Opinion formation through language games

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Broad Areas of Interest

- **Modeling color categorization, metastability and aging in language dynamics, empirical analysis of color name distribution** – PNAS, PLoS One, Journal of Computational Science, Elsevier, Journal of Statistical Mechanics: Theory & Expt., Advances in Complex Systems.

- **Media Coverage:** PNAS Press Highlights, BBC Future, Prospect Magazine, UK, Scientific American, Live Science, MedicalXpress, The Hindu, Business Line, Times of News, Yahoo! News, Deccan Herald, MSN, Wikipedia on "Color Terms"

- **Opinion formation modeled as a language game, numerical and analytical techniques to reason for faster/slower agreement in language dynamics, agreement on time-varying social structure** – Physical Review E, Socialcomm

- **Online-social systems and their bipartite representations, message dissemination in delay-tolerant networks** – ACM Mobiopp, IEEE JSAC

- **Structure and dynamics of linguistic networks, unsupervised methods for Indian language NLP** – ACL 2006, ACL 2007, Coling 2008, EACL 2009, ACL 2009, Coling 2010, Physical Review E, Euro. Phys. Lett.

Language dynamics:
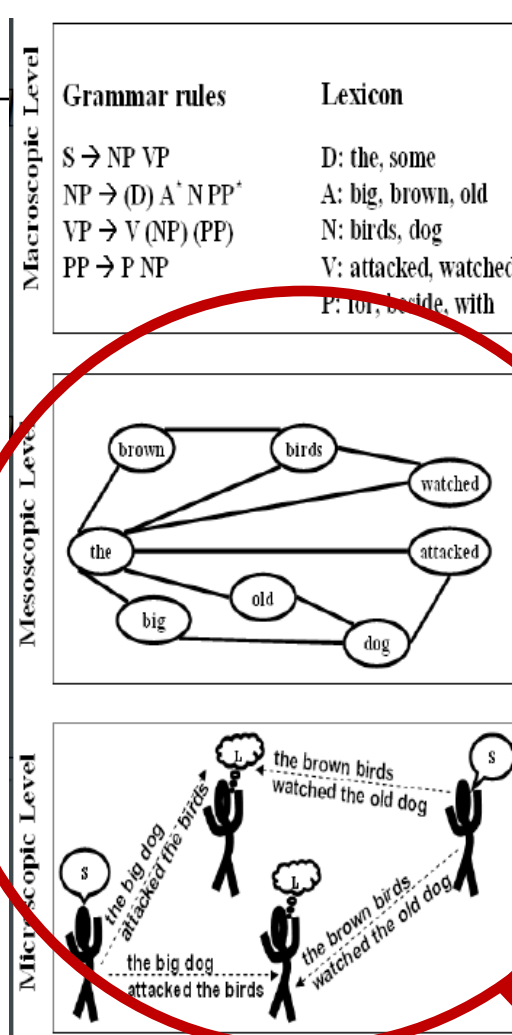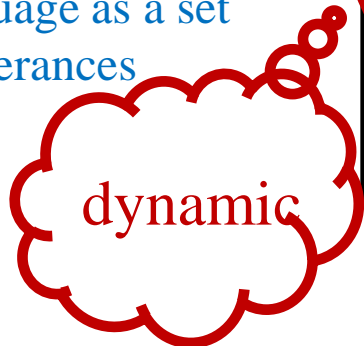# A Physical System Perspective
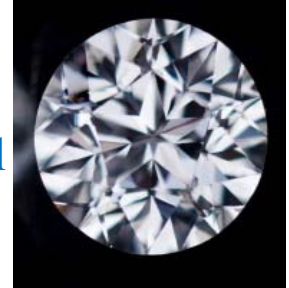
Language as a whole
(grammatical constructs)

Language as a set of
interactions among
linguistic units

Language as a set
of utterances

dynamic

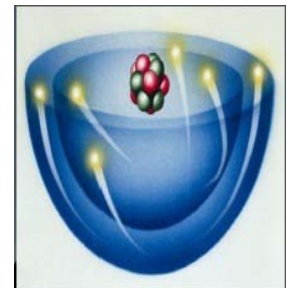Macroscopic level

Mesoscopic level

Microscopic level

Macroscopic Level

Grammar rules	Lexicon
S → NP VP	D: the, some
NP → (D) A* N PP*	A: big, brown, old
VP → V (NP) (PP)	N: birds, dog
PP → P NP	V: attacked, watched
	P: for, beside, with

Mesoscopic Level

brown, birds, watched, the, attacked, old, big, dog

Microscopic Level

the brown birds watched the old dog
the big dog attacked the birds
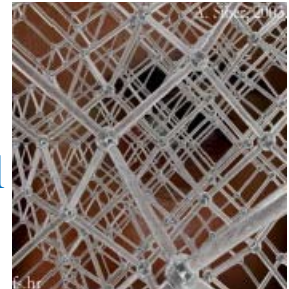
The Naming Game

Speaker **Hearer**

- Perceive scene
- Choose topic
- Conceptualize
- Verbalize

- Interpret utterance
- Perceive scene
- Apply meaning
- Point to referent

In silico abstraction

- ☐ Interaction of **N** artificial agents communicate to agree on the **name** of an object in the environment.
- ☐ Each interaction counts as a time step of the dynamics
- ☐ Agents can keep in their memory an unlimited number of words
- ☐ Games proceed through a series of **success** and **failure** interactions
- ☐ One studies the phenomenological properties – total number of words in the system $N_w(t)$, number of unique words $N_d(t)$, maximum memory N_w^{max}, time to reach agreement t_{conv} etc.

