Naming to Color Naming

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Language Dynamics

- Language is complex adaptive system
- Evolves through the process of self-organization
- Question: How can one explain the interplay of structure and dynamics of such a system?
  => Statistical Physics tools

A Physical System Perspective

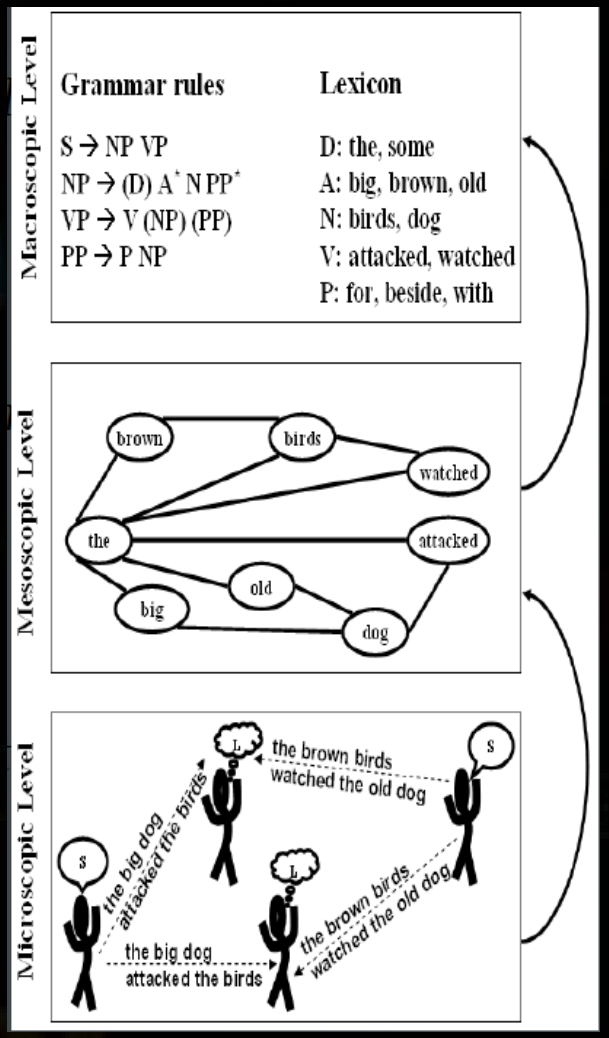
Language as a whole (grammatical constructs)

↓

Language as a collection of interactions among linguistic units

↓

Language as a collection of utterances



Macroscopic level

↓

Mesoscopic level

↓

Microscopic level

A Physical System Perspective

Language as a whole (grammatical constructs)

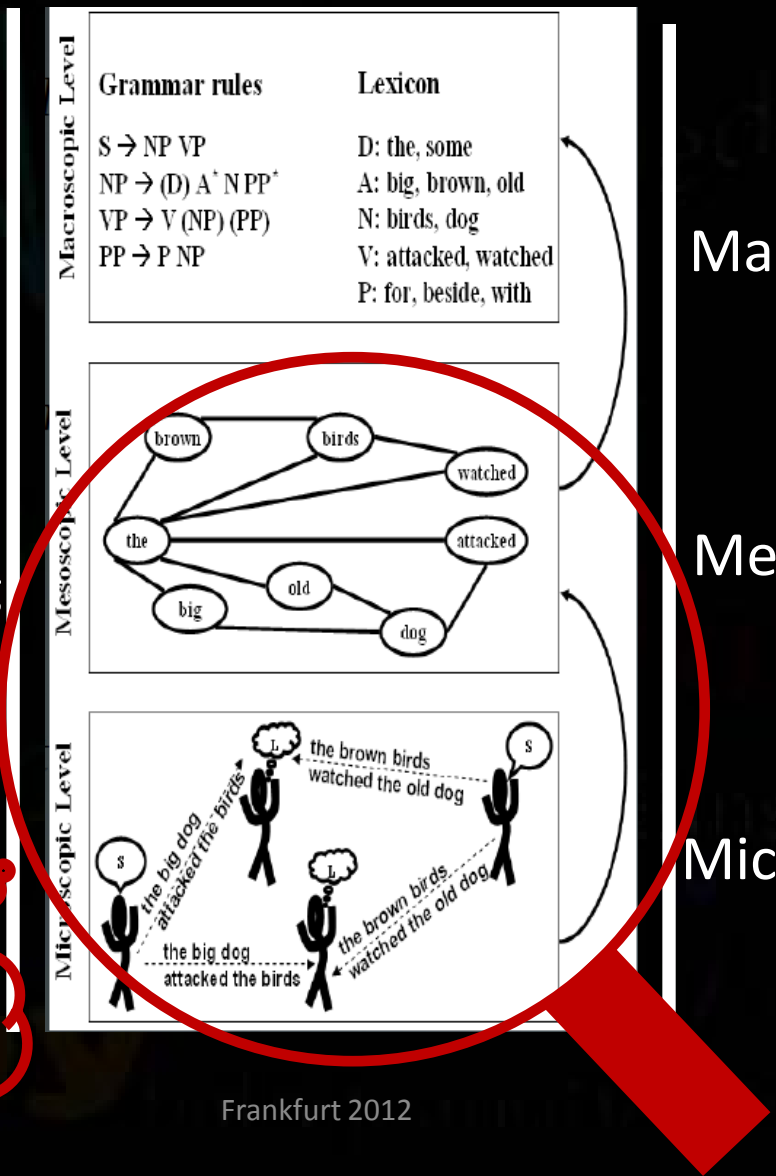
↓

Language as a collection of interactions among linguistic units

↓

Language as a collection of utterances

dynamic



Macroscopic level

↓

Mesoscopic level

↓

Microscopic level

Names for meanings

SPAM !

Names for meanings

SPAM !

Spiced HAM

Monty Python's spam comedy (1970 TV show)

Mr. and Mrs. Bun enter a cheap pub

Mr. Bun: What have you got, then?

Waitress: egg & SPAM; egg, bacon, &SPAM; egg, bacon, sausage & SPAM; SPAM, bacon, sausage, & SPAM; SPAM, egg, SPAM, SPAM, bacon, & SPAM; SPAM, SPAM, egg, and SPAM; baked beans, SPAM & SPAM….

Mrs. Bun : Have you got anything without SPAM in it?

Waitress: Well, there's SPAM, egg, sausage, and SPAM. That's not got MUCH SPAM in it.

Mrs. Bun: I don't want any SPAM!

Mr. Bun: Why can't she have egg, bacon, SPAM, and sausage?

Mrs. Bun: That's got SPAM in it!

Mr. Bun: Not as much as SPAM, egg, sausage, and SPAM.

Mrs. Bun: Look, could I have egg, bacon, SPAM, and sausage without the SPAM?

Waitress: Uuuuuuuuuggggggh!

Mrs. Bun: What d'you mean uuugggh!? I don't like SPAM.

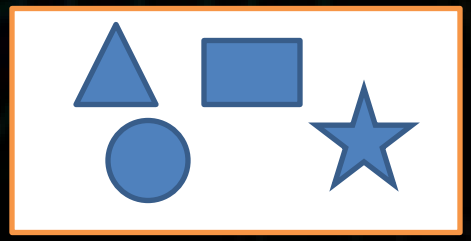
Vikings: (singing) SPAM, SPAM, SPAM, SPAM ….. Lovely SPAM,wonderful SPAM....

((e-)spam to spam)?

The Naming Game

The “Talking Heads” Experiment

Speaker



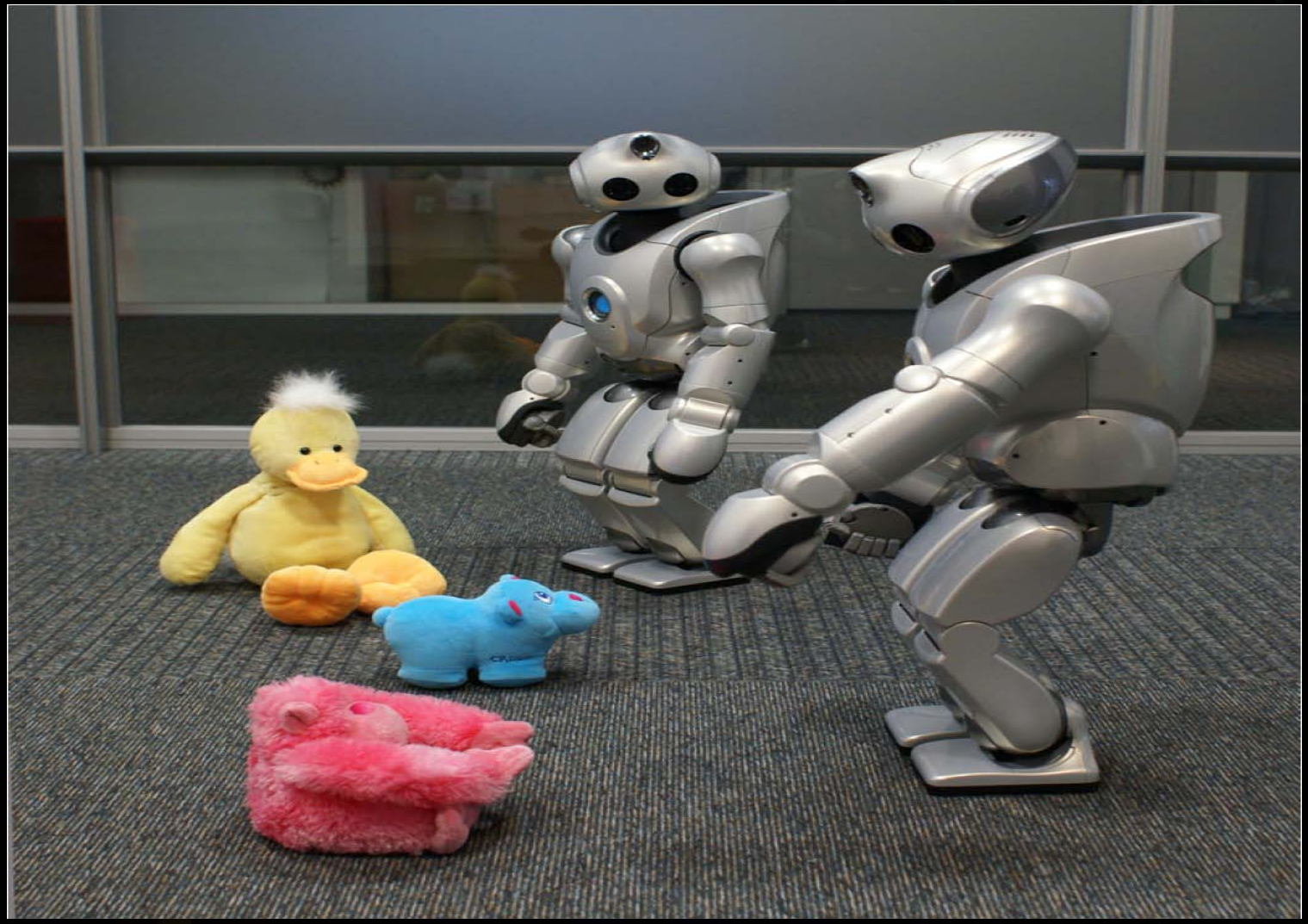
Hearer

- Perceive scene
- Choose topic
- Conceptualize
- Verbalize

interpret utterance
perceive scene
apply meaning
point to referent

Luc Steels, Autonomous Agents and Multi-agent Systems (1998)

