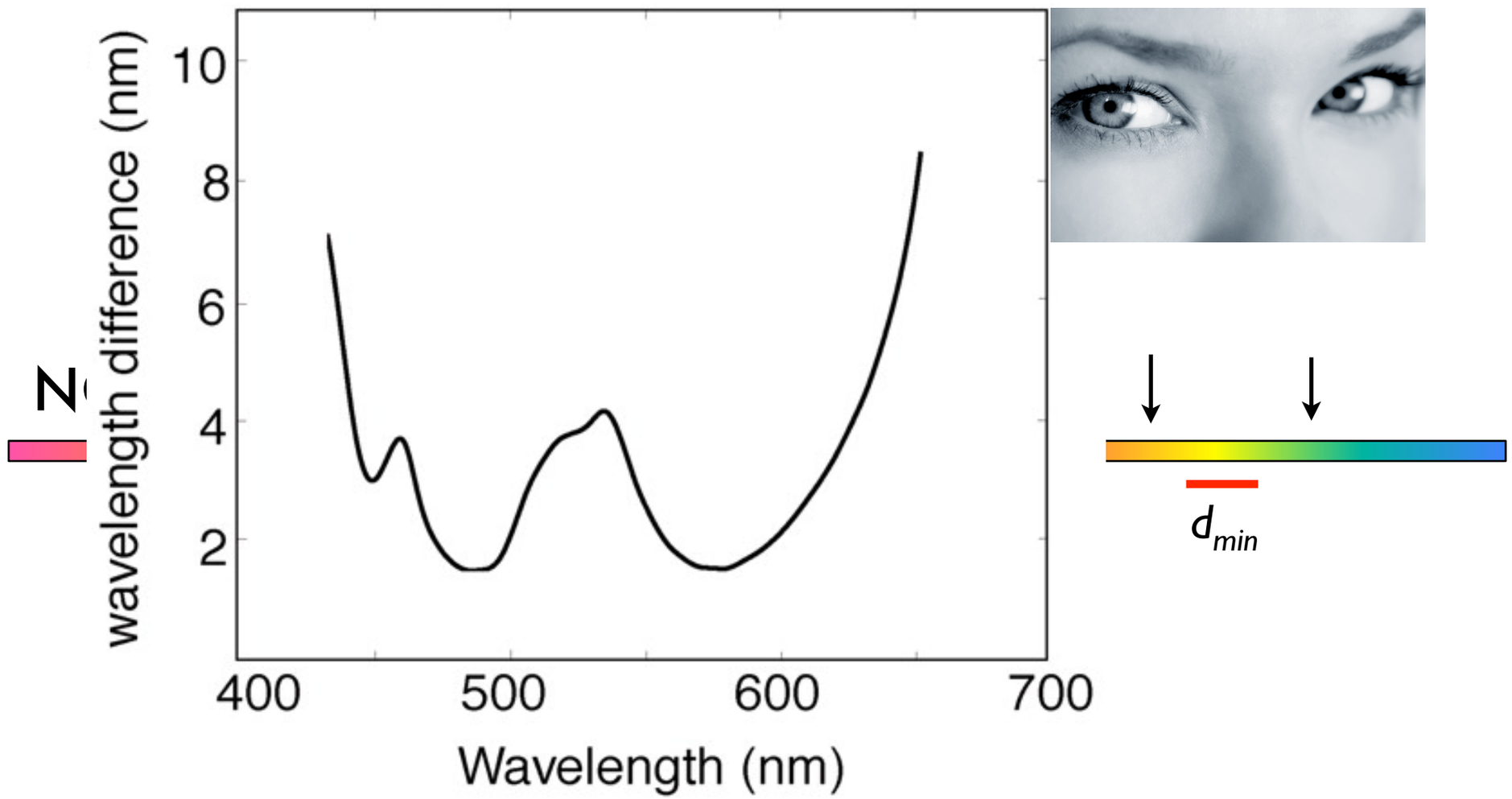


HUMANS HAVE A d_{min}





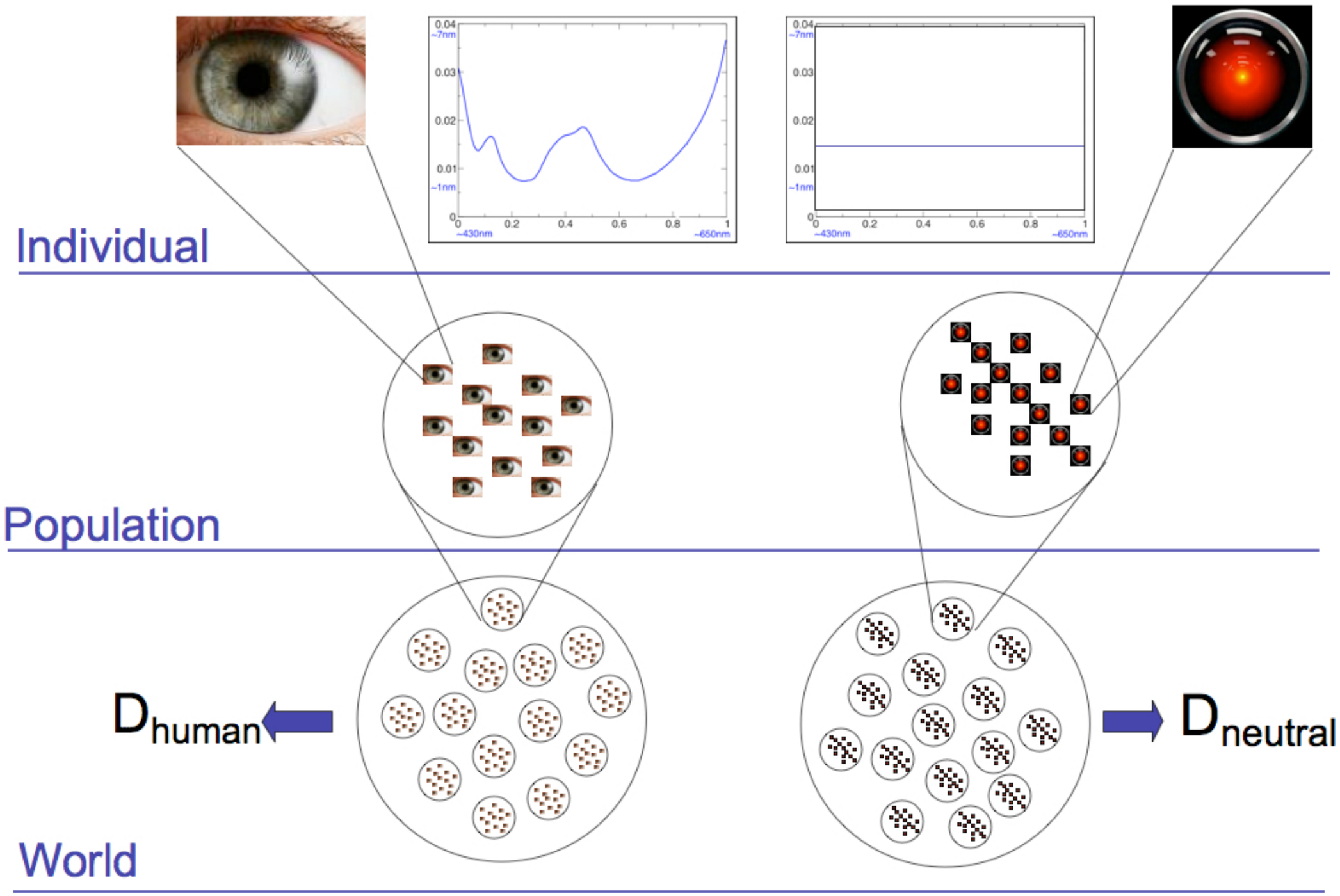
the Just Noticeable Difference - JND



Just Noticeable Difference: objects not closer than d_{min}

with A. Puglisi , V. Loreto et al. PNAS 2010, PLoS ONE 2011 and 2015

THE NUMERICAL WORLD COLOR SURVEY



PNAS 2010

WCS:

Experimental data vs.

