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:
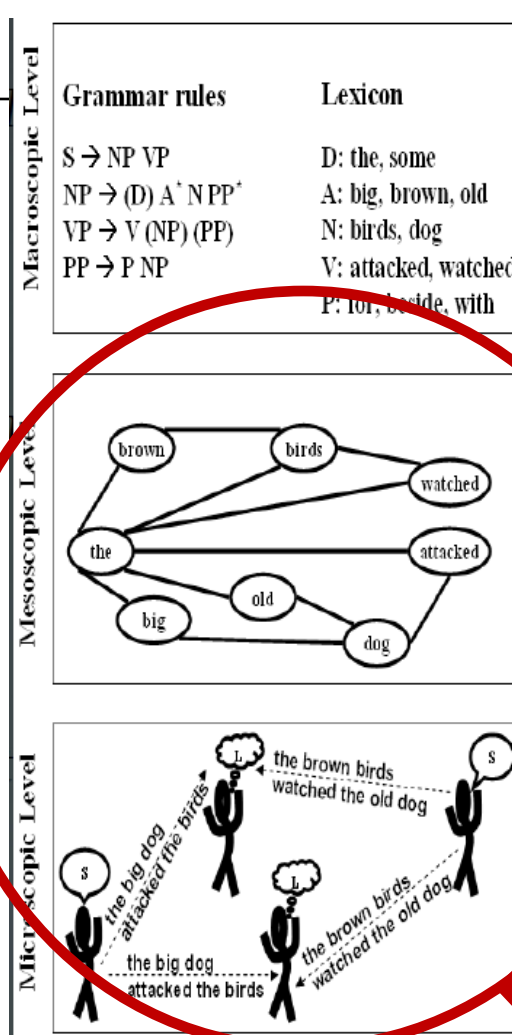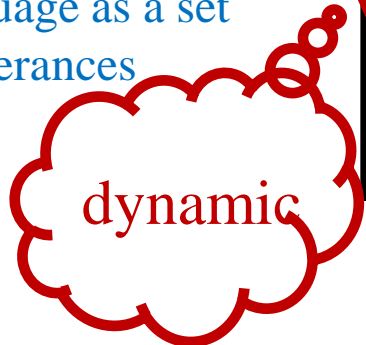# A Physical System Perspective

Language as a whole (grammatical constructs)

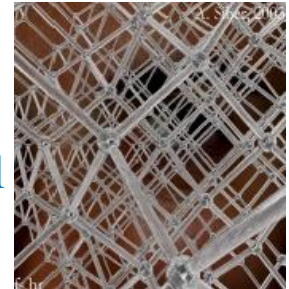Language as a set of interactions among linguistic units

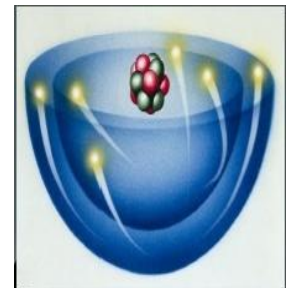Language as a set of utterances

dynamic

Macroscopic level

Mesoscopic level

Microscopic level

Words and their meanings

□ Teacher to student: please bring your presentation tomorrow surely …

Words and their meanings

- Teacher to student: please bring your presentation tomorrow surely

- Student (on that fine "tomorrow"):

The Naming Game

Speaker **Hearer**

In silico abstraction

- Perceive scene
- Choose topic
- Conceptualize
- Verbalize

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

☐ 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.

