# NAMING GAME AND HOMONYMY – SYNONYMY PUZZLE

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- Language is a complex adaptive system, which emerges from local interactions between its users and
evolves according to principles of evolution and self-organization.

- Research techniques:
  - genetic algorithms
  - neural networks
  - game theory
  - optimization techniques
  - statistical methods
  - learning techniques
  - multi-agent modelling
- *bottom-up* approach – the best for studying dynamic complex systems

## Two dominant paradigms in agent-based modelling

1) Iterated Learning Model (Kirby 2002)
   - „vertical" transmission of language (from one generation to the next)

2) Language Game Model (Steels 1995)
   - egalitarian agents in an open population
   - „horizontal" transmission of language (cultural)
   - naming game

- *There is no such thing as a true synonym* (L. Urdang 1979)

- synonymy is rare
  - *napkin/serviette; flat/apartment …*
  - *bicycle/bike; hippopotamus/hippo …*
  - *die/expire; shit/crap …*

- homonymy is common
  - *bank*
  - *file*
  - *present*
  - *list*
  - *port*
  - *…*

- E. **CLARK**: Principle of Contrast (Clark 1990)
- E. **MARKMAN**: Mutual Exclusivity Principle (Markman 1989)
- K. **WEXLER**, P. **CULICOVER**: Uniqueness Principle (Wexler & Culicover 1980)
- S. **PINKER** (Pinker 1984)

- homonymy – synonymy puzzle
  - synonymy does not disturb communication
  - homonymy gives rise to misinterpretations
- computer languages
  - synonyms allowed
  - no homonyms

*Humans evolved to be well adapted as senders of messages;*

*accurate reception of messages was less important…*

*We may be primarily speakers, and secondarily listeners.*

- James R. Hurford (2003)
  *Why synonymy is rare: Fitness is in the speaker*

- genetic algorithm favours
  - either communicative success :
    rare synonyms, homonyms tolerated
    (as in natural languages)
  - or interpretive success :
    rare homonyms, synonyms tolerated
    (unlike natural languages)

- the homonymy-synonymy asymmetry
  - distinctive feature of natural languages
  - potential test of computational models of language development

*Homonyms and synonyms in the n-object naming game*

- naming game
  - → two agents (speaker and hearer – in turns)
  - → many objects

- each agent has lists of words (one list for each object)
- each word has a weight assigned to it
- words are integer numbers

- the speaker selects an object
  and a word for it from its respective list
  (randomly, according to weights of words)

- the hearer determines the meaning
  of the word

- success or failure
  determine modification to the vocabularies

- the hearer
  - calculates measures of similarity of the word $x$ to each of the lists :