Many randomized sets

Q: Are data more clustered? (yes)

Numerical WCS:

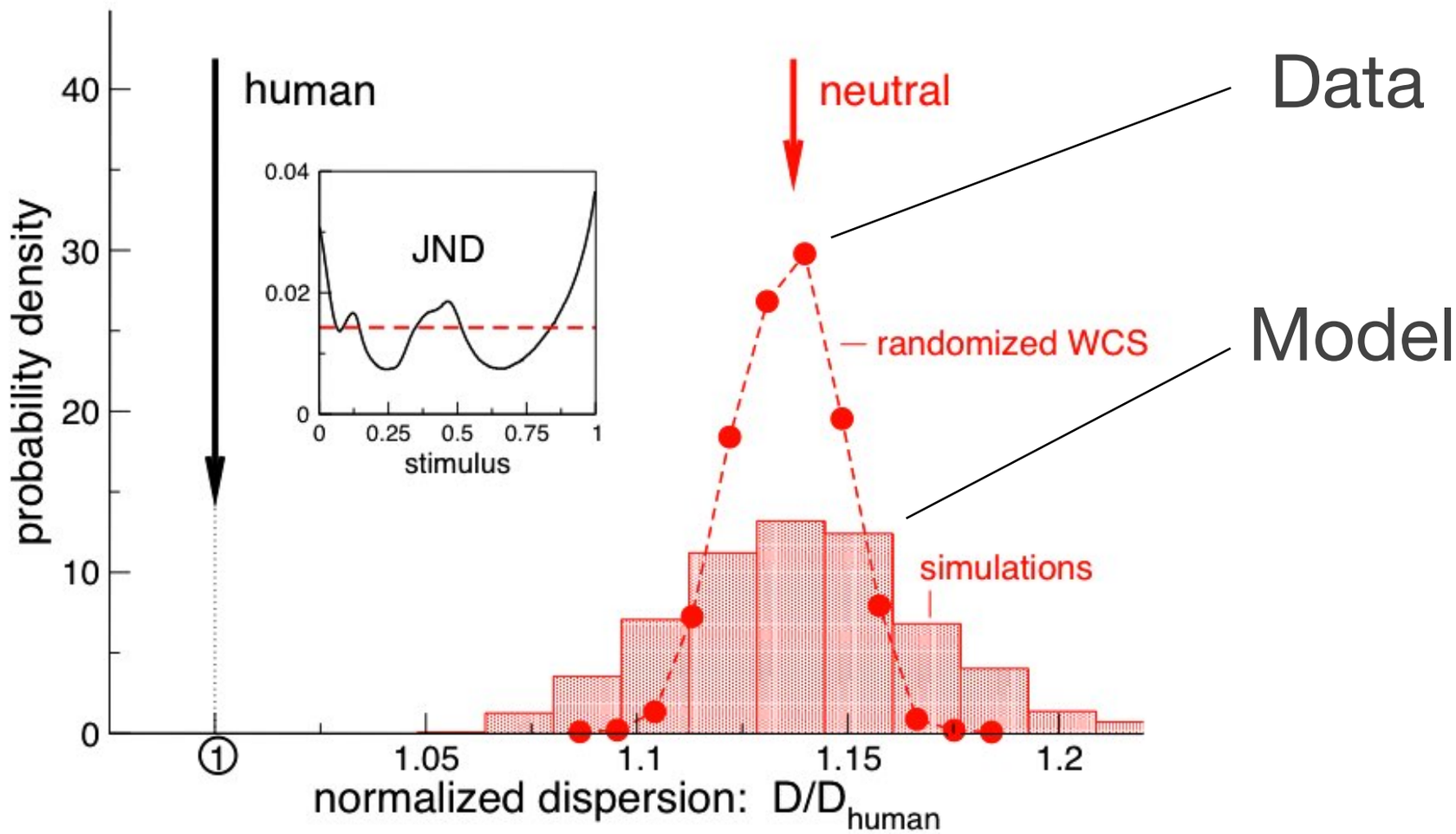
Human worlds: human JND vs.