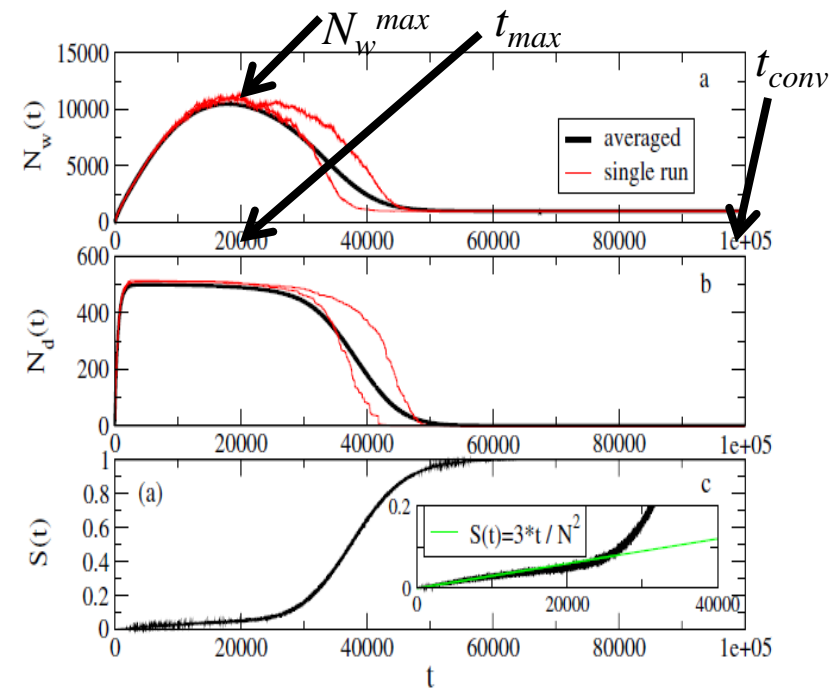| Speaker	Hearer		Speaker	Hearer		Speaker	Hearer		Speaker	Hearer
Bottle **Apple** Tiger Car	Bag Berry Tree	**Failure**	Bottle **Apple** Tiger Car	Bag Berry Tree **Apple**		Bottle **Apple** Tiger Car	Bag Berry Tree **Apple**	**Success**	**Apple**	**Apple**

Phenomenology
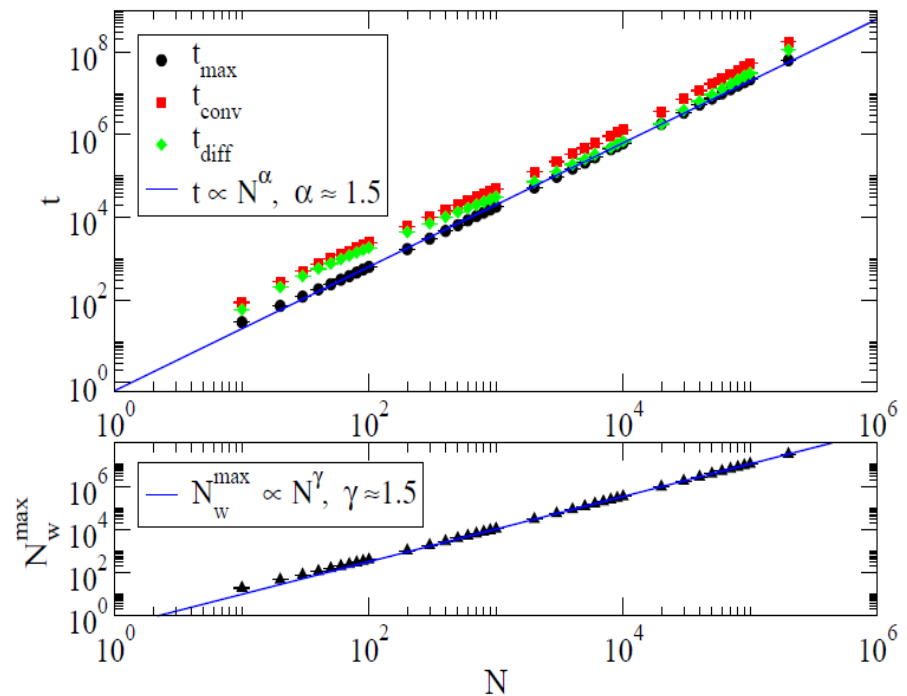
$$\frac{dN_w(t)}{dt} \propto \frac{1}{cN^a}\left(1 - \frac{2cN^a}{N}\right) - \frac{1}{cN^a}\frac{2cN^a}{N}2cN^a$$

$$\frac{dN_w(t)}{dt} \propto \frac{1}{cN^{1/2}}\left(1 - \frac{ct}{N^2}\right) - \frac{1}{cN^{1/2}}\frac{ct}{N^2}2cN^{1/2}$$

Failure   **Success**   **Failure**   **Success**

$$N_w{}^{max} \sim N^{3/2} \quad t_{max} \sim N^{3/2} \quad t_{conv} \sim N^{3/2}$$

Scaling relations for various topologies

	N^w_{max}	t_{max}	t_{conv}
Mean-field	$N^{1.5}$	$N^{1.5}$	$N^{1.5}$
Scale-free	N	N	$N^{1.4}$
Erdos-Renyi	N	N	$N^{1.4}$
Small-world	N	N	$N^{1.4}$

What about time-varying networks?