Failure

Speaker	Hearer
Bottle Apple Tiger Car	Bag Berry Tree

Speaker	Hearer
Bottle Apple Tiger Car	Bag Berry Tree Apple

Success

Speaker	Hearer
Bottle Apple Tiger Car	Bag Berry Tree Apple

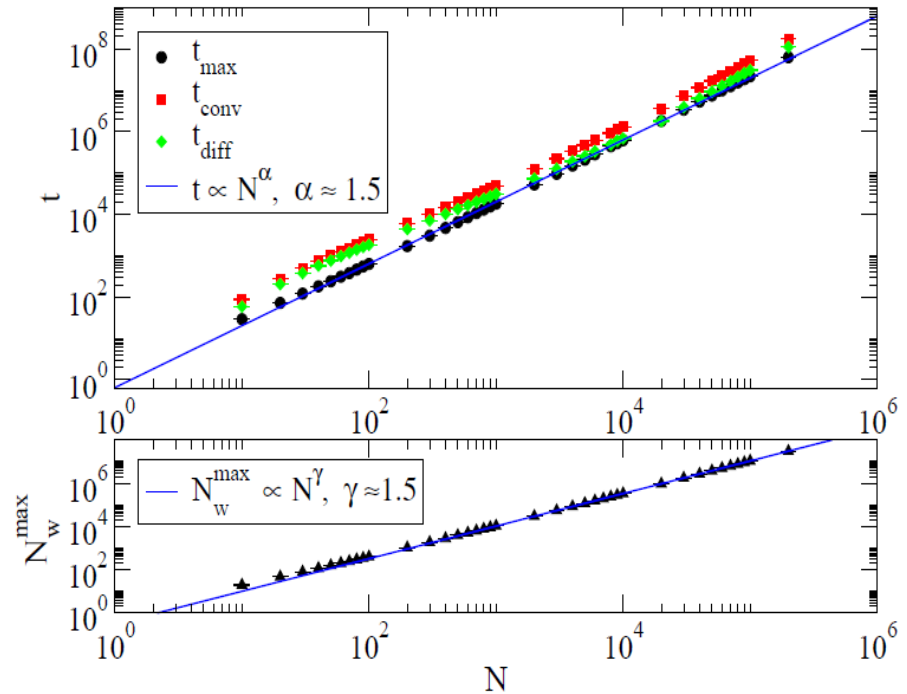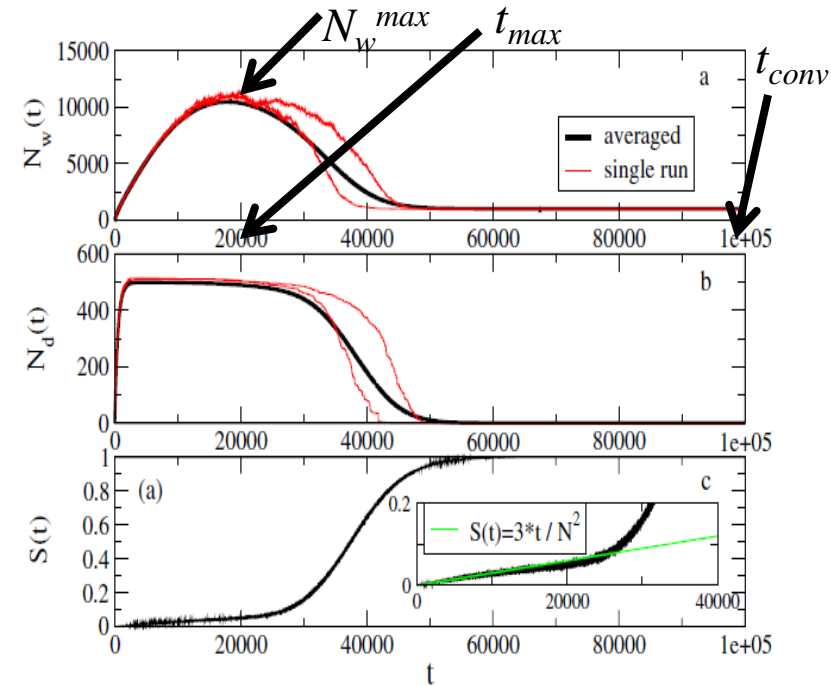| Speaker	Hearer
Apple	Apple