Neutral worlds: uniform JND

Q: Are “human data” more clustered?

SIMULATIONS MATCH EMPIRICAL DATA

The universal properties of the empirical data are reproduced

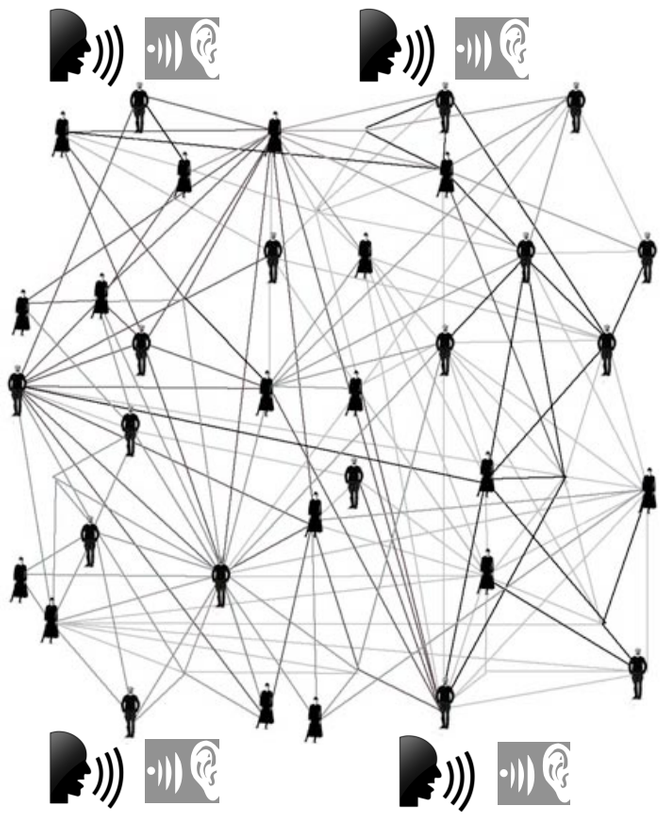


LOCAL INTERACTIONS + COGNITIVE BIAS =

CONSENSUS + UNIVERSAL PATTERNS

with A. Puglisi , V. Loreto et al. PNAS 2010, PLoS ONE 2011 and 2015

COGNITION SHAPES CULTURAL EVOLUTION



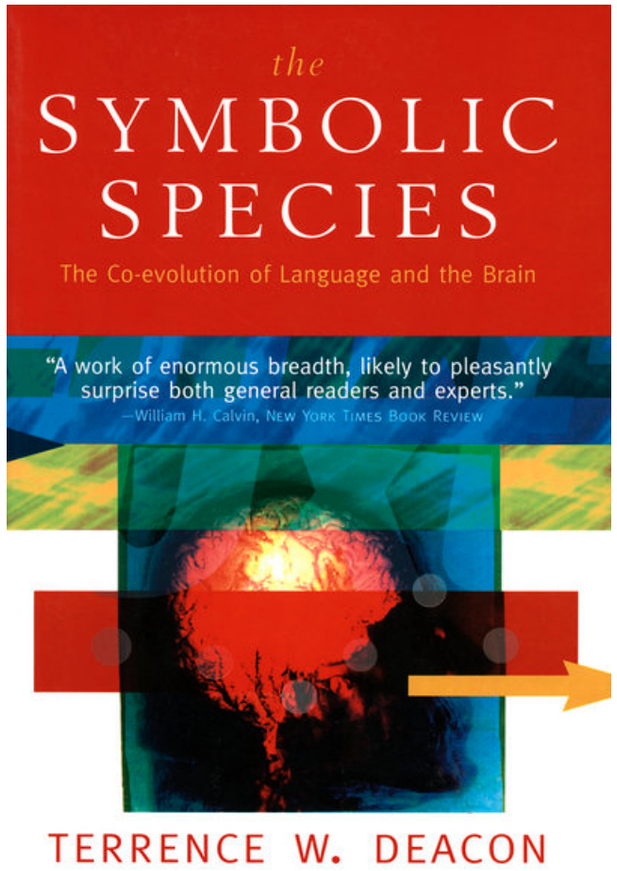
culture: group specific history, randomness