The Grounded Naming Game



Bleys et al., Roman-09 (2009)

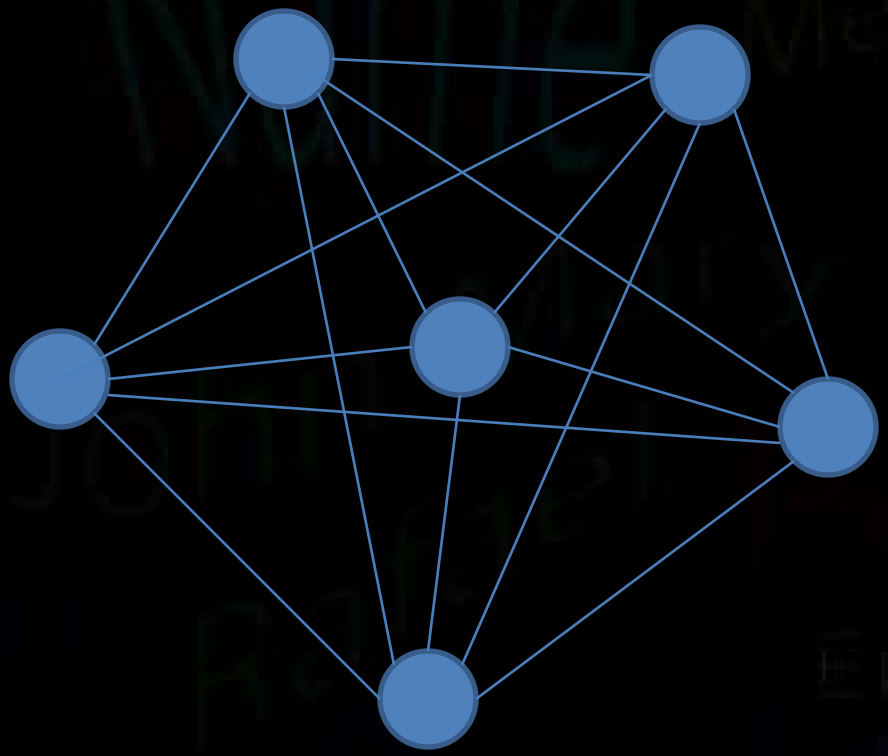
Minimal Naming Game

- In silico settings
- Interactions of *N* agents who communicate on how to associate a name to a given object

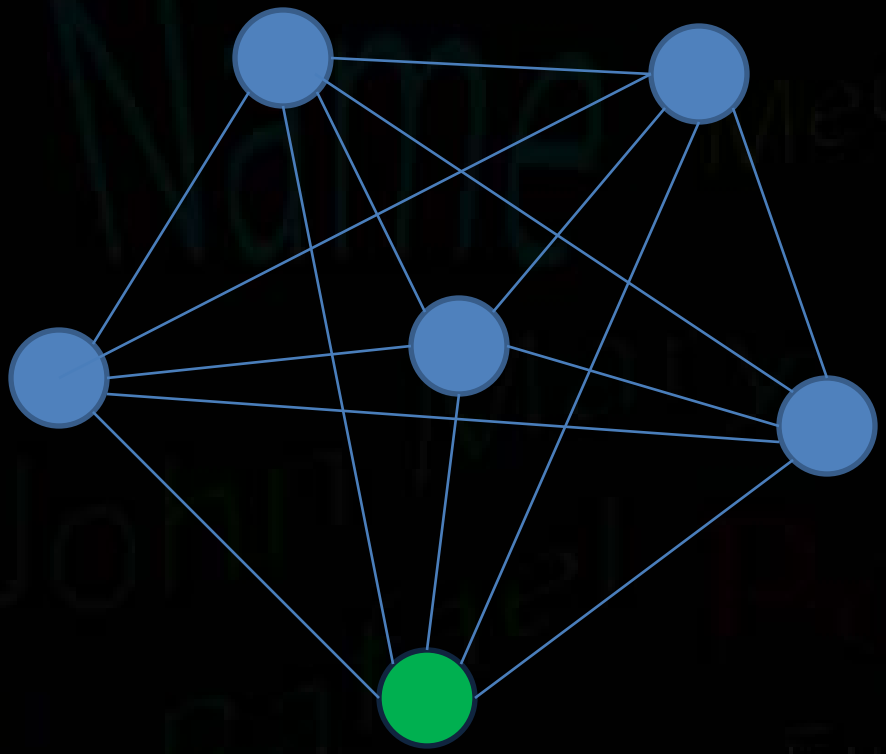
- Agents:
- can keep in memory different words
- can communicate with each other

Baronchelli et al., J. Stat. Mech. (2006)

Mean field: fully-connected network



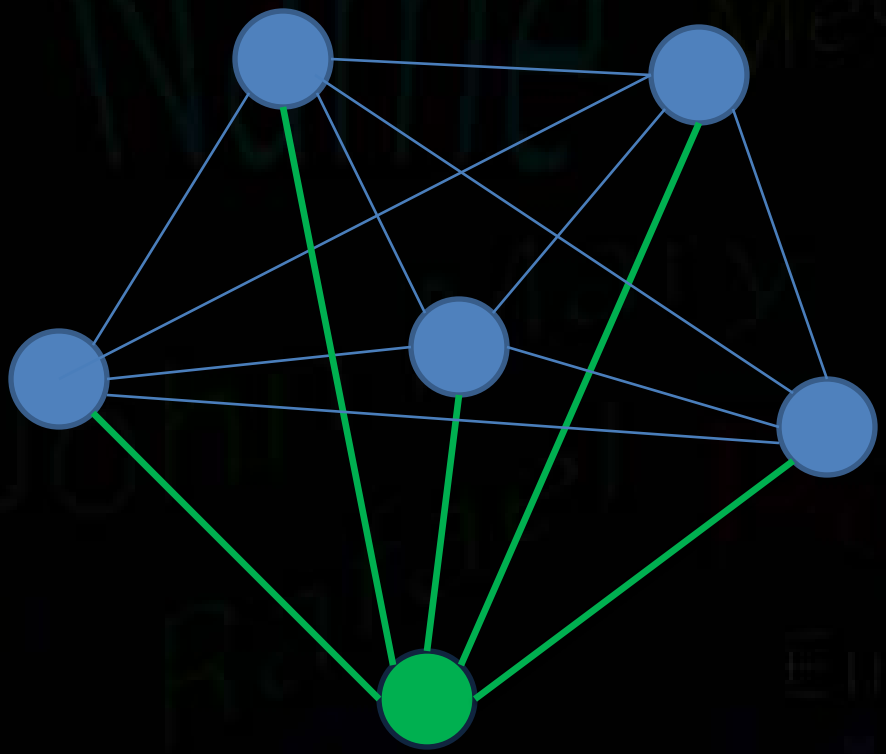
Mean field: fully-connected network



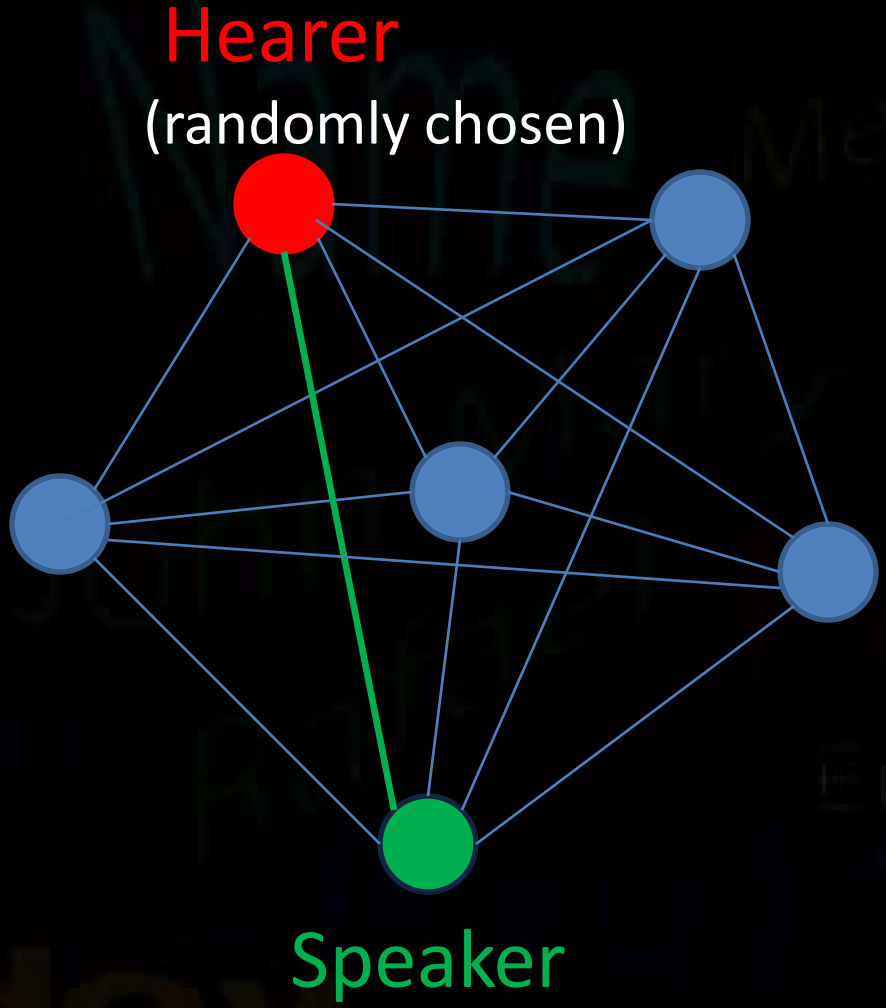
Speaker

(randomly chosen from population)

Mean field: fully-connected network



Mean field: fully-connected network



Game Rules

Speaker

Bottle
Apple
Tiger
Car

Hearer

Bag
Blackberry
Tree

Game Rules

Speaker

Bottle
Apple
Tiger
Car

Hearer

Bag
Blackberry
Tree

Randomly choose a word

Game Rules

Speaker

Bottle
Apple
Tiger
Car

Searched in hearer's inventory

Hearer

Bag
Blackberry
Tree

Not Found → Failure!!