- Social interactions and human activities are intermittent

- Links appear and disappear from the system

- As time progresses, societal structure keeps changing with social conventions, shared cultural and linguistic patterns reshaping themselves

CNeRG lab (time *t*)

CNeRG lab ($t \rightarrow t+1$)

Workshop on Social Computing, 2012
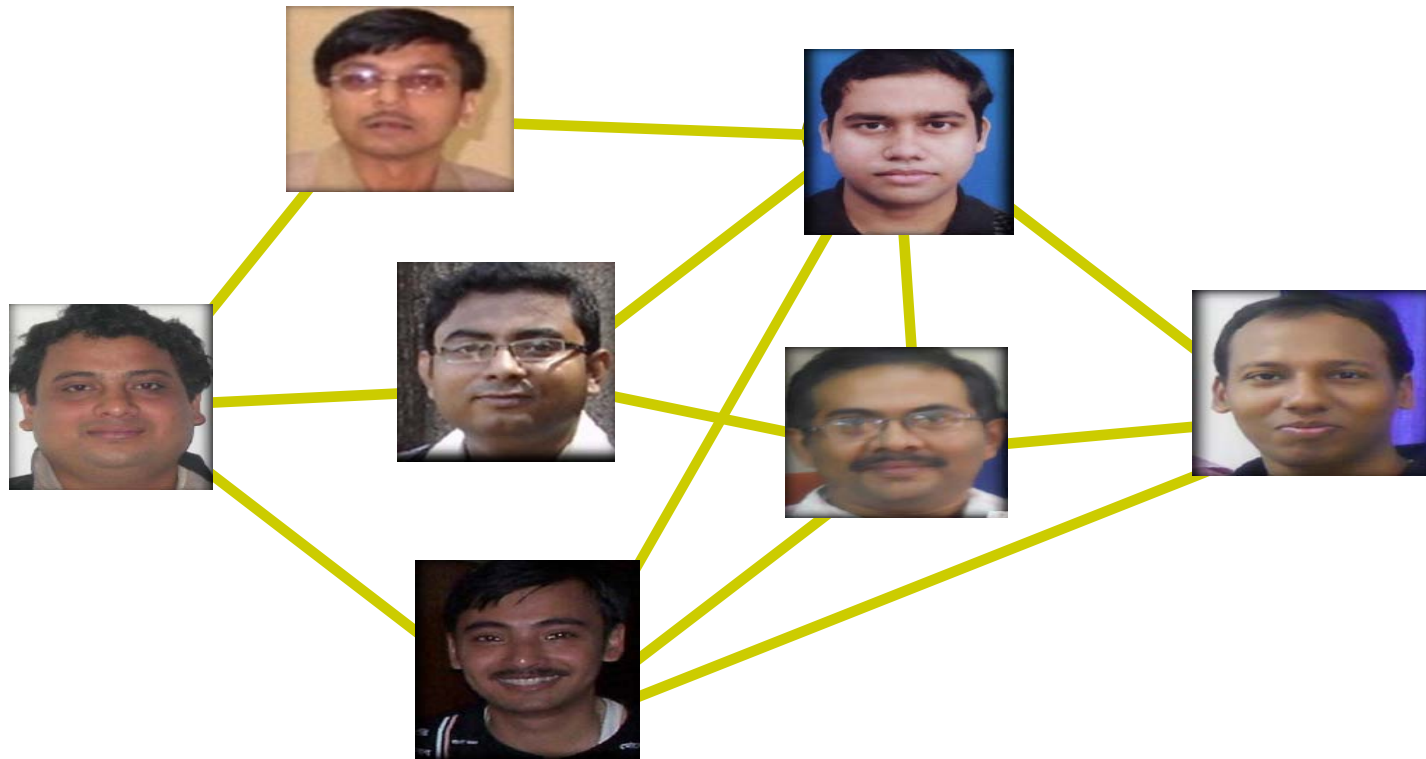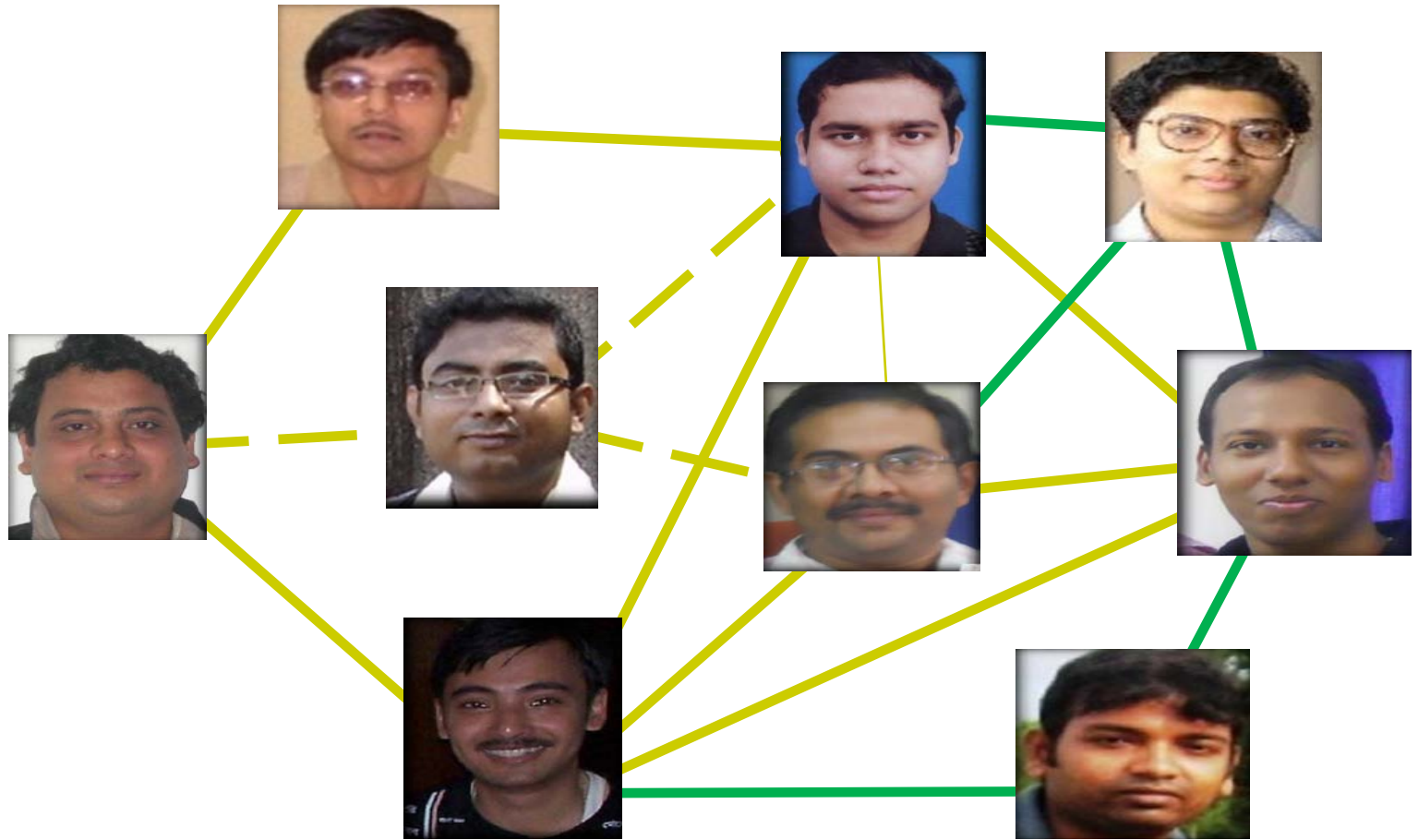
CNeRG lab (time $t + 1$)
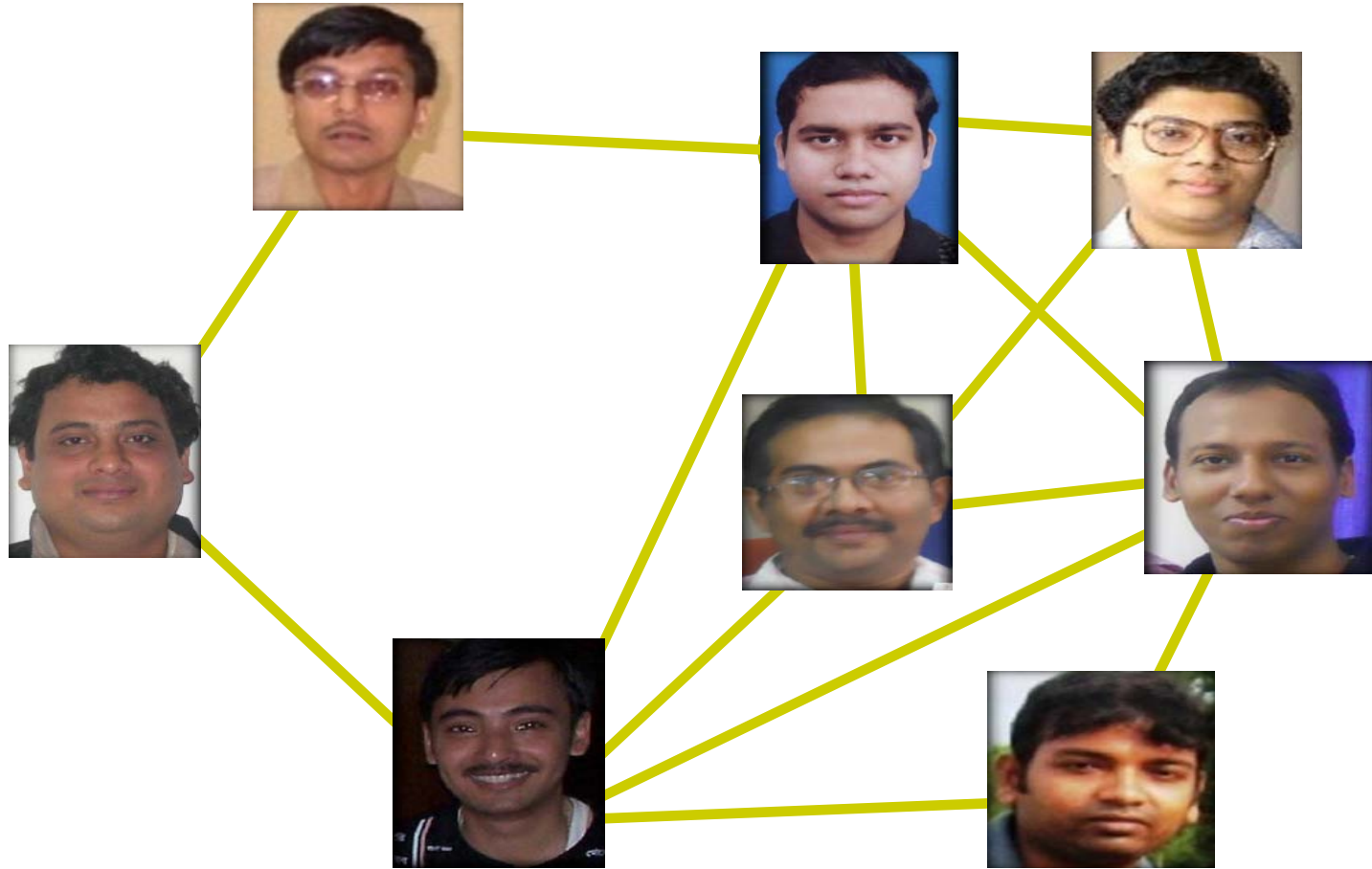
Datasets