Phenomenology

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

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

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

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*)
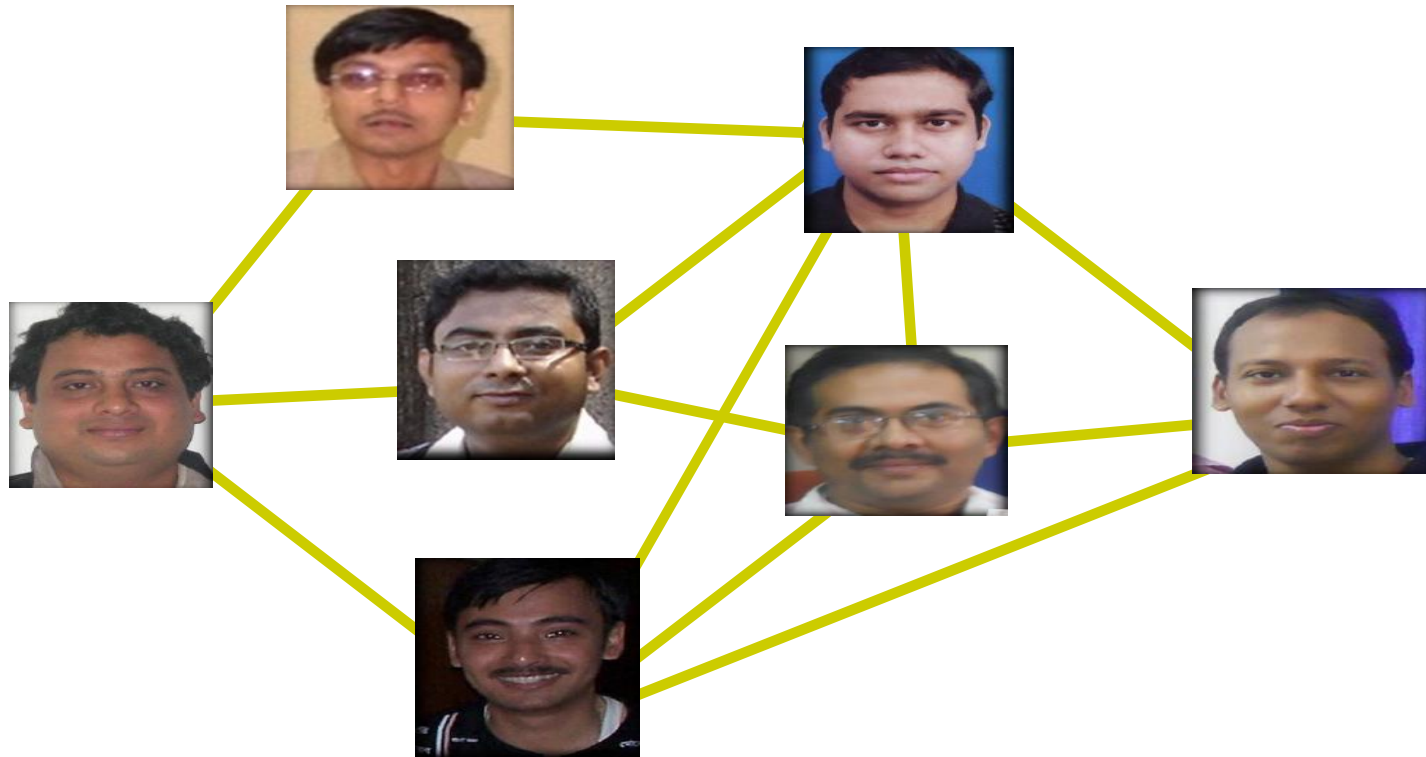
CNeRG lab ($t \rightarrow t+1$)
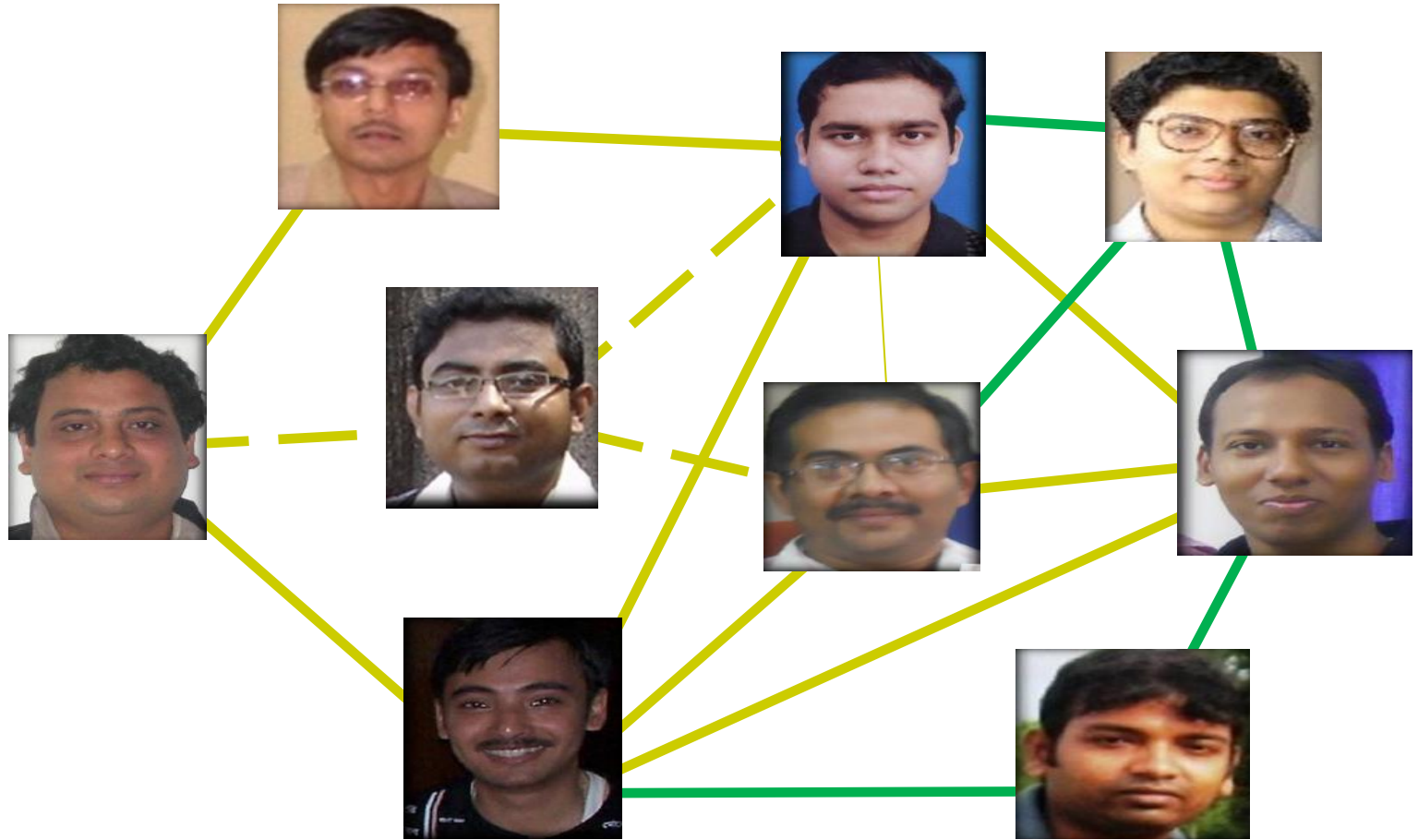
CNeRG lab (time $t + 1$)
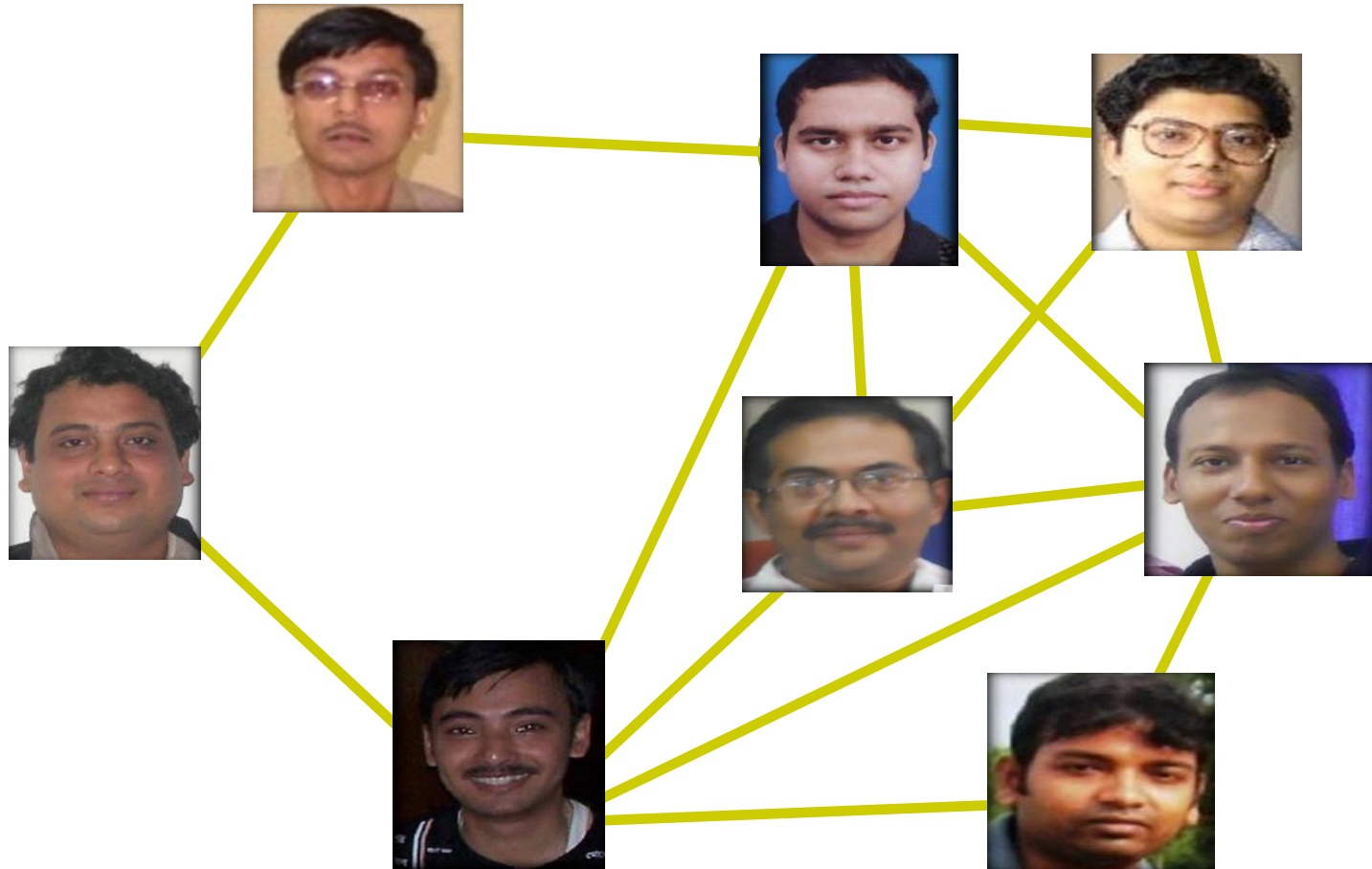
Datasets