$$s^k(x) = \frac{1}{\sum_i w_i} \sum_i \frac{w_i}{\varepsilon + |x_i - x|}$$

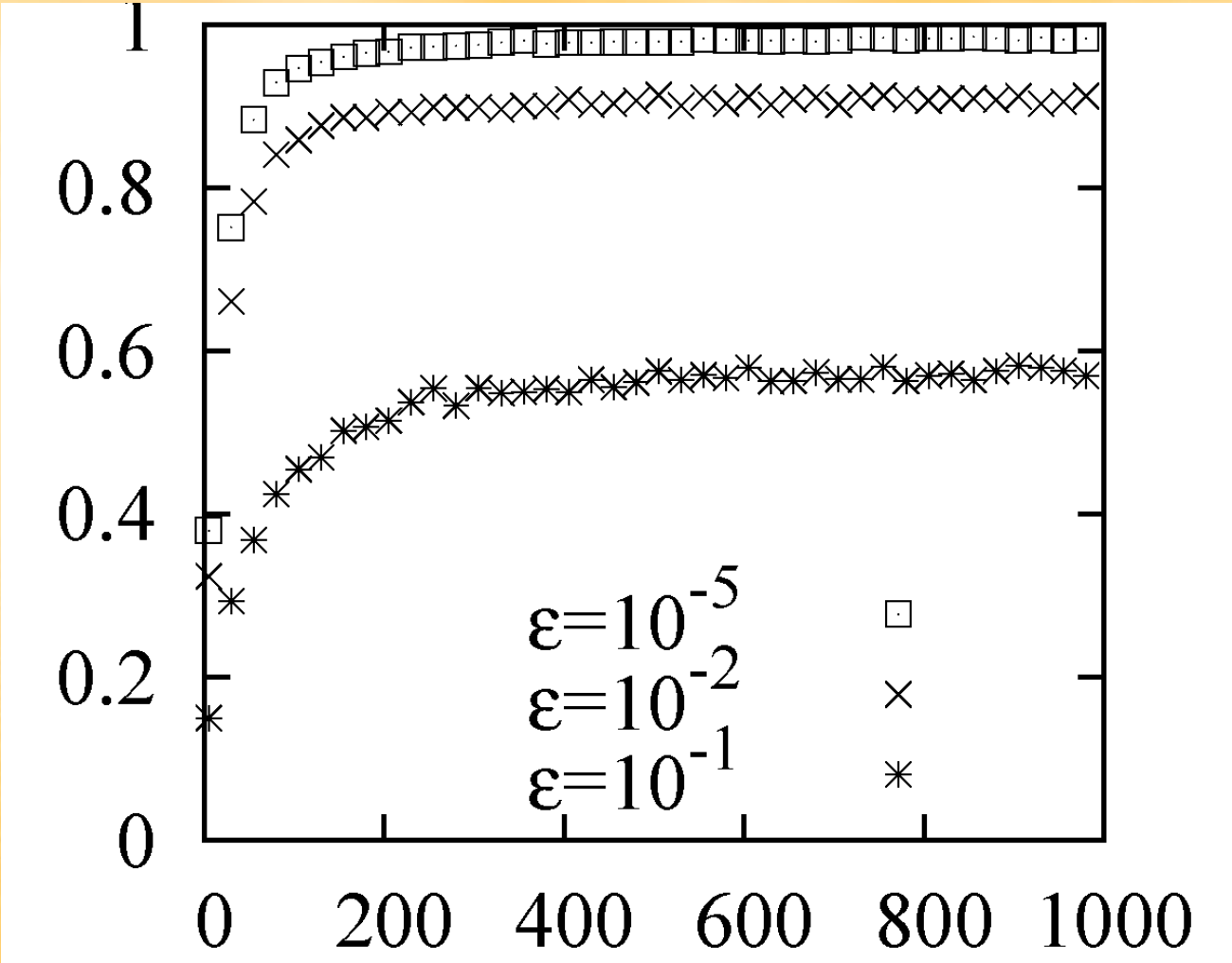
$w_i$ – the weight of the word $x_i$

$10^{-5} \leqslant \varepsilon \leqslant 