- Face-to-face interaction (SG)
  - Science Gallery in Dublin, Ireland (2009)
  - "INFECTIOUS:STAY AWAY" initiative for 69 days
- Face-to-face interaction (HT)
  - conference attendees of the ACM Hypertext 2009
- Nodes   -> visitors/participants
- Edges   -> close-range face-to-face proximity existent for 20 seconds

http://www.sociopatterns.org/datasets/

Scaling of N_w^{max} and t_{max}
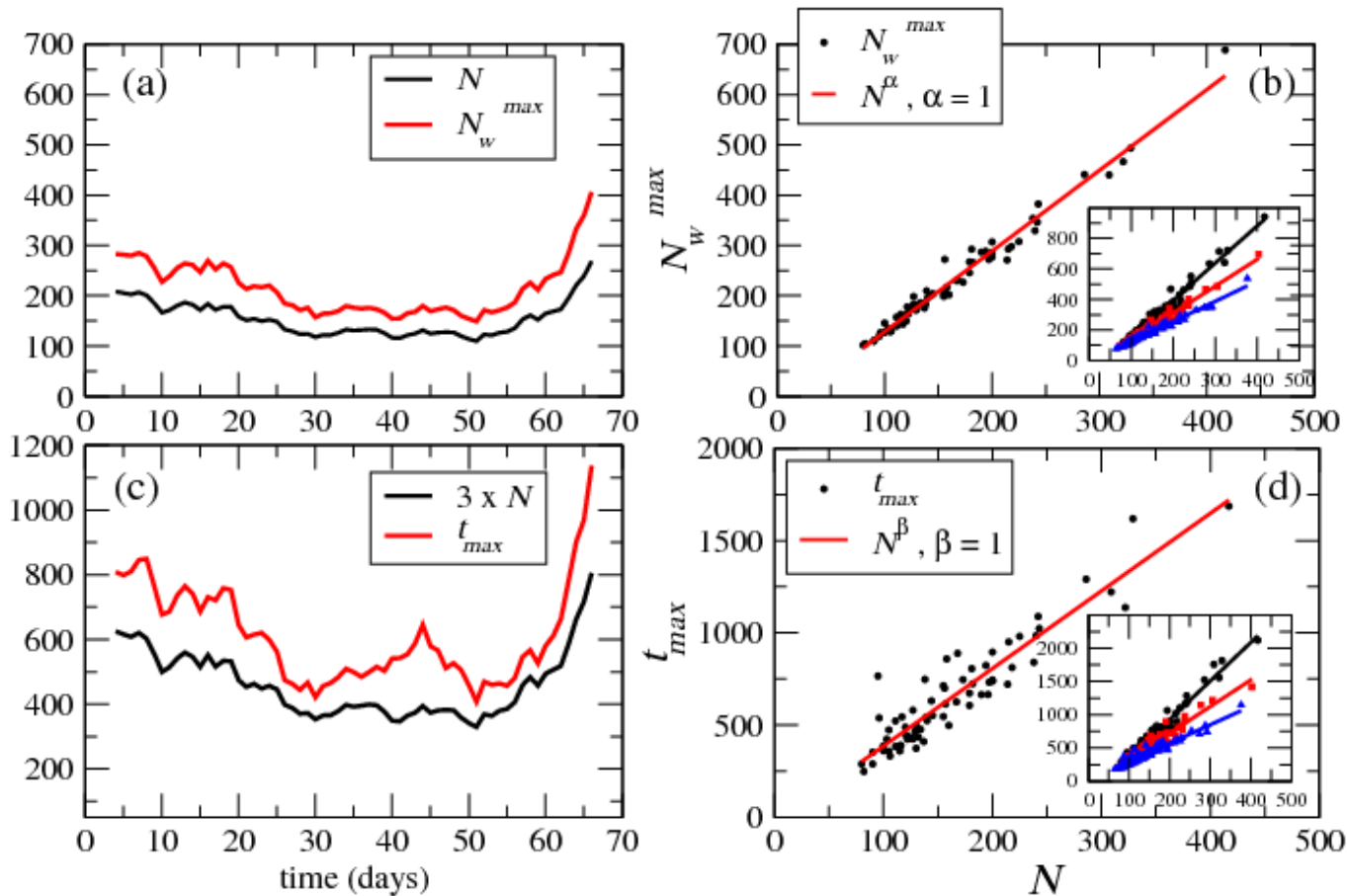
Scaling Relations

□ $N_w^{max} \sim O(N)$ [✓]

□ $t_{max} \sim O(N)$ [✓]