- 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}
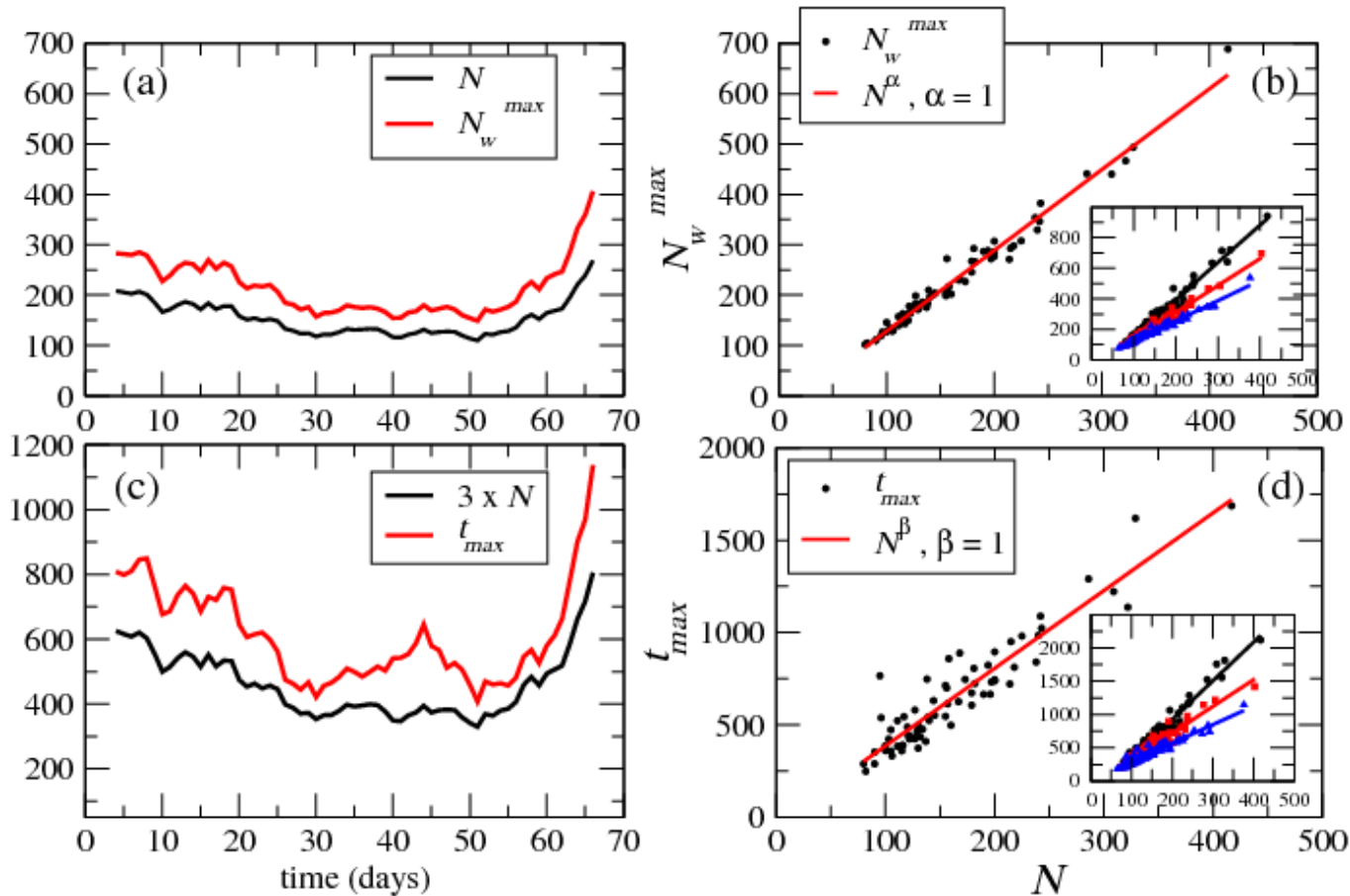
Scaling Relations