shared bias: universal properties

A ‘THOUGHT EXPERIMENT’..

‘Consider the thought experiment of coining a new name for the color of a specific object..’

‘In summary, the universality.. is an expression of shared neurological biases, but - and this is a crucial point - **the translation of this biological constraint into a social universal** is brought about through the action of nongenetic forces’



T. Deacon, 1997

.. becomes a computational experiment.

+ THE MODEL IDENTIFIES THE CANDIDATE SOURCE OF BIAS

The Biological Basis of a Universal Constraint on Color Naming: Cone Contrasts and the Two-Way Categorization of Colors

Youping Xiao[1]*, Christopher Kavanau[1], Lauren Bertin[2], Ehud Kaplan[1]

1 The Neuroscience Department and the Friedman Brain Institute, Mount Sinai School of Medicine, New York, New York, United States of America, **2** Natural Sciences and Mathematics, Bennington College, Bennington, Vermont, United States of America

Received June 3, 2011; **Accepted** August 22, 2011; **Published** September 21, 2011

Statistical analyses of the WCS data demonstrated that color categories of most languages are centered around a modest set of locations in color space [2,3], and thus provided strong evidence for the existence of universal constraints. Computer simulations suggested that this non-random distribution of color categories can be accounted for by the wavelength discrimination function of humans [27]. Since the wavelength discrimination function seems to be partially attributed to the characteristics of the L−M and S-(L+M) channels in the lateral geniculate nucleus [28], that simulation study implies a link between the universal constraints and the functional characteristics of the retinogeniculate pathway.

TAKE HOME (II)

The Category Game describes the **spontaneous emergence of categories**. PNAS 2008.

Informed by the human JND, **the model reproduces the empirical data**, and suggests a deep explanation for the interplay between culture and biology. **PNAS 2010, PLoS ONE 2011, 2015.**

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THANK YOU!

Luis Amaral (Northwestern)
Alain Barrat (Marseille)
Damon Centola (MIT - U. Penn.)
Fabio Ciulla (Quid Inc.)
Luca Dall'Asta (Politecnico Torino)
Emanuele Caglioti (Sapienza)
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Nicola Perra (Greenwich)
Andrea Puglisi (CNR)
Filippo Radicchi (Indiana)
Bruno Ribeiro (Purdue)
Luc Steels (Pompeu Fabra, SONY)
Alessandro Vespignani (Northeastern)

THANK YOU!

The Emergence of Consensus

Andrea Baronchelli*

City, University of London

The origin of population-scale coordination has puzzled philosophers and scientists for centuries. Recently, game theory, evolutionary approaches and complex systems science have provided quantitative insights on the mechanisms of social consensus. This paper overviews the main dimensions over which the debate has unfolded and discusses some representative results, with a focus on those situations in which consensus emerges 'spontaneously' in absence of centralised institutions. Covered topics include the macroscopic consequences of the different microscopic rules of behavioural contagion, the role of social networks, and the mechanisms that prevent the formation of a consensus or alter it after it has emerged. Special attention is devoted to the recent wave of experiments on the emergence of consensus in social systems.

arXiv:1704.07767v1

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