□ But what about t_{conv} ? $O(N^{1.4})$
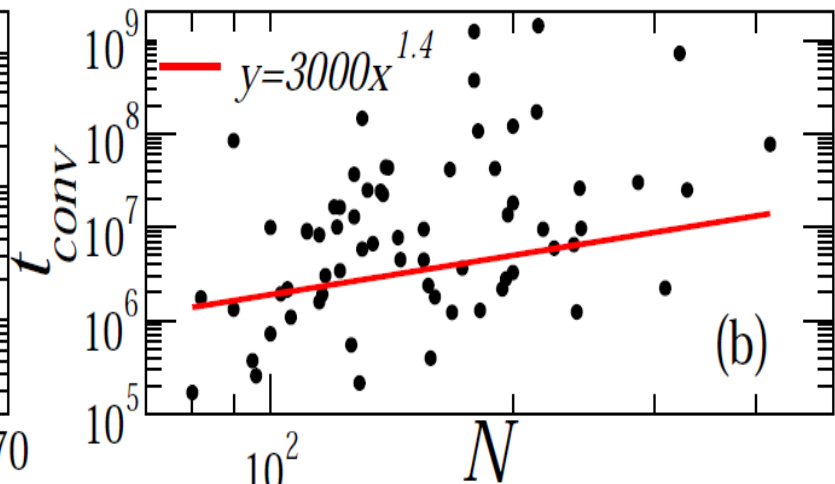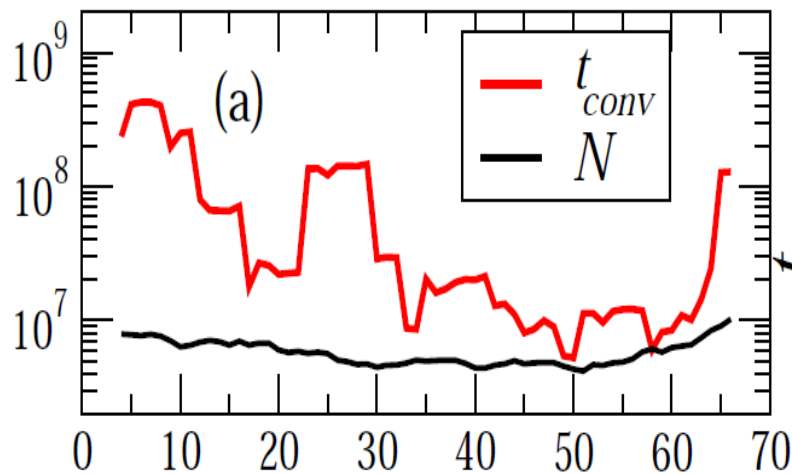
Opinions trapped in communities

Time resolved SG data

- Day 9 (representative)

Composite Network

The new connections at each time step causes late-stage failures
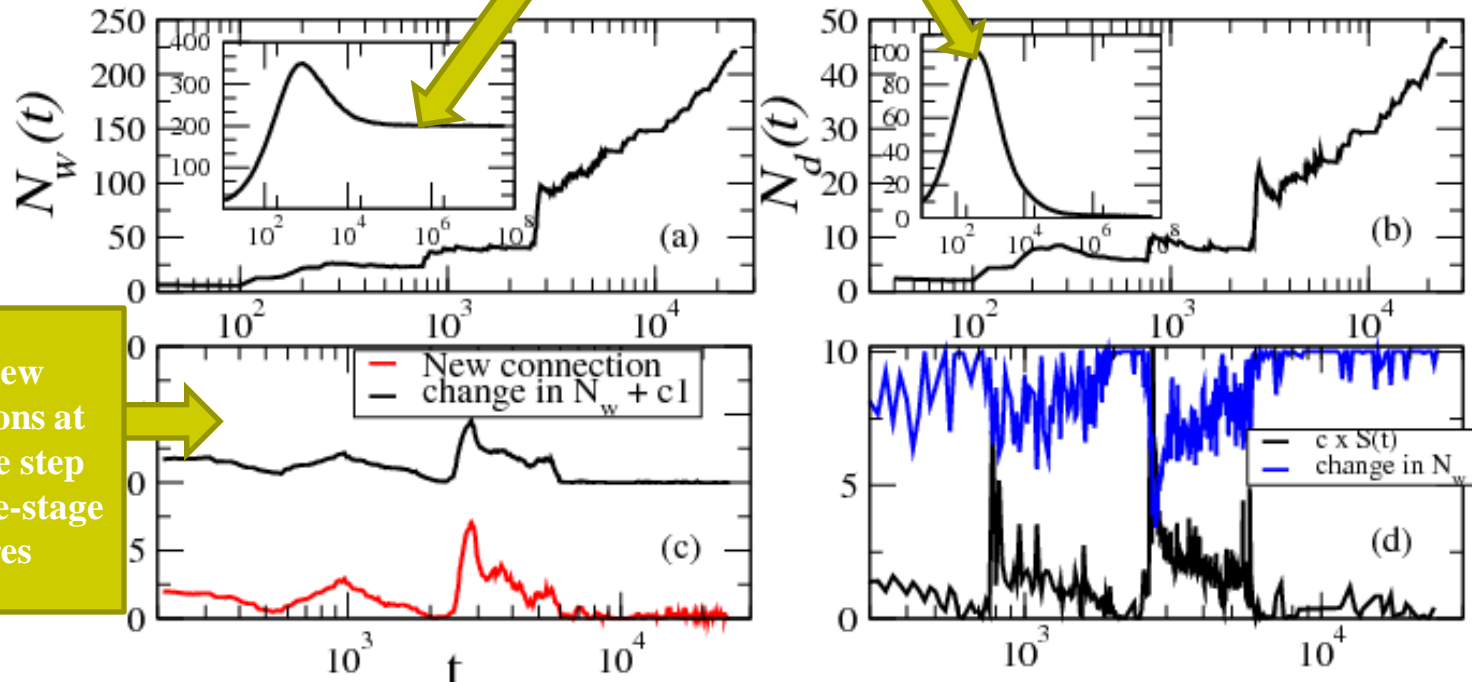
HT Dataset