- $N_w{}^{max} \sim O(N)$ [✓]
- $t_{max} \sim O(N)$ [✓]
- But what about t_{conv} ? $O(N^{1.4})$ ~~X~~

Workshop on Social Computing, 2012
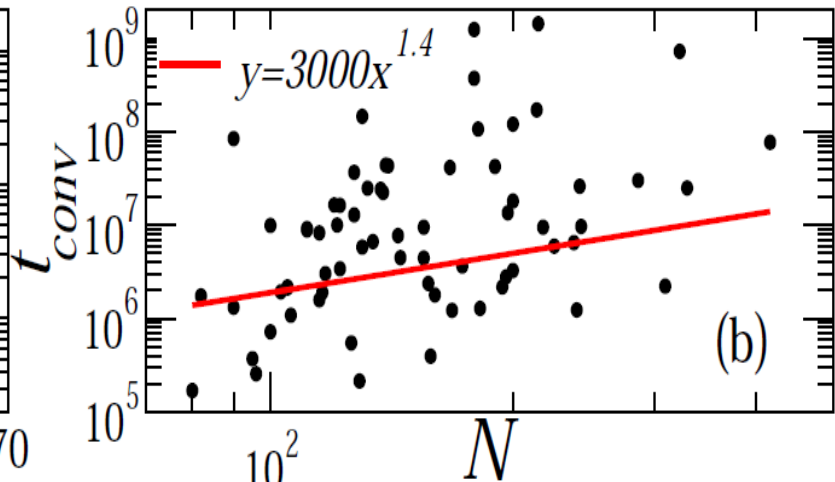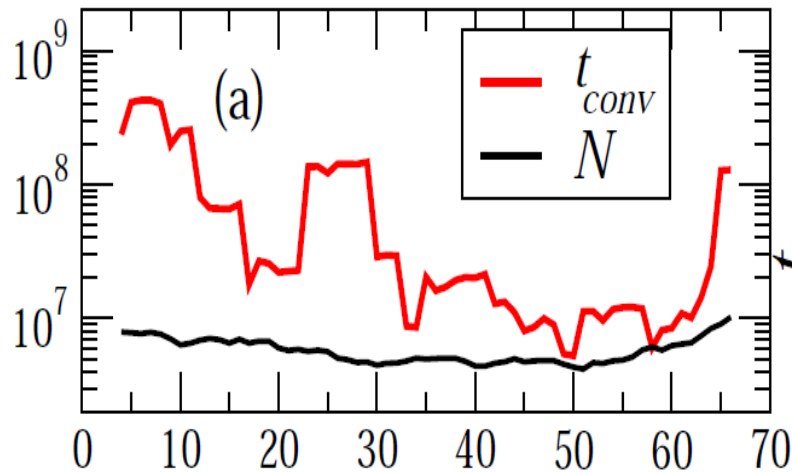
Opinions trapped in communities
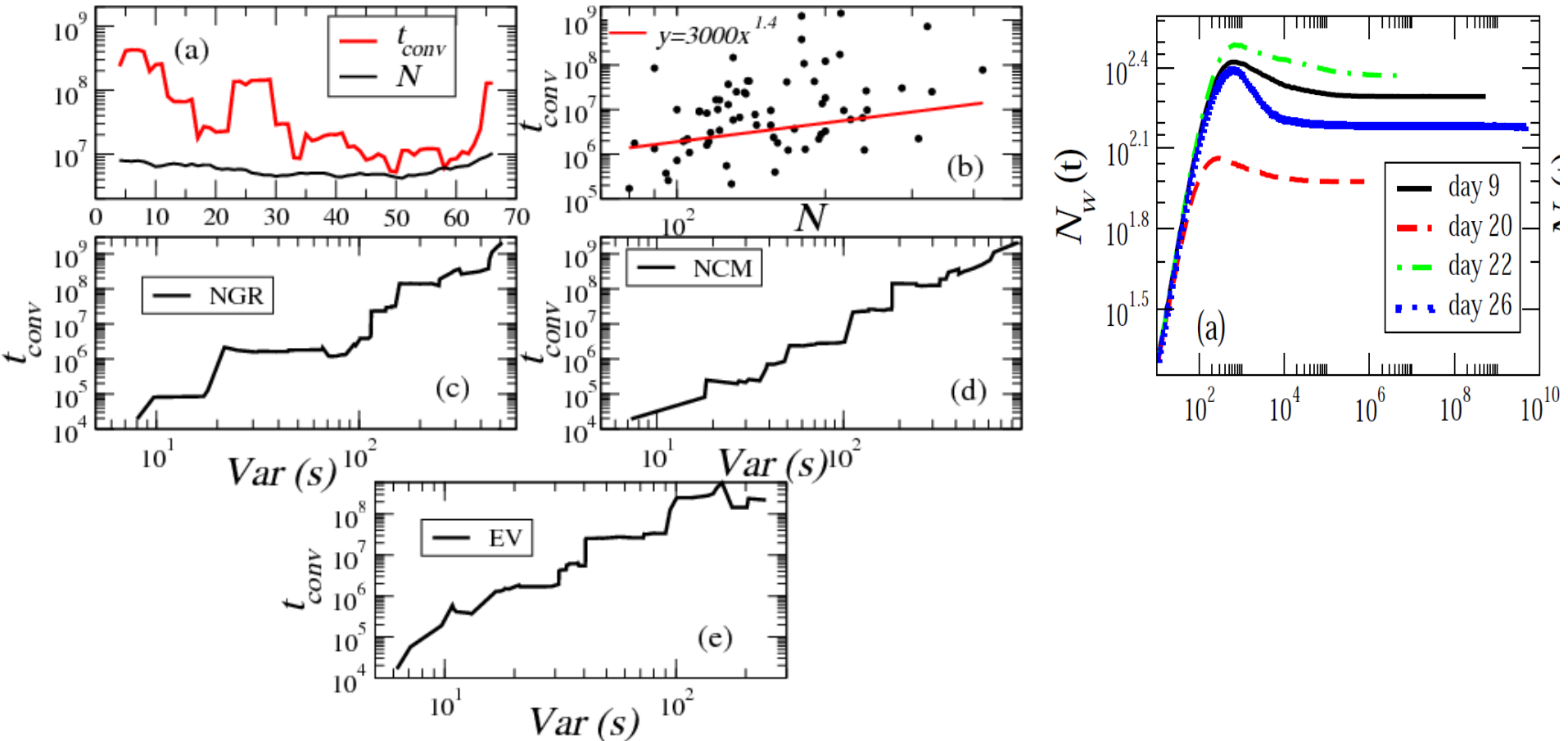
Maity, Venkat and Mukherjee, Opinion formation in time-varying social networks: the case of the naming game, *Physical Review E*, September 14, 2012, **86**, 036110.