Game Rules

Speaker

Bottle
Apple
Tiger
Car

Hearer

Bag
Blackberry
Tree
Apple

Add the word

Game Rules

Speaker

Bottle
Apple
Tiger
Car

Hearer

Bag
Apple
Tree

Randomly choose a word

Game Rules

Speaker

Bottle
Apple
Tiger
Car

Hearer

Bag
Apple
Tree

Uttered word found → Success

Game Rules

Speaker

Hearer

Apple

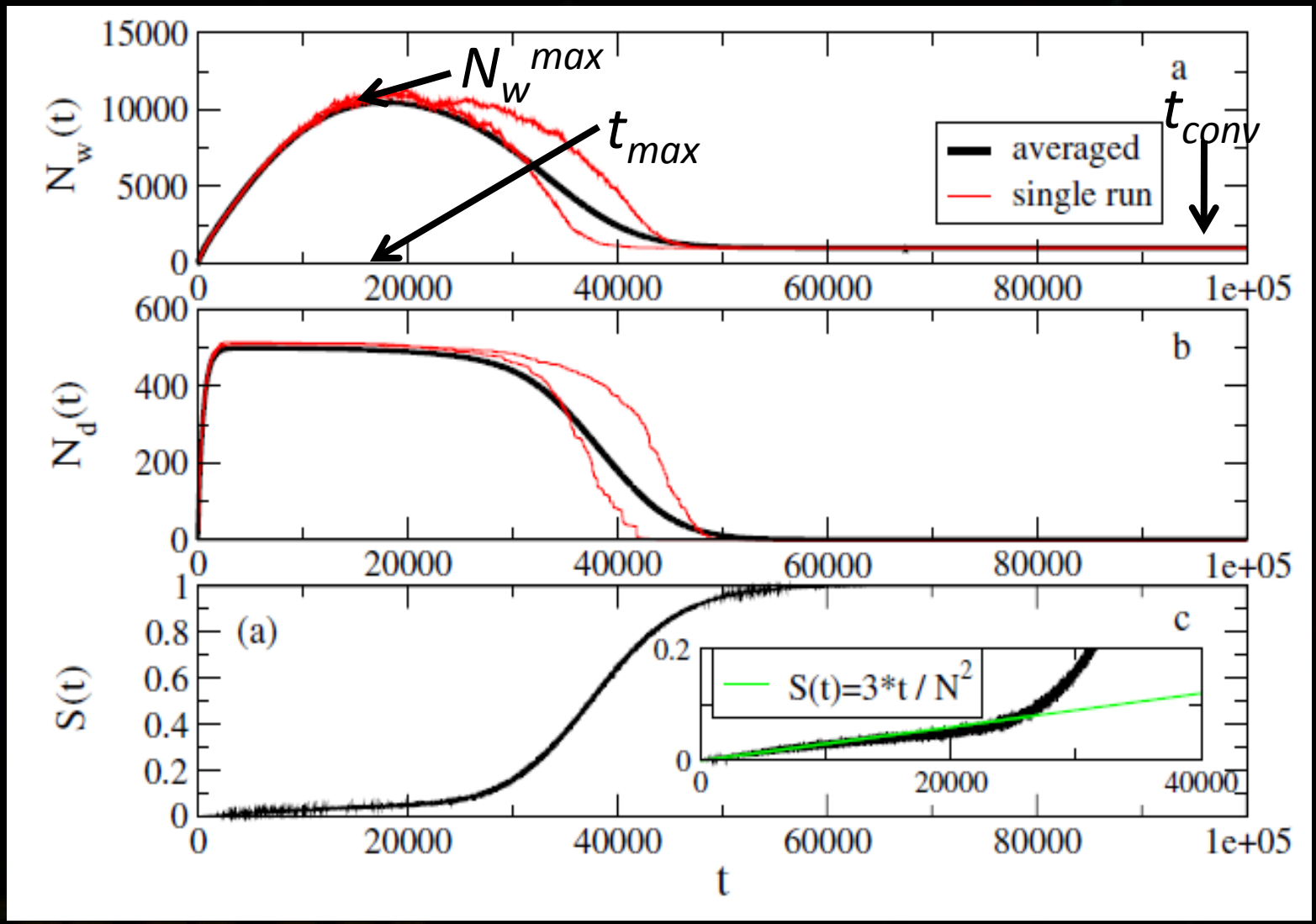
Apple

Retain only the successful word

Phenomenology

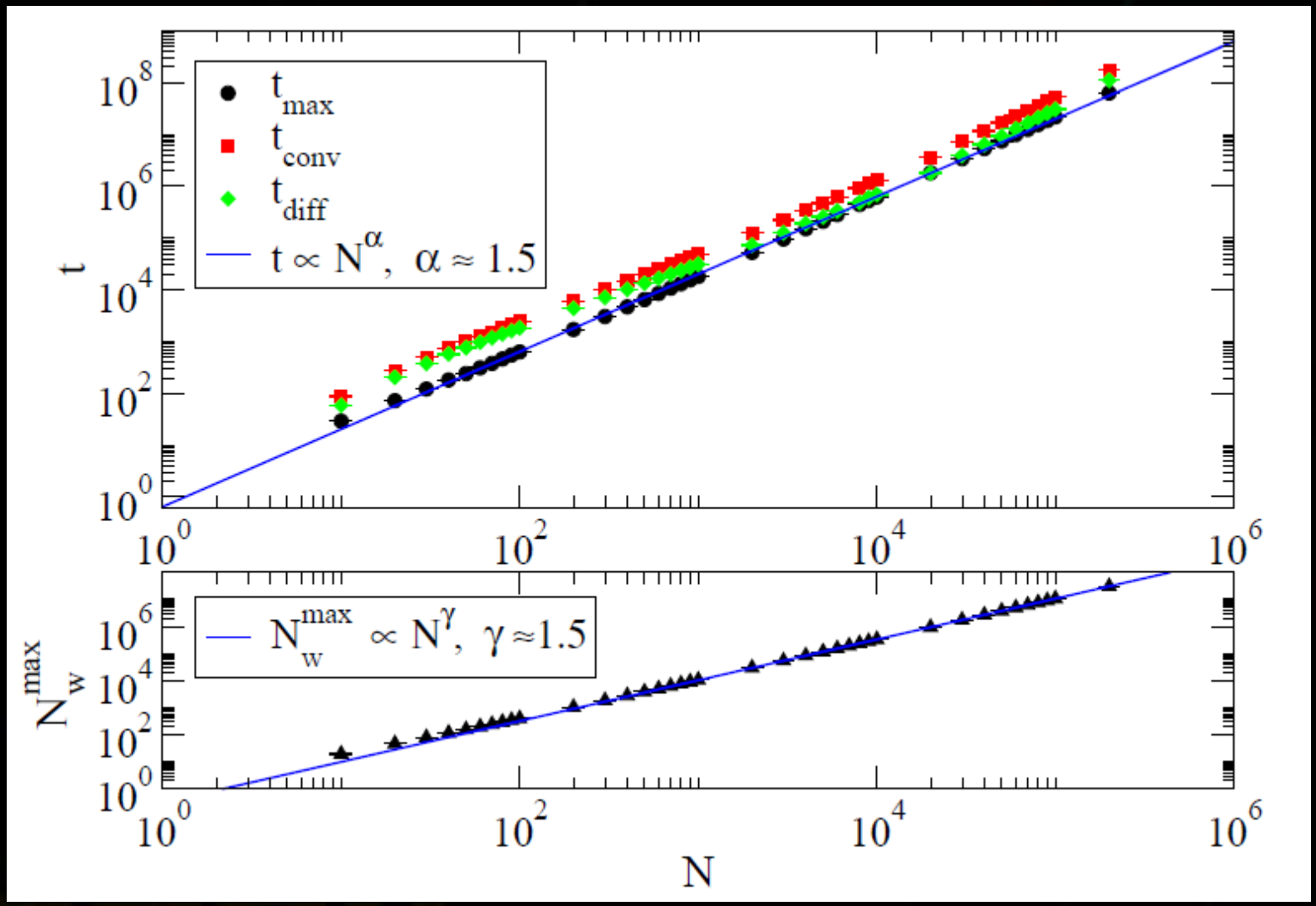
- t - Game time (no. of games)
- $N_w(t)$ - total number of words in the system at time t
- $N_d(t)$ - number of different words in the system at time t
- $S(t)$ - average success rate at time t
- N_w^{max} - maximum memory required by the system
- t_{max} - the time required to reach the memory peak
- t_{conv} - the time required to reach the global consensus

Temporal evolution of observables



Baronchelli et al., J. Stat. Mech. (2006)

Scaling Relations



Baronchelli et al., J. Stat. Mech. (2006)

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	$N^{1.4}$

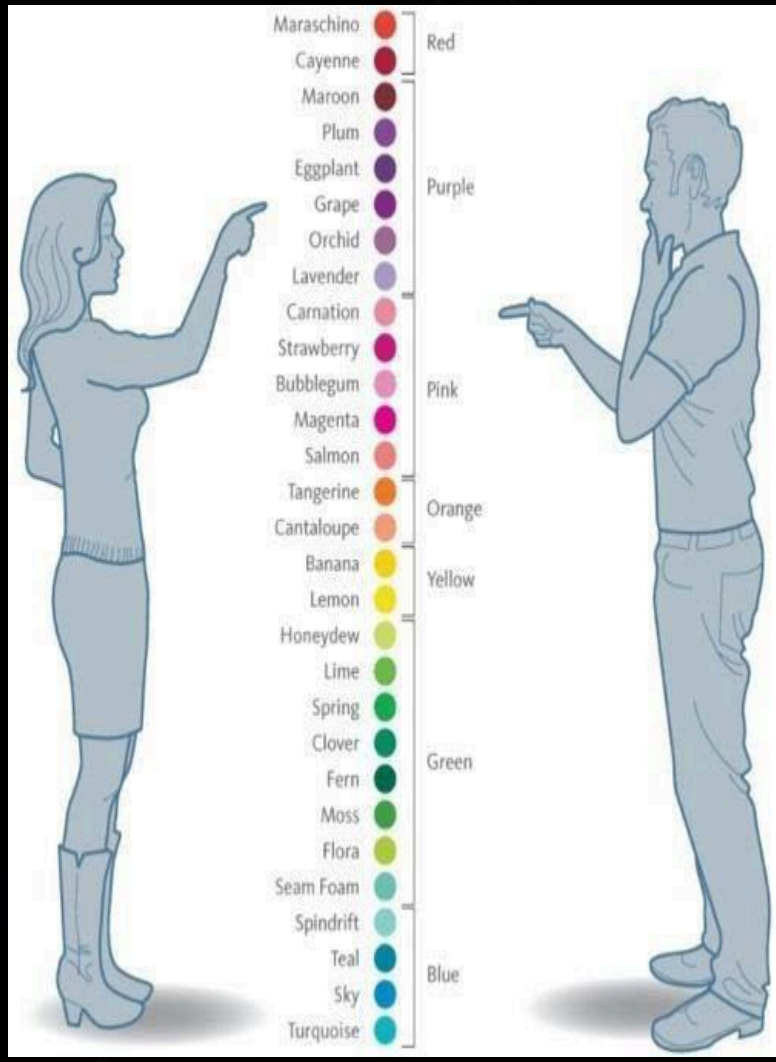
The Category Game

- Emergence of categorization from scratch
- No pre-existing categorization in a group of individuals
- Emerge a categorization through pairwise interactions without any central coordination