Composite Network
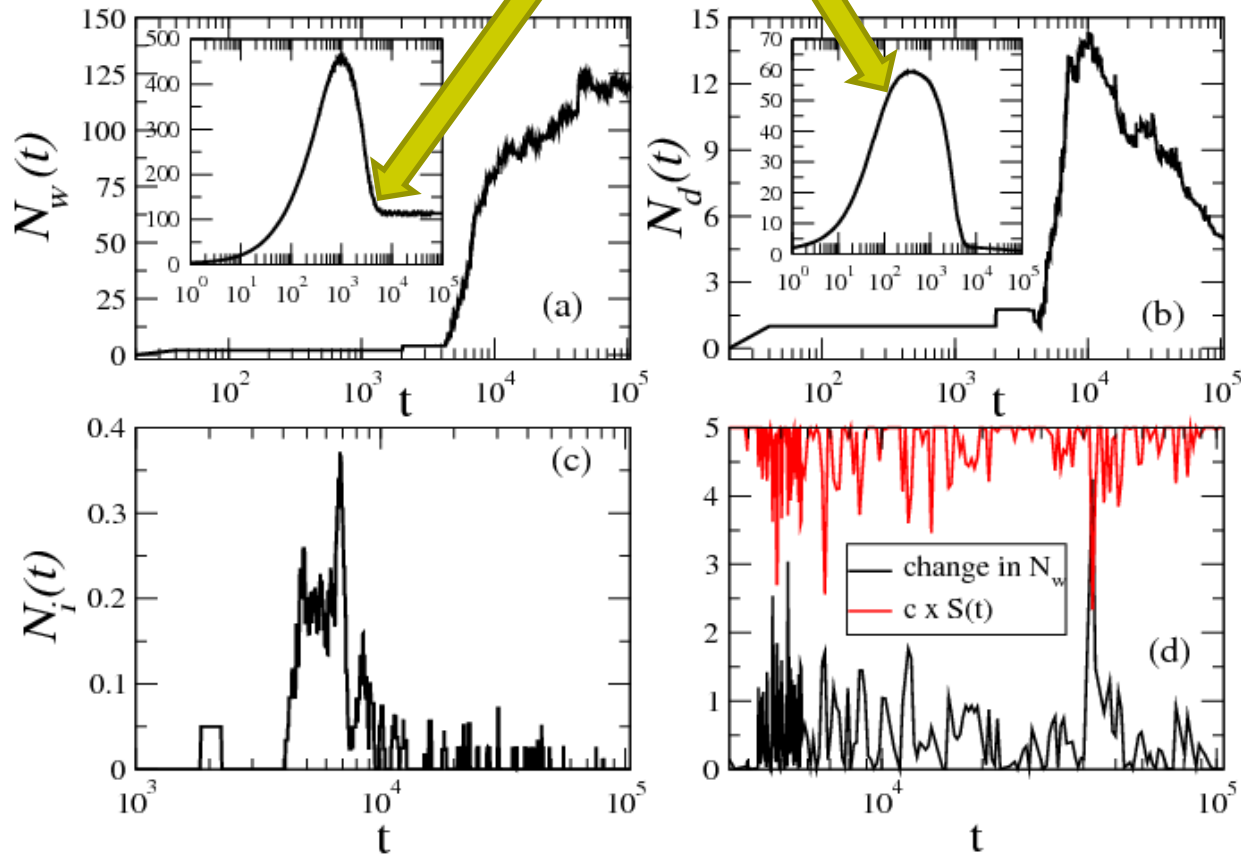
Maity, Venkat and Mukherjee, Opinion formation in time-varying social networks: the case of the naming game, *Physical Review E*, September 14, 2012, **86**, 036110.

From Naming to Color Naming

- Color categorization: a central issue both in linguistics and in cognitive science
- Evolution of English color categories [English color terms → gradual semantic shift from largely brightness color concepts (Old English) to almost exclusively hue concepts (Middle English)]

Speaker (S)

Hearer (H)