Time resolved SG data

- Day 9 (representative)

Composite Network
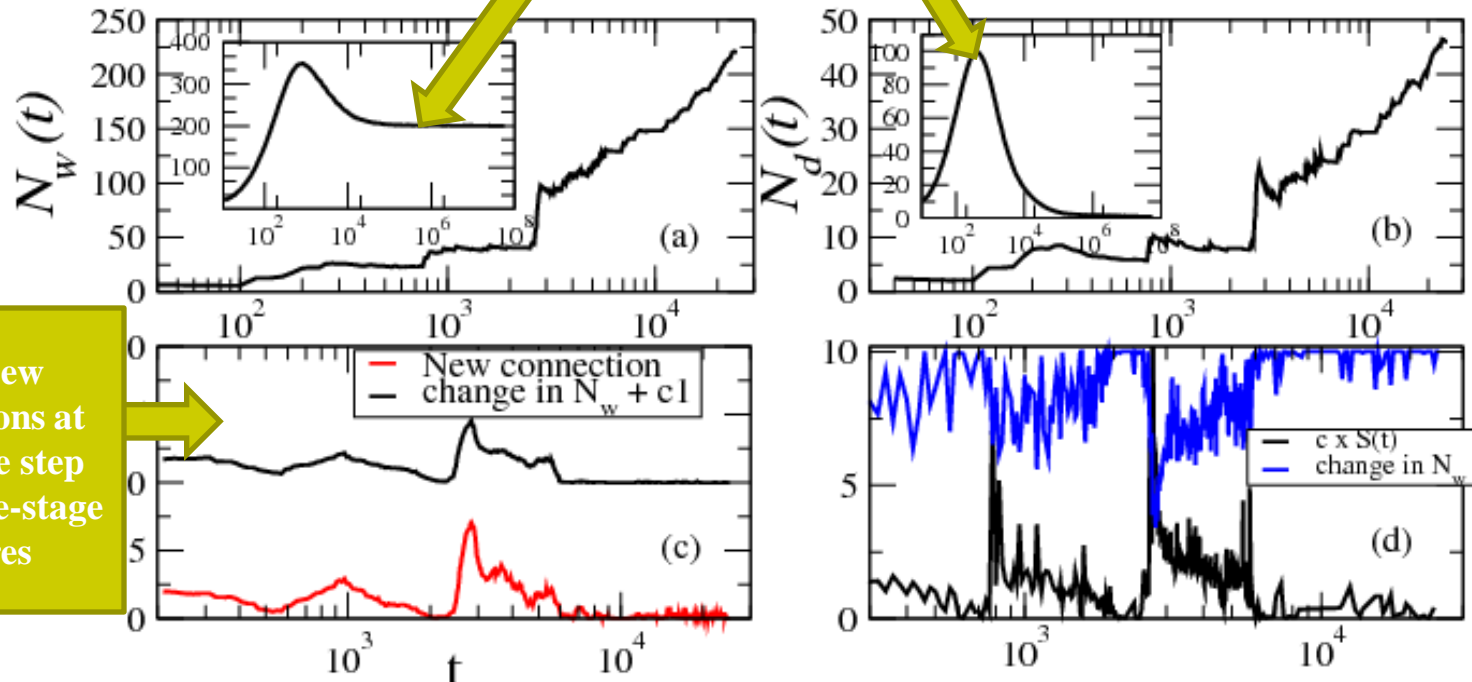
The new connections at each time step causes late-stage failures