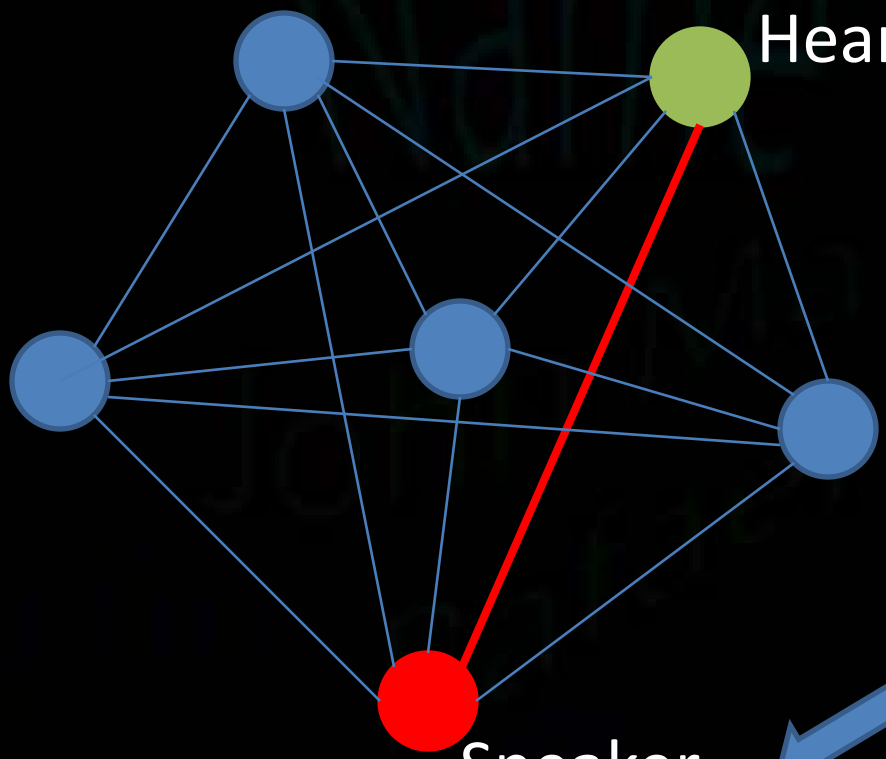
Motivation

- 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)]



The Model



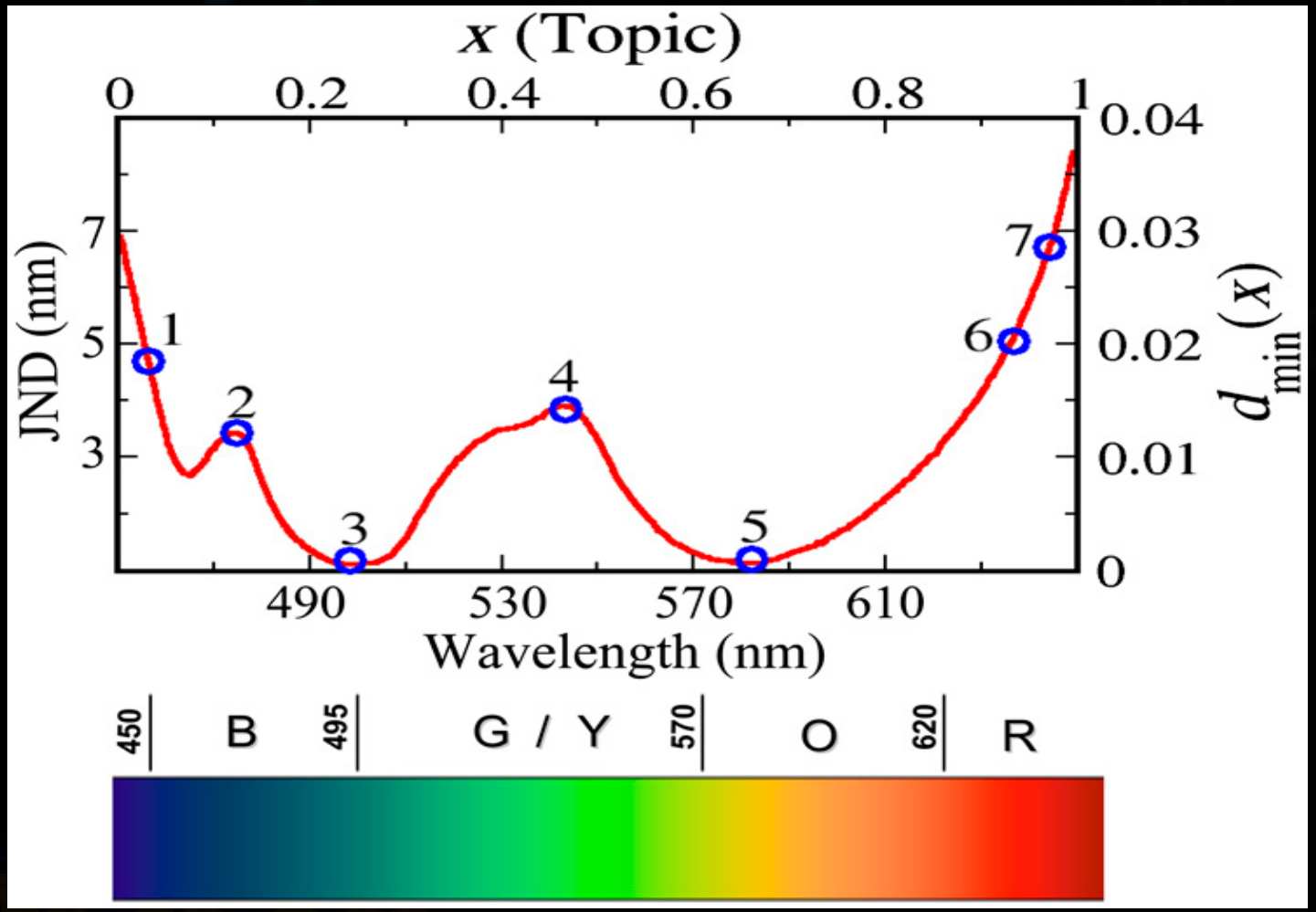
randomly chosen from population

The Model

- Both the speaker and hearer are presented with a scene of *M* >= 2 stimuli (objects)

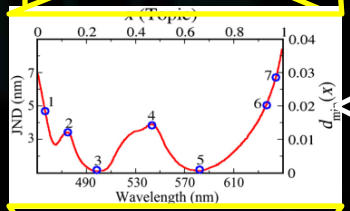
- No two stimuli appearing in the same scene can be at a distance closer than d_{min} (x) → the only parameter of the model encoding the finite resolution power of any perception: the human Just Noticeable Difference (JND).

Just Noticeable Difference

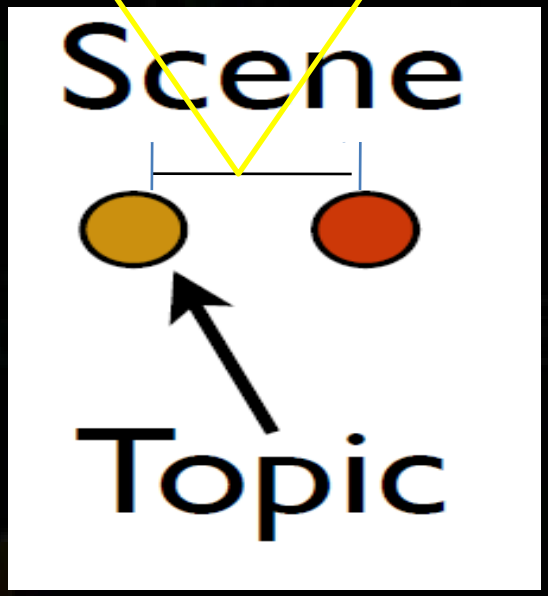


Scene Perception

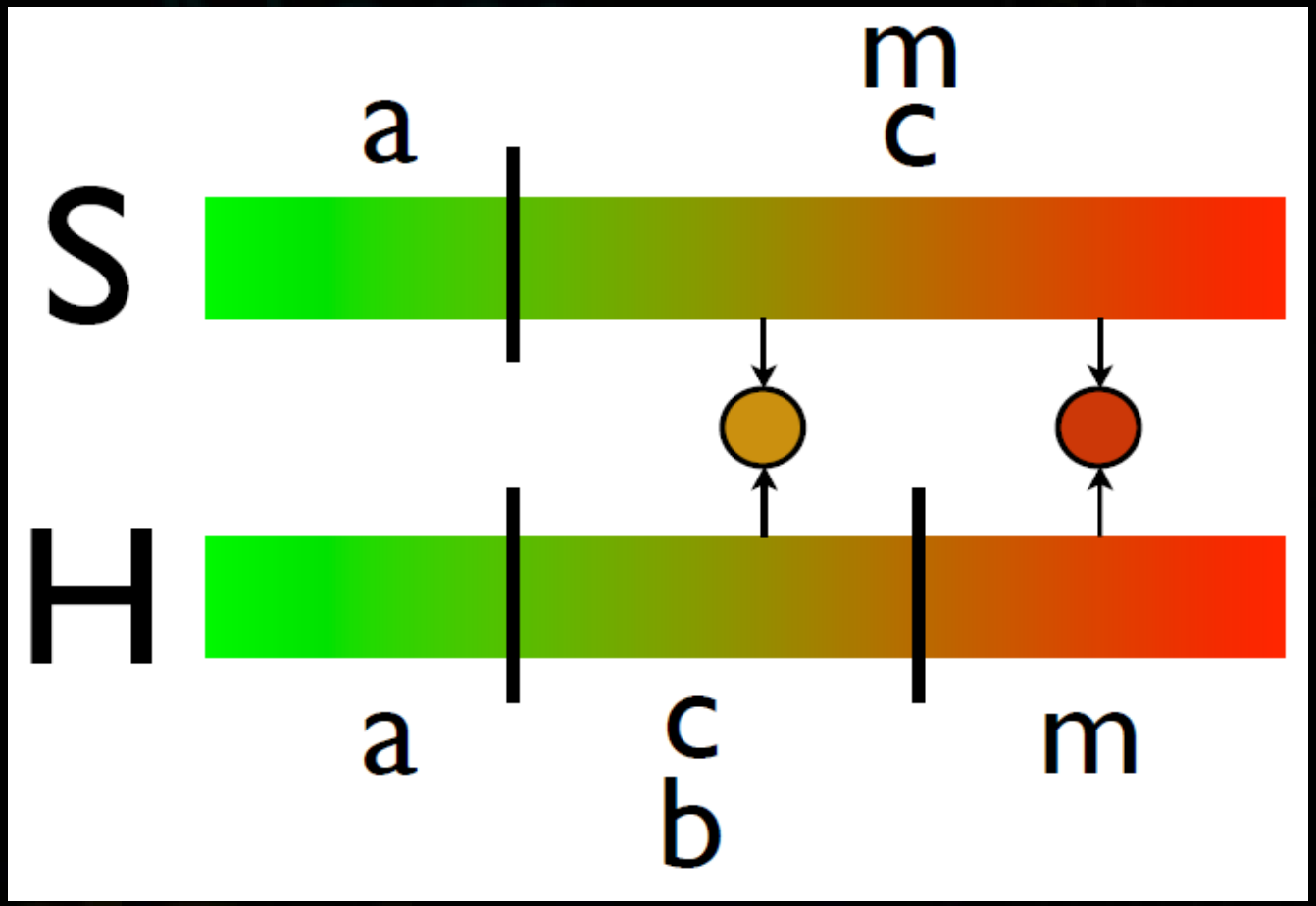
Speaker (S) Hearer (H)