10^{-1}$ – ensures finiteness of $s^k$

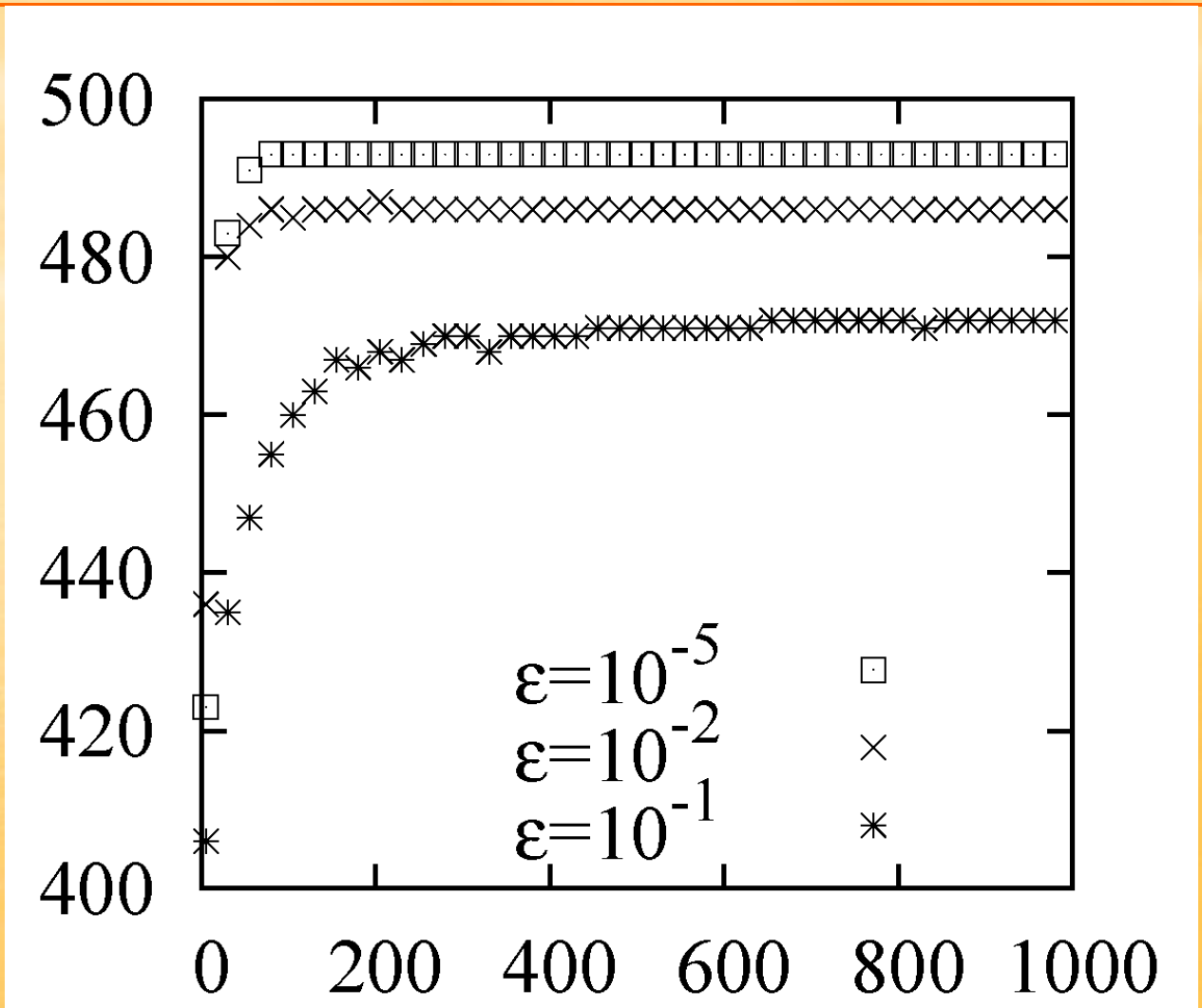
  - using these measures as weights, makes a roulette selection of a list (and so an object) as the meaning