← *Just noticeable difference*

Scene

Topic
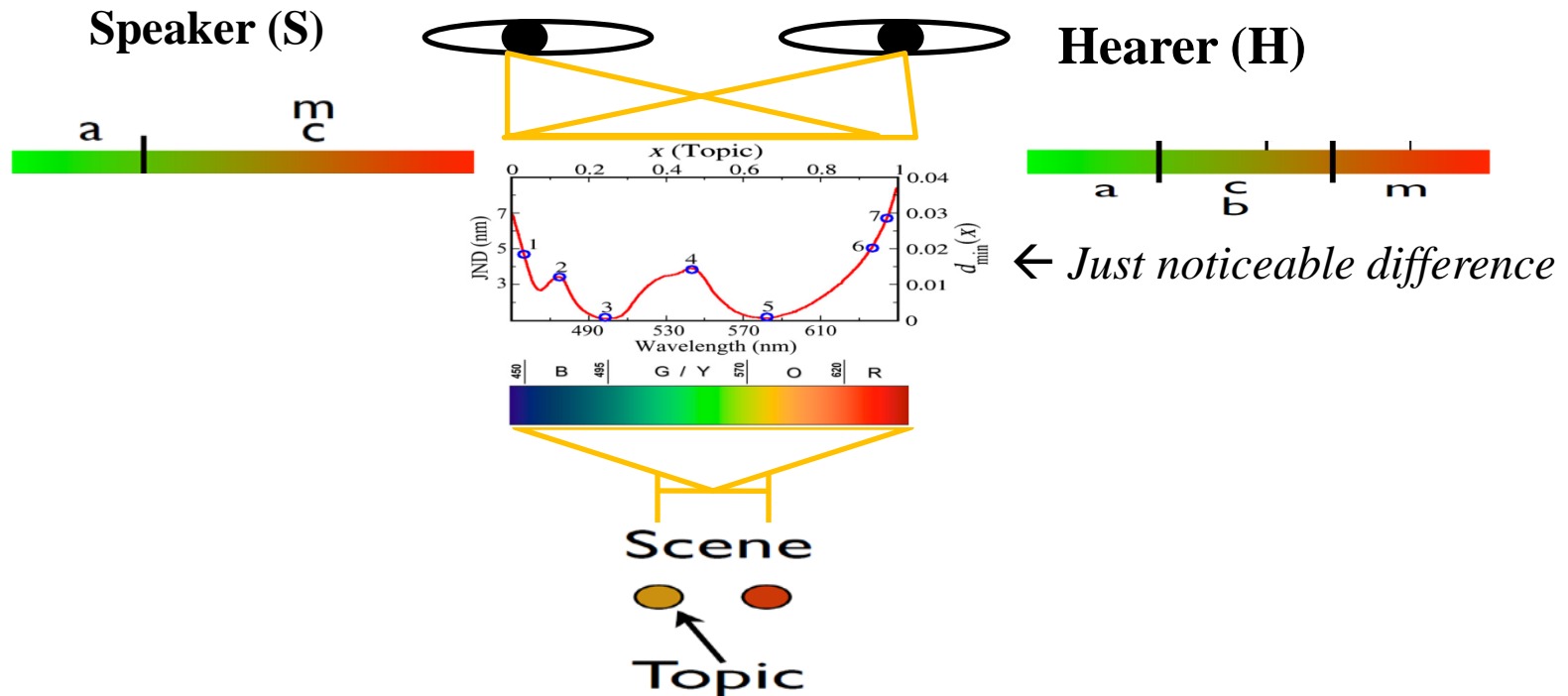
The Category Game
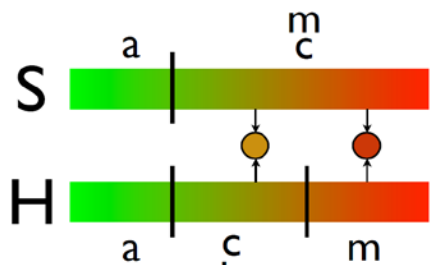
Locate the Stimuli two stimuli colliding on the same perceptual category → a new boundary is created
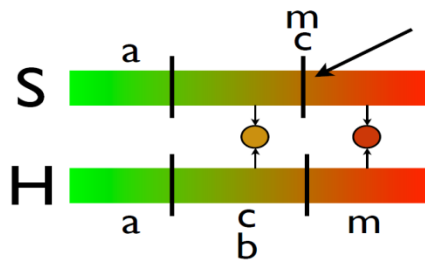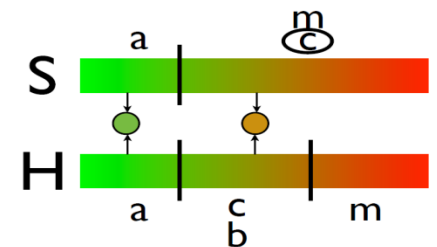
Discrimination
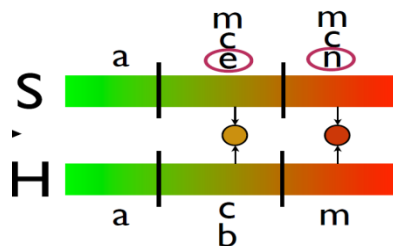
Invention of new words

Failure
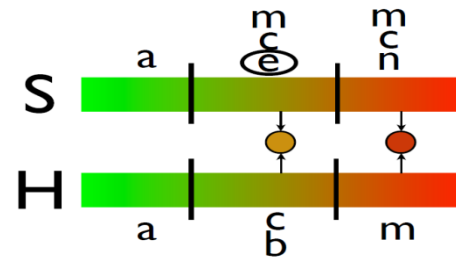
Utterance
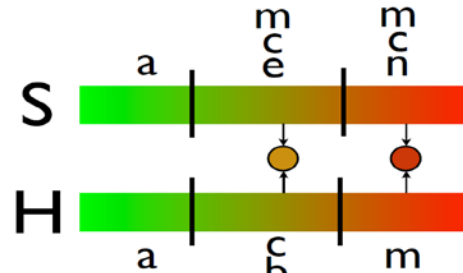
Outcome: Failure

Success

Utterance

Outcome: Success

Workshop on Social Computing, 2012

The Color Hierarchy

Loreto, Mukherjee and Tria, On the origin of the hierarchy of color names, *PNAS* , May 1, 2012 vol. **109** no. 18 6819-6824

Thank You