<-- $d_{min}(x)$

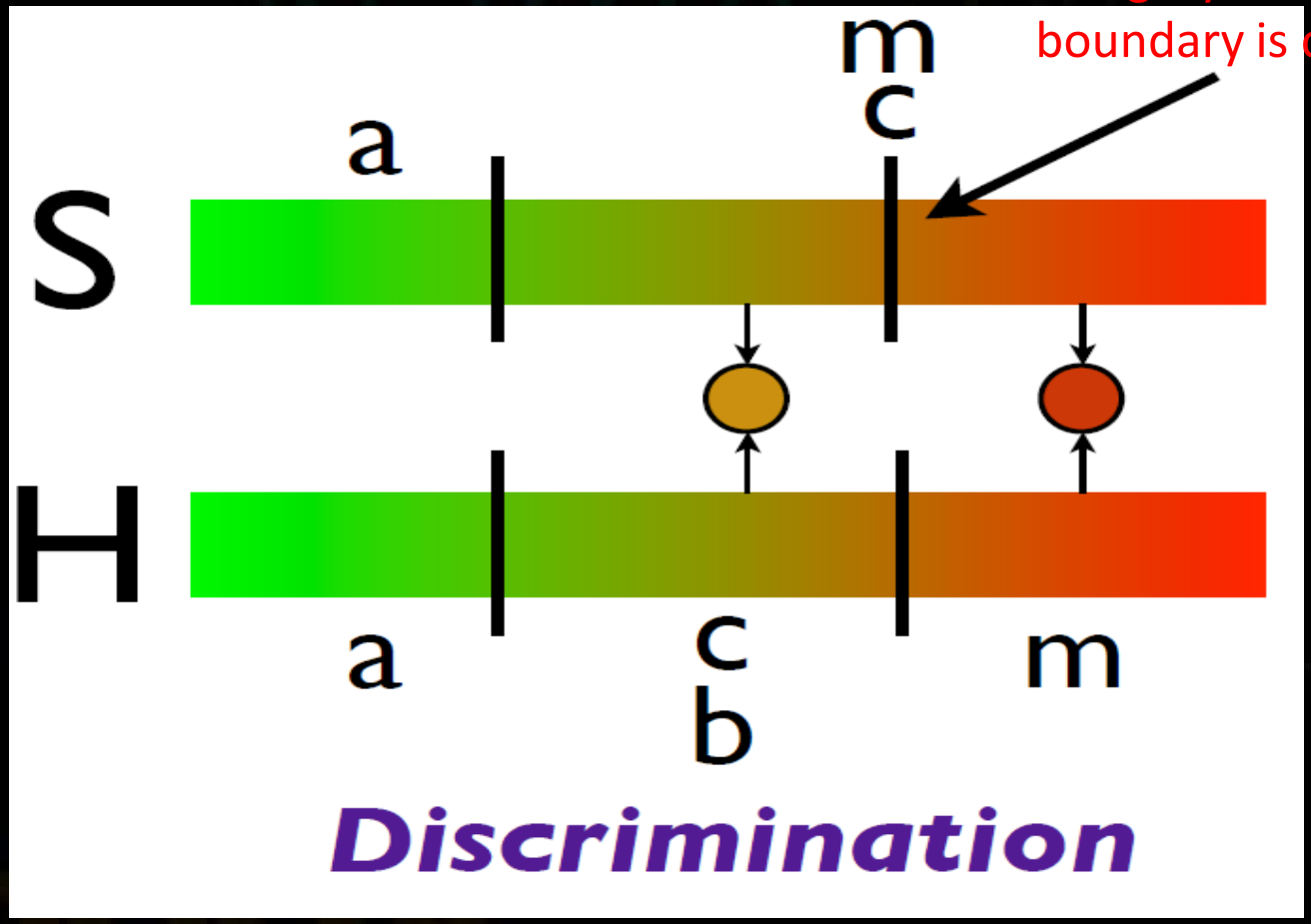


Locating stimuli in perceptual space

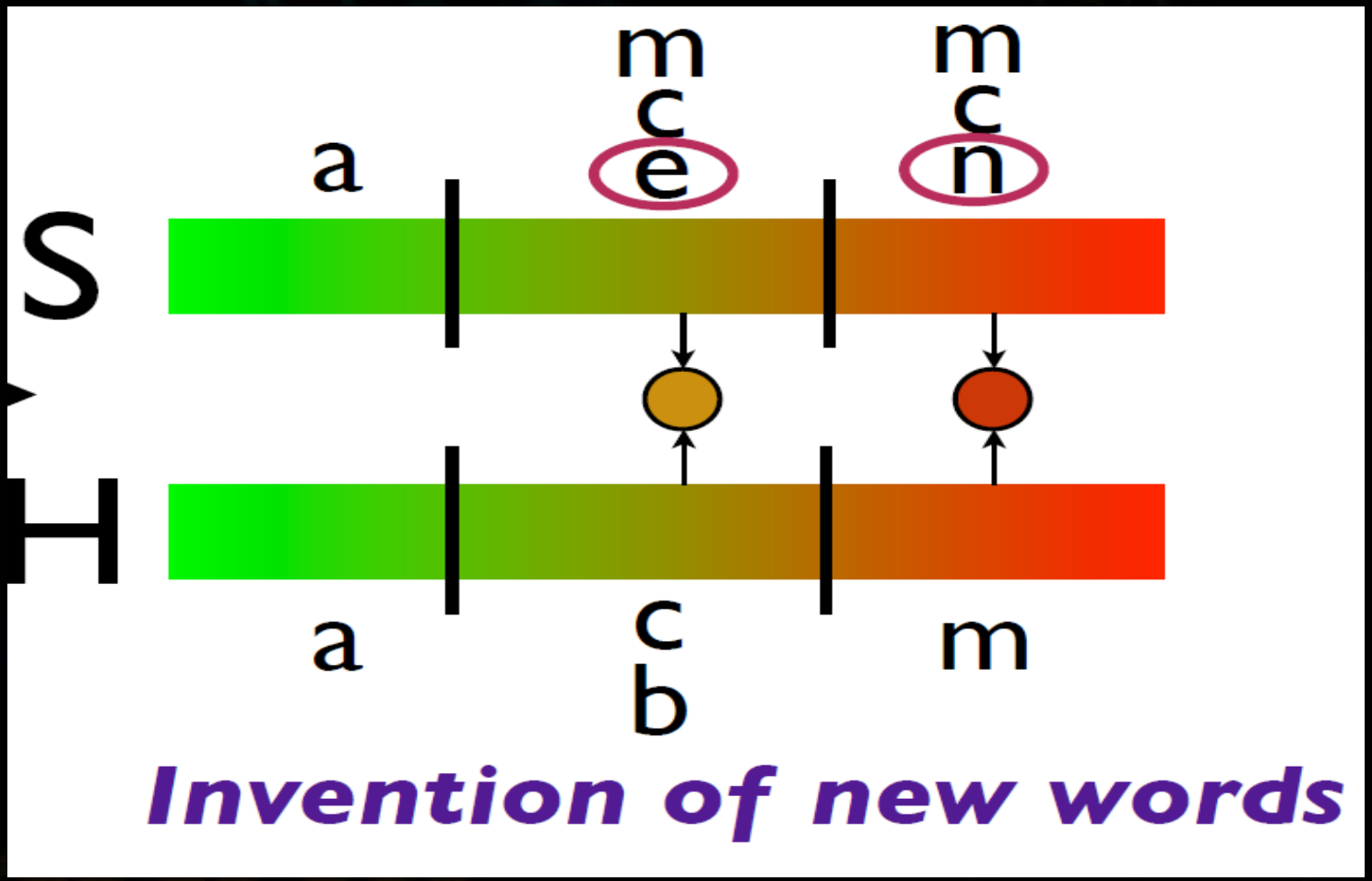


Discrimination

two stimuli colliding on the same perceptual category → a new boundary is created