## Modification of vocabularies

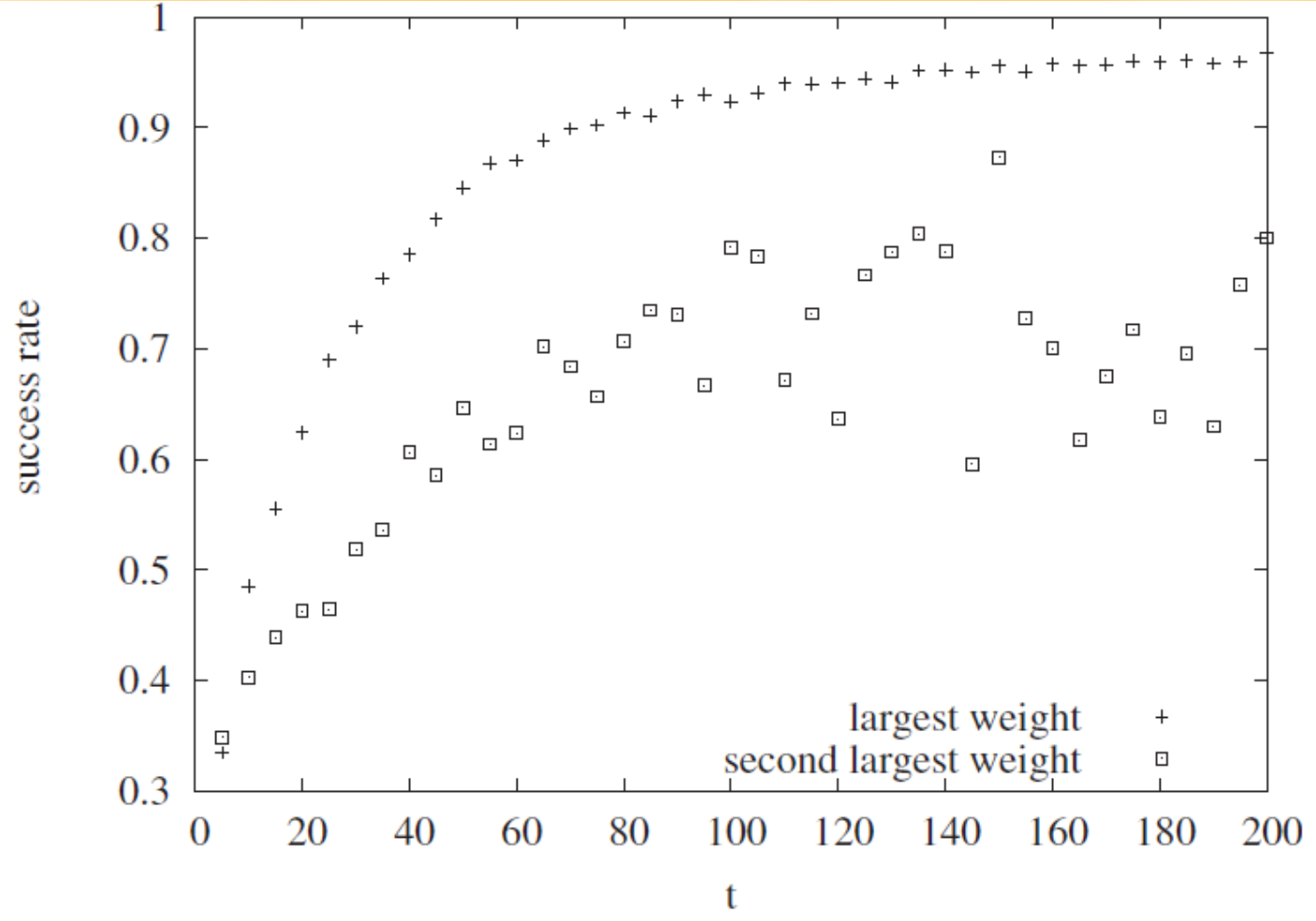
- success
  - both agents increase the weights of the word
- failure
  - the speaker decreases the weight of the word
  - the hearer adds the word to the appropriate list or increases its weight
- *reinforcement learning approach*