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.

HT Dataset

Composite Network
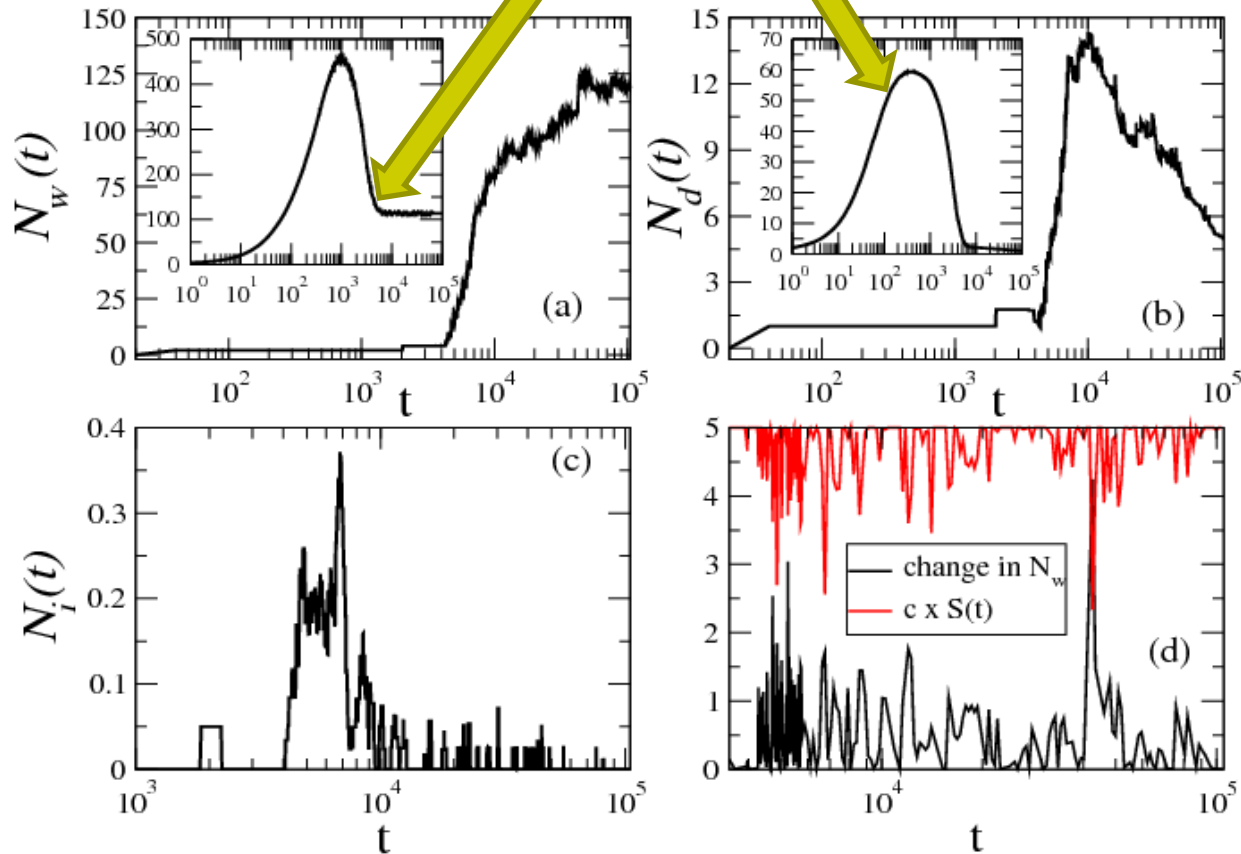
From Naming to Color Naming