Word Invention

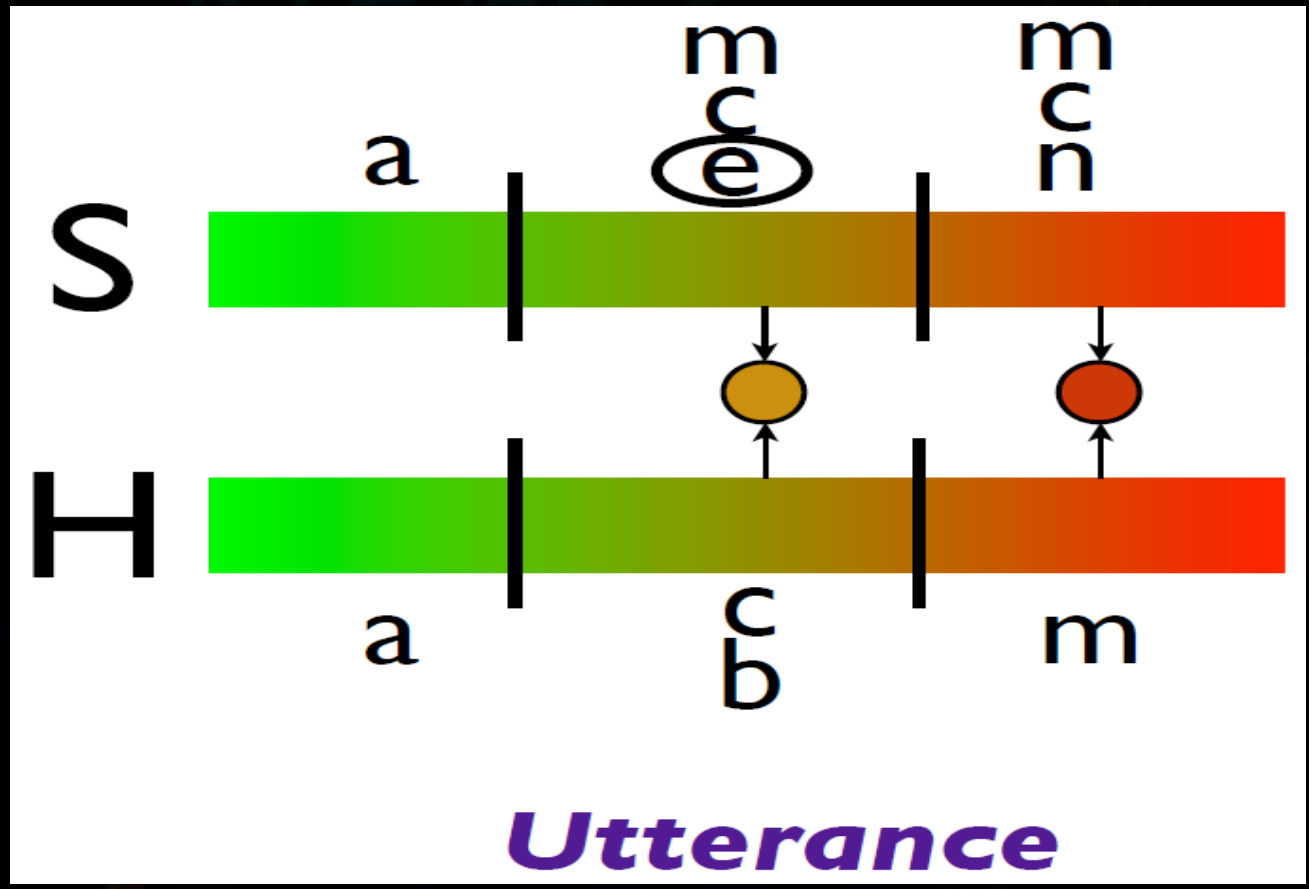


Word Selection

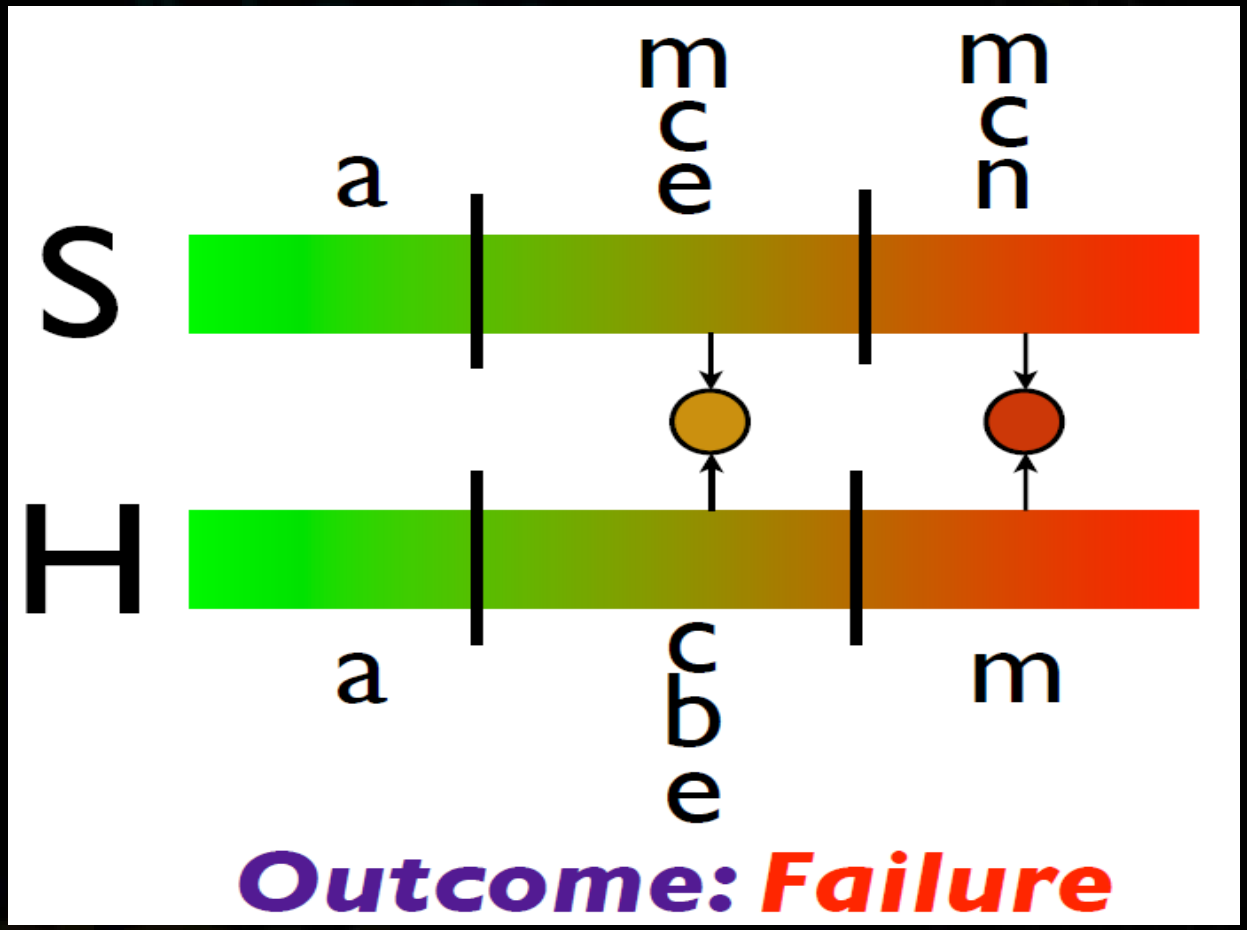
- Speaker browses its list of words associated with the perceptual category containing the topic

- 2 possibilities (the most relevant name):
  - chooses the last winning word
  - Otherwise, choose the newly created one