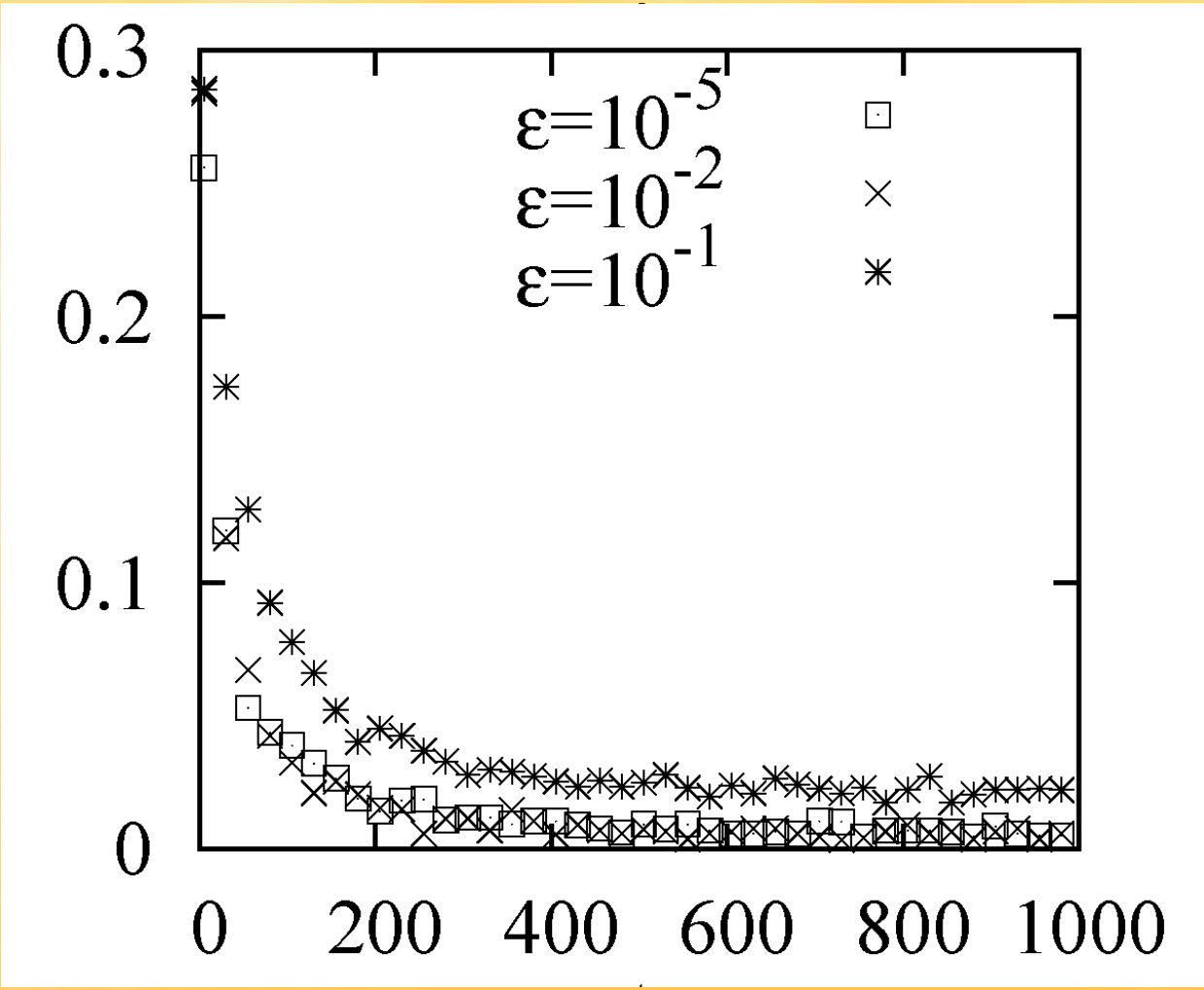

The time evolution of the success rate
(n=500, l=10, r=1000)




The time evolution of the number of different largest-weight words




The time evolution of the success rate of utterances with largest- and second-largest-weight words




The time evolution of the fraction of second-largest-weight utterances

## Noise

- with the probability $p$ the word $x$ chosen by the speaker is changed to

$$x_c = x+\eta$$

$-a \leqslant \eta \leqslant a$ ($a$ – the amplitude of noise,

$\eta$ – random integer)

- with the probability $1-p$ the communicated word $x$ does not change

- For $p=0$ a redistribution of largest-weight words reduces homonymy
- For $p>0$ noise enhances such a redistribution
- For $p>0$ noise changes a distribution of second-largest-weight words (reducing synonymy ?)

- In the model, the noise plays an important role in the evolution of language:
  - results in a more even distribution of words within the available verbal space
  - reduces the number of homonyms
  - reduces the number of synonyms

- Homonymy and synonymy
  - homonymy persists over time („dynamic trap”)
  - synonymy diminishes over time (transient characteristic)
- Noise
  - facilitates communication

- Asymmetry between homonymy and synonymy can thus be explained within a fairly simple naming game model, without resorting to evolutionary Hurford's argument (that a speaker benefits more from conversation than a listener).

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