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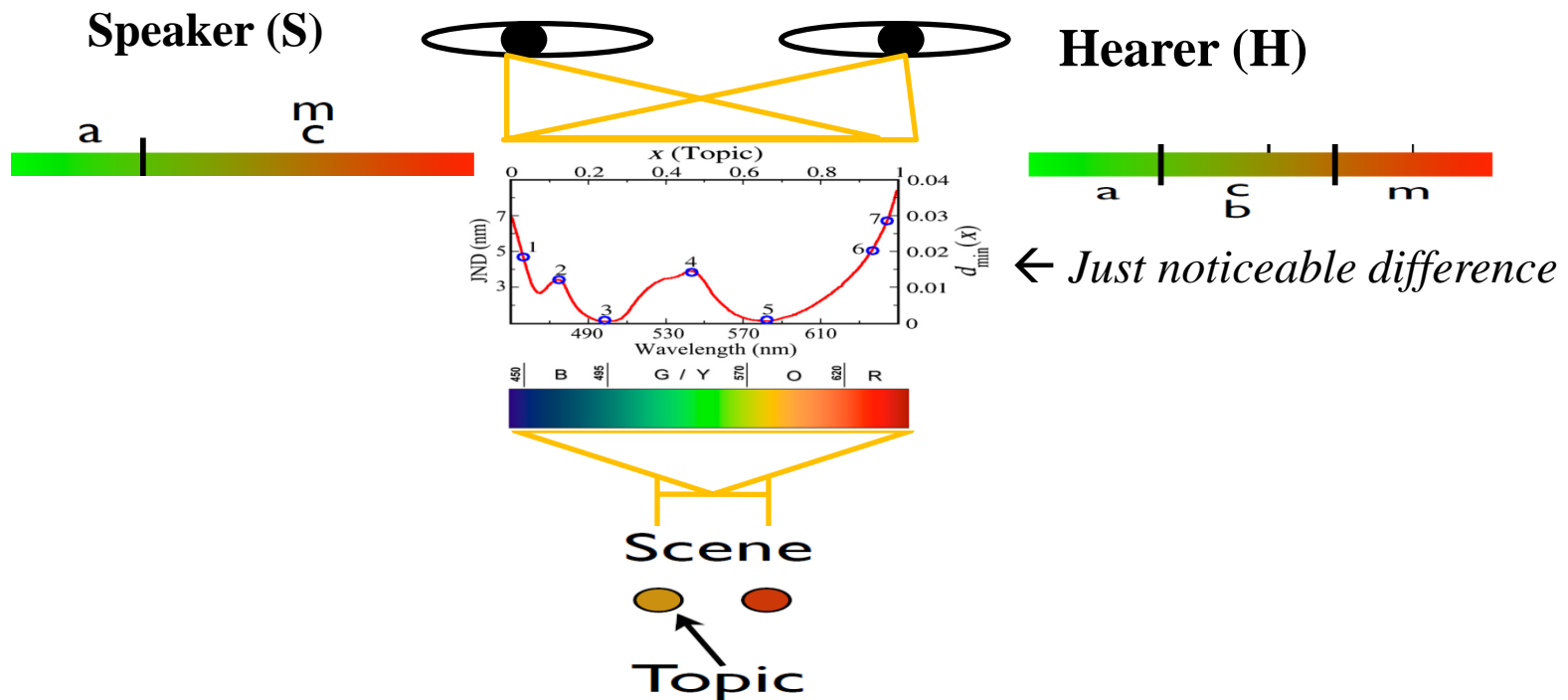
The Category Game
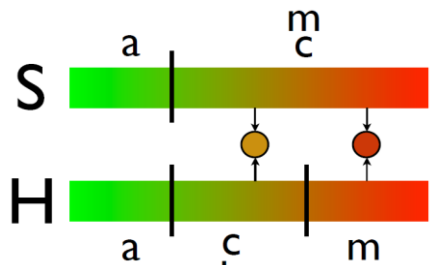
Locate the Stimuli two stimuli colliding on the same perceptual category → a new boundary is created
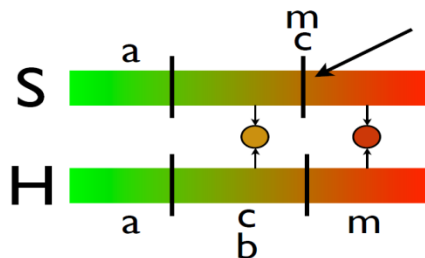
Discrimination
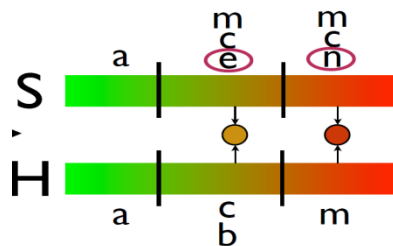
Invention of new words

Failure
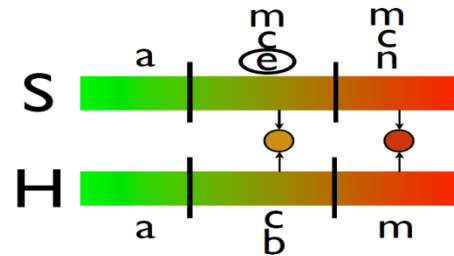
Utterance
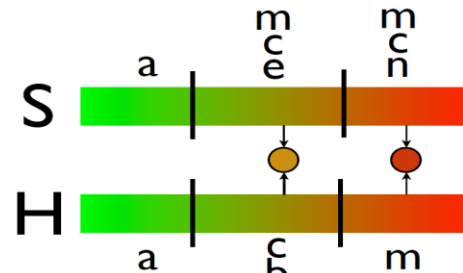
Outcome: Failure

Success
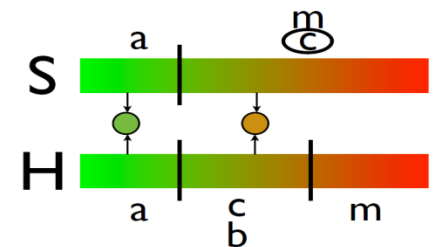
Utterance

Outcome: Success

Workshop on Social Computing, 2012

The Color Hierarchy

Thank You