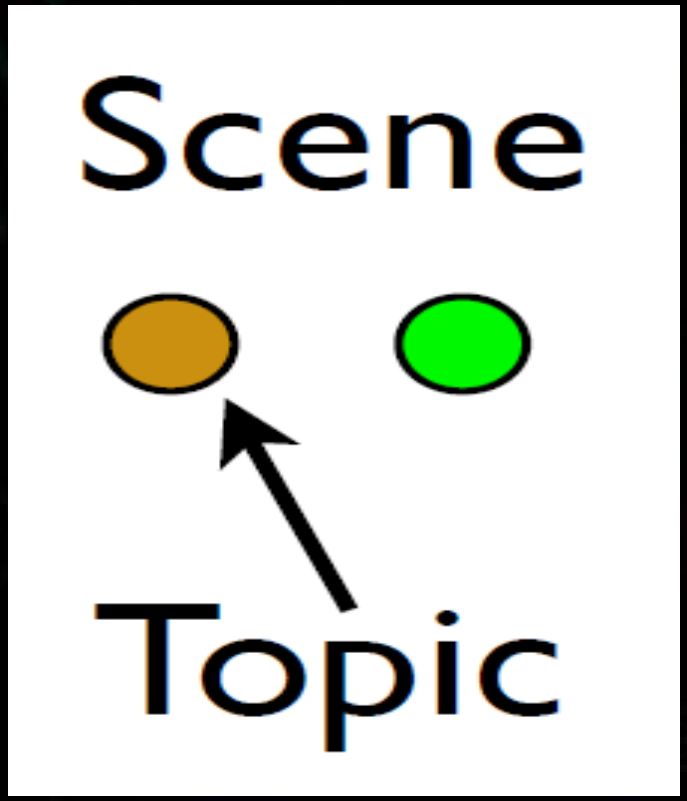
Word Selection



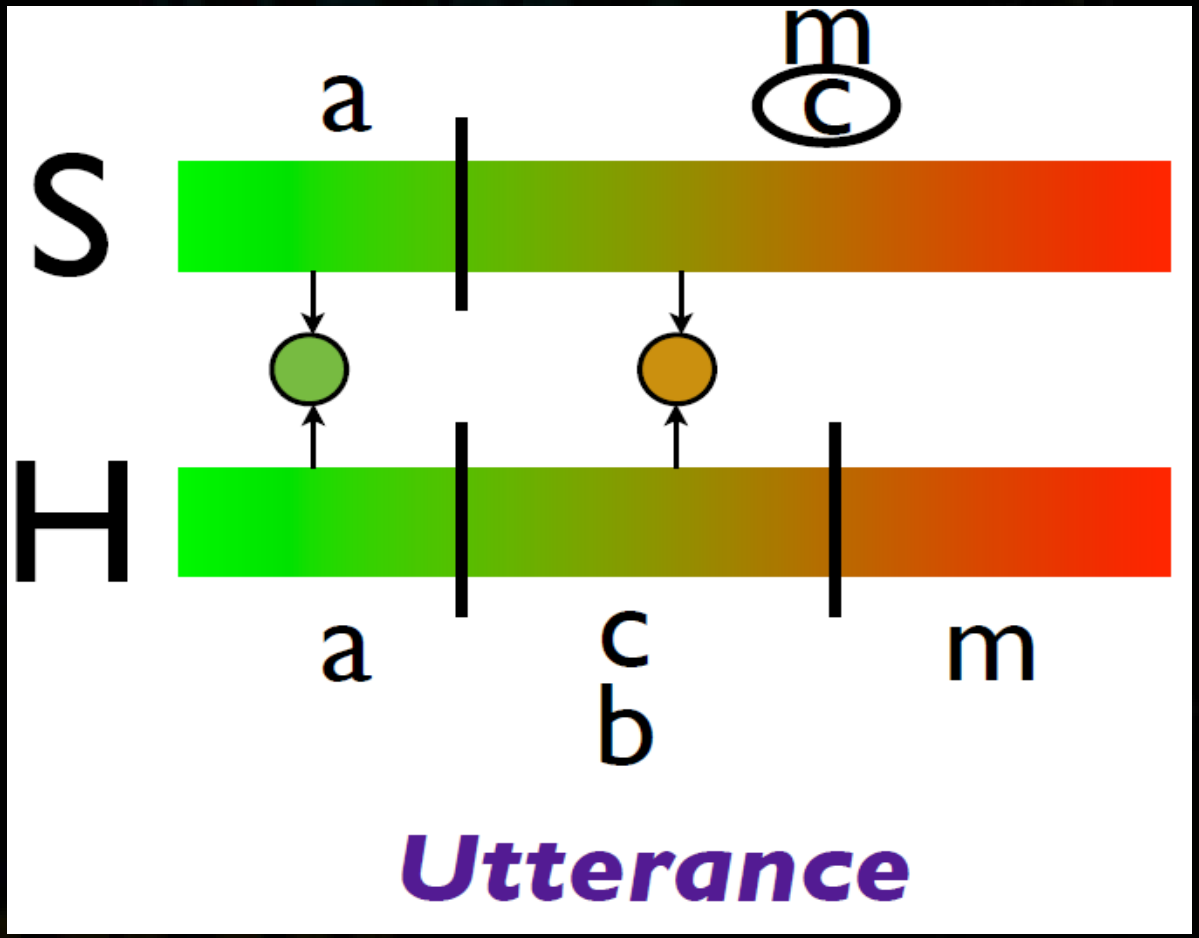
Failure in Communication



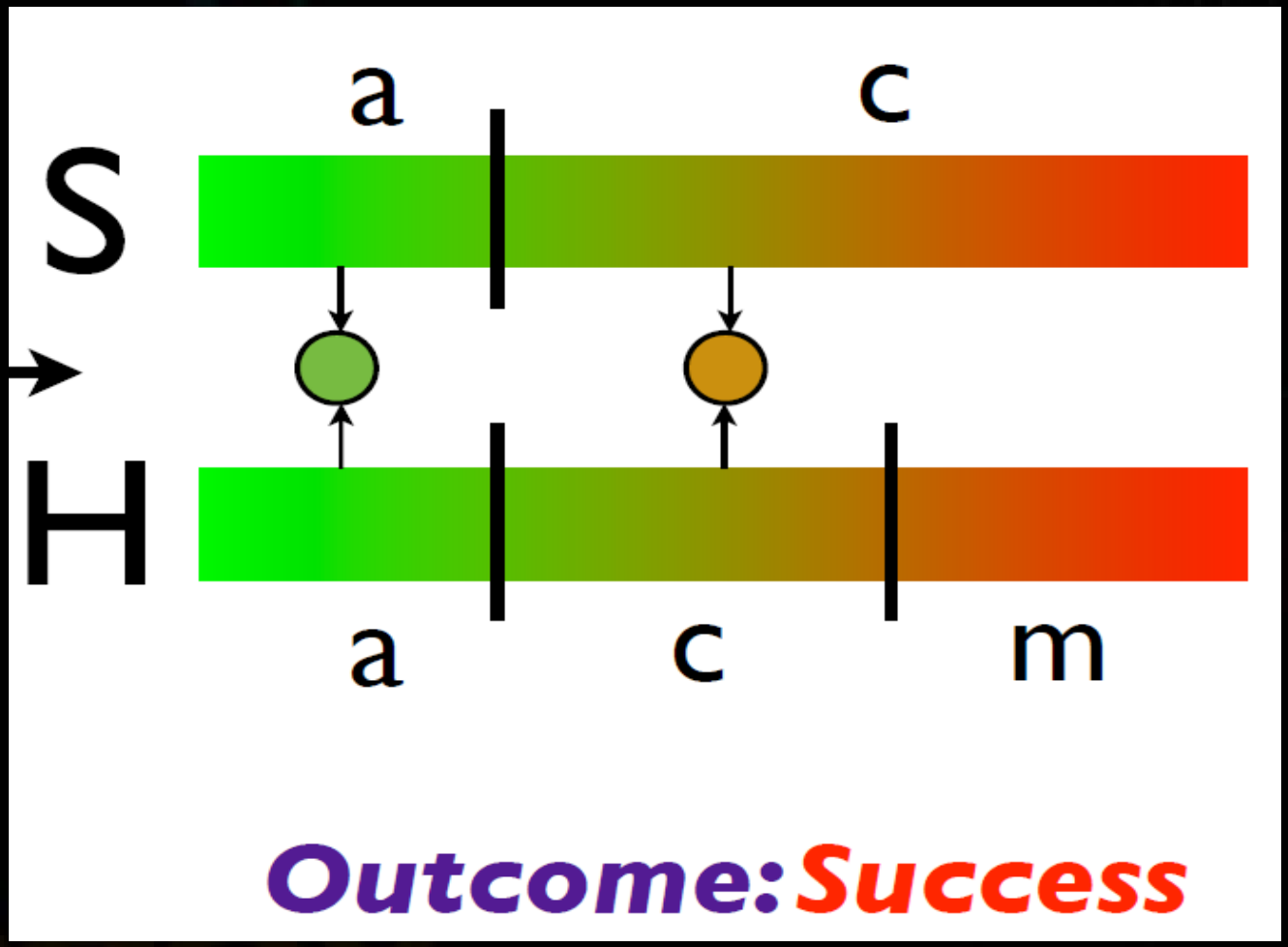
Successful Communication



Word Selection

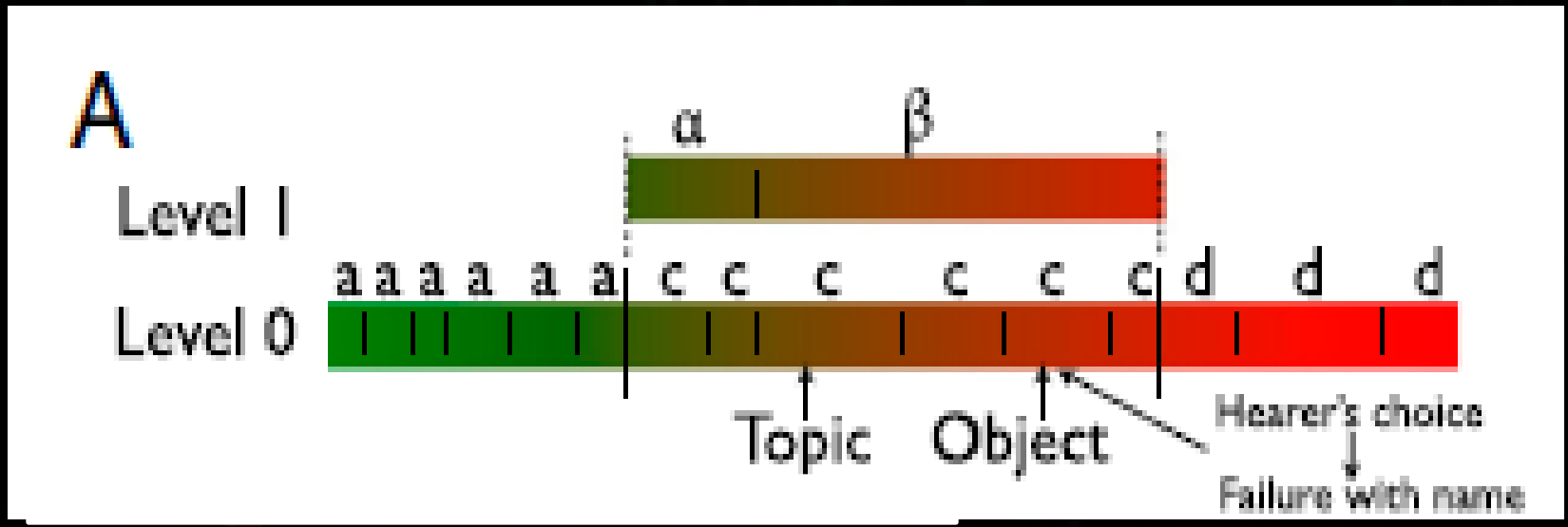


Emergence of Success

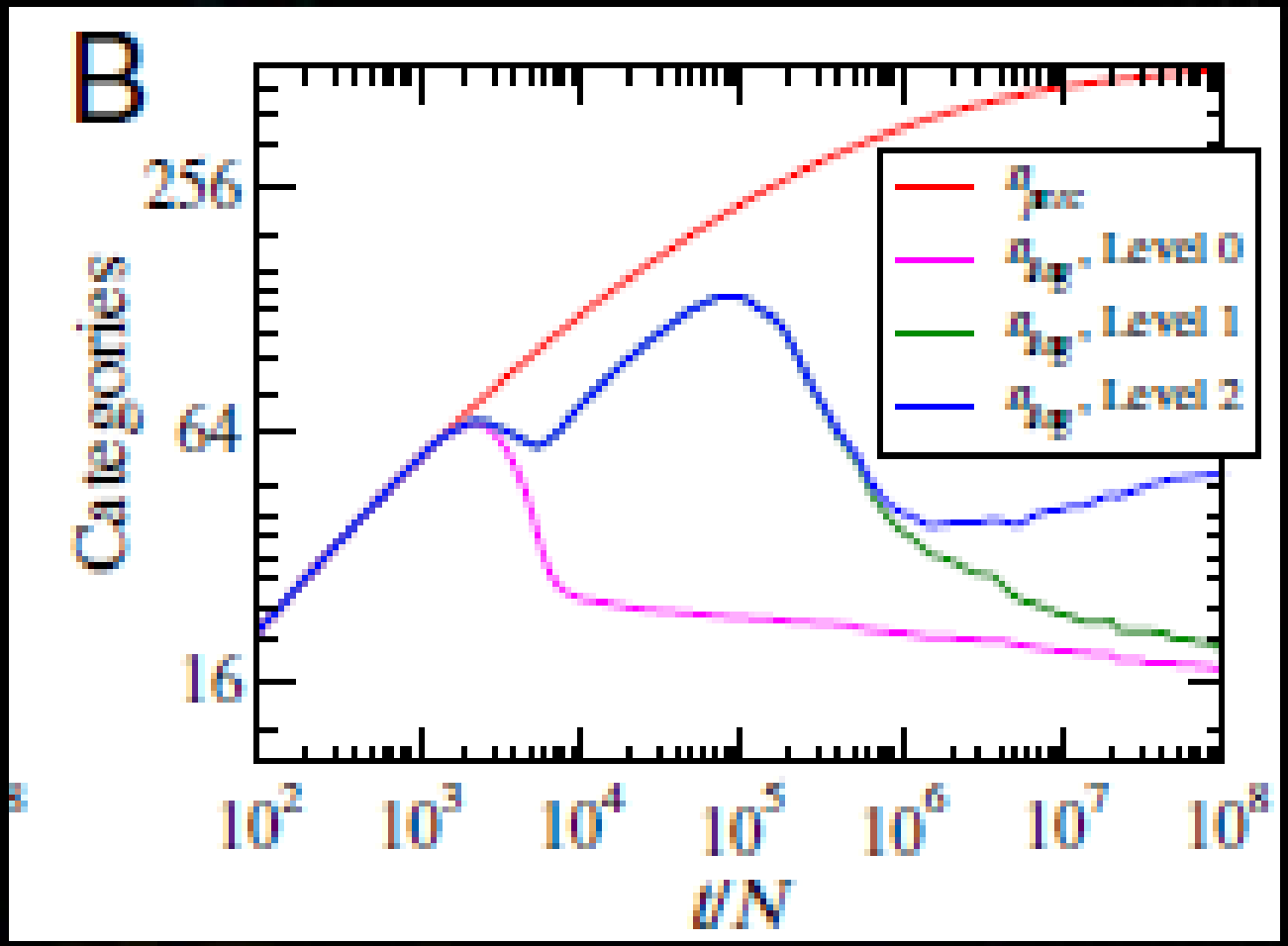


Multi-level hierarchy

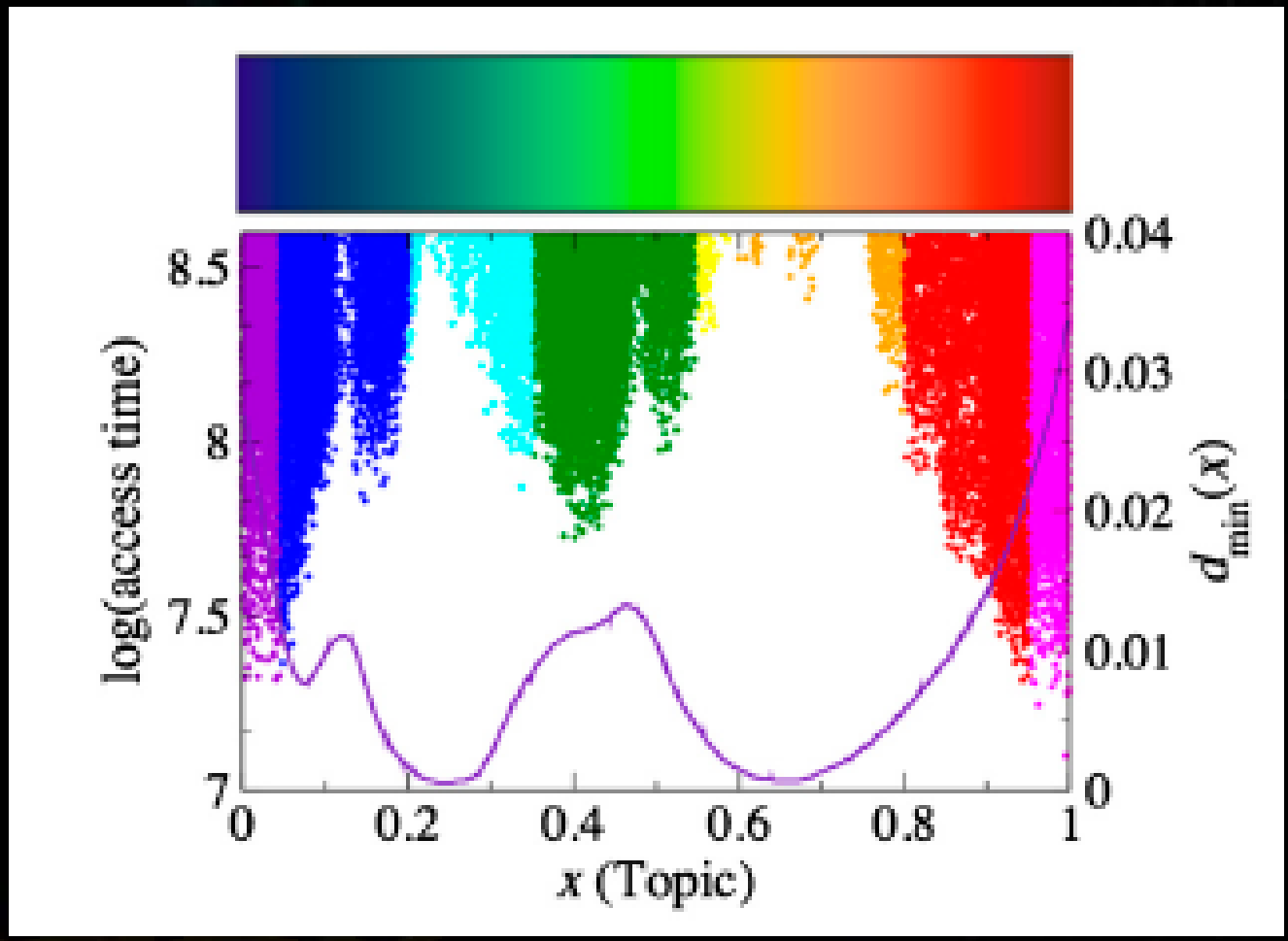
Failure with name → Failure due to confusion → Create a new level → A more complex reference for the corresponding region



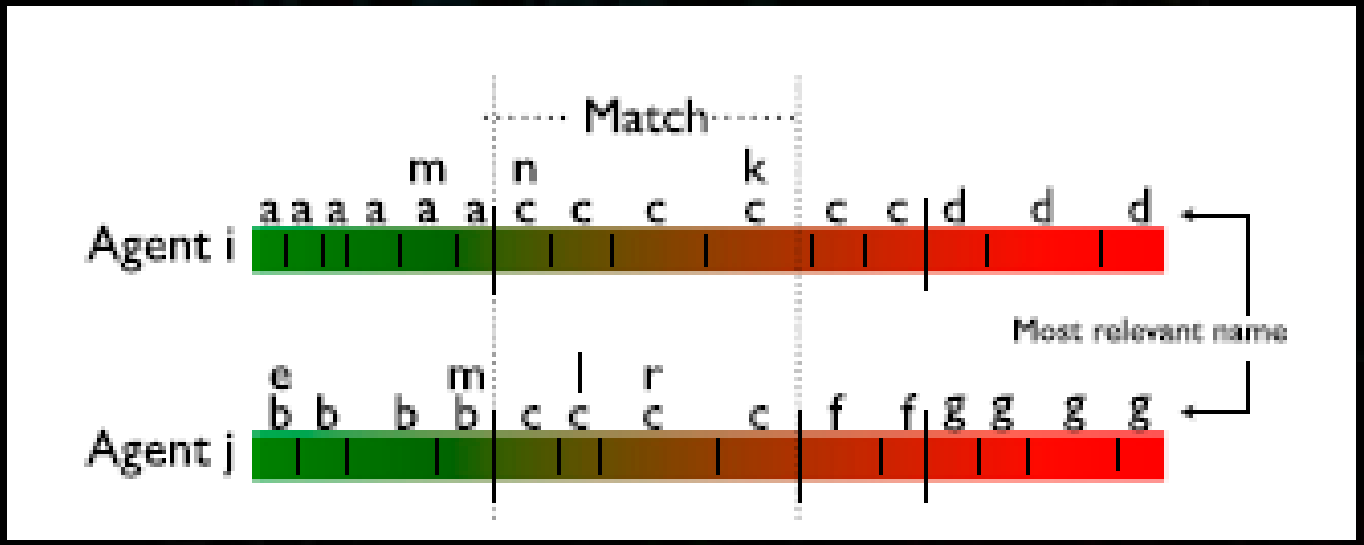
Emergence of categories



Frequency of higher level access

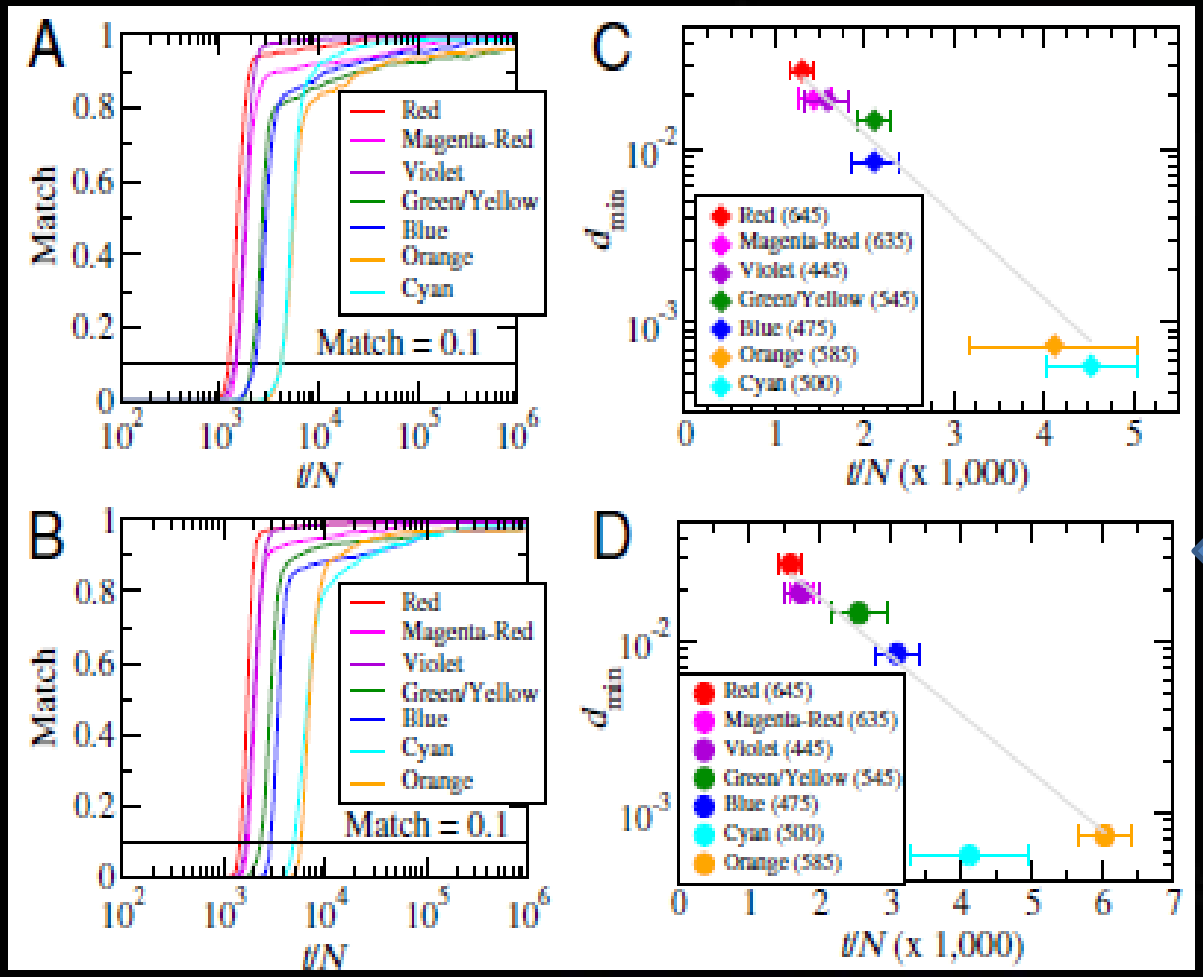


Measuring agreement



$$\frac{2\sum_{i=1}^{N}\sum_{j=i+1}^{N}\mathrm{match}(i,j)}{N(N-1)}.$$

Emergence of color hierarchy



[white, black] < [red] < [green, yellow] < [blue] < [brown] < [purple, pink, orange, gray]

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

Danke ....