A Multi-language State In The Naming Game On Adaptive Weighted Networks

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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.

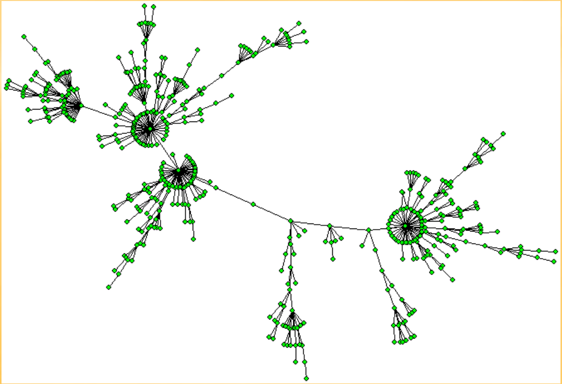
Two main paradigms in agent-based modelling

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

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

Topology

- complete graph
- regular lattice
- small-world network
- scale-free network



Sharp transition towards shared vocabularies (Baronchelli *et al.*, 2006)

Stable multi-language structures (Dall'Asta *et al.*, 2006) preference for better communicating interlocutors

weights of links

(1) determine the probabilities of communication

(2) change along with the communicative success rates

NG on a graph – complete / weighted / adaptive } complex / dynamic / structure

N agents play a single-object naming game

lexicons – (initially empty) lists of words

a speaker i and a hearer j are selected

the speaker selects a word and communicates it to the hearer success – both agents retain only the communicated word in their lexicons

failure – the word is added to the hearer's lexicon

communicative success rate of the pair of agents ($\boldsymbol{s_{ij}} = \boldsymbol{s_{ji}} = successes_{ij} / games_{ij}$)

minimal version of the naming game

(Baronchelli *et al.*, 2006)

The speaker $\boldsymbol{i}$ is selected randomly

The hearer $\boldsymbol{j}$ is selected with the probability

$$p_{ij} = \frac{w_{ij}}{\sum_{k=1}^{N} w_{ik}}$$

where the weights

$$w_{ij} = \begin{cases} s_{ij} + \varepsilon & for \quad i \neq j \\ 0 & for \quad i = j \end{cases}$$

initially, all weights $\boldsymbol{w_{ij}} = \boldsymbol{\varepsilon}$ (for $i \neq j$)

clusters of agents

linguistic synchronization –
the same language

dynamic structure of the network

outside-cluster communication $(\boldsymbol{w_{ij}} = \boldsymbol{s_{ij}} + \boldsymbol{\varepsilon})$

coarsening dynamics and
order / disorder transition

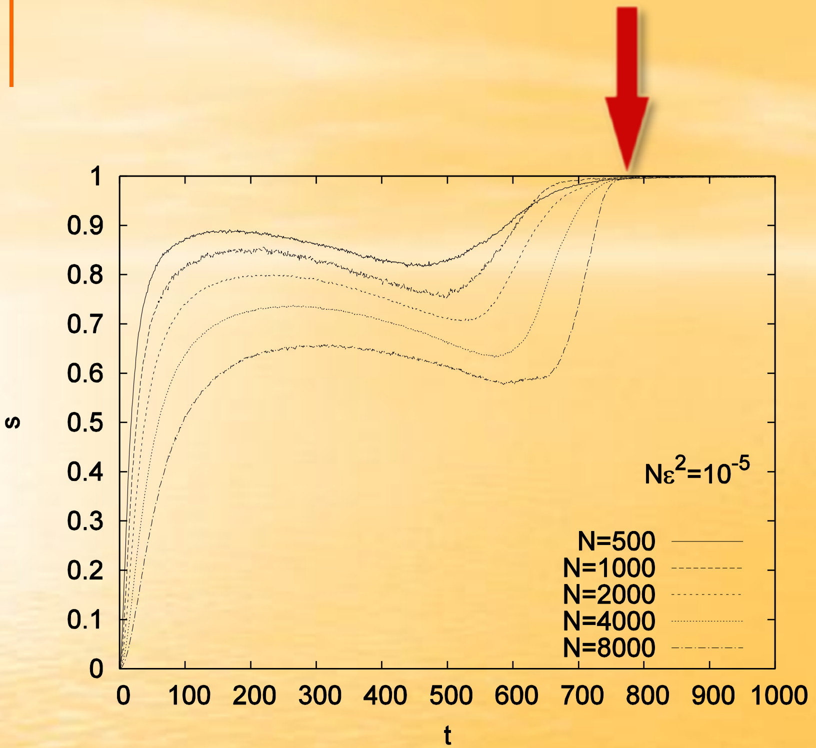
control parameter : $\boldsymbol{N\varepsilon^2}$

s – the communicative success rate, i.e., a fraction of all successes during the last N communication attempts

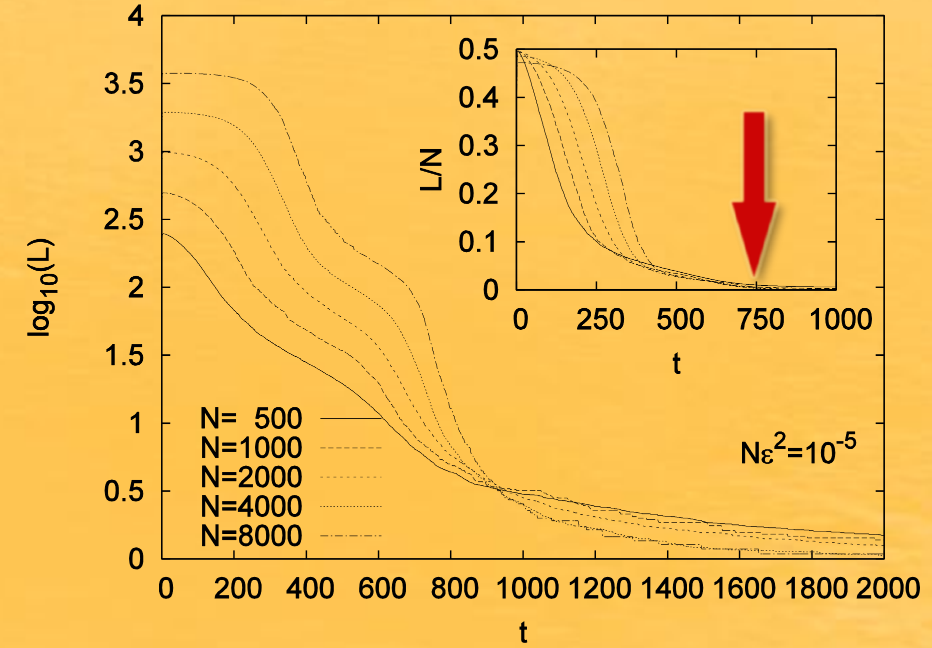
L – the number of different words in all agents' lexicons

N_d – the number of agents that have the most common word in their lexicons

single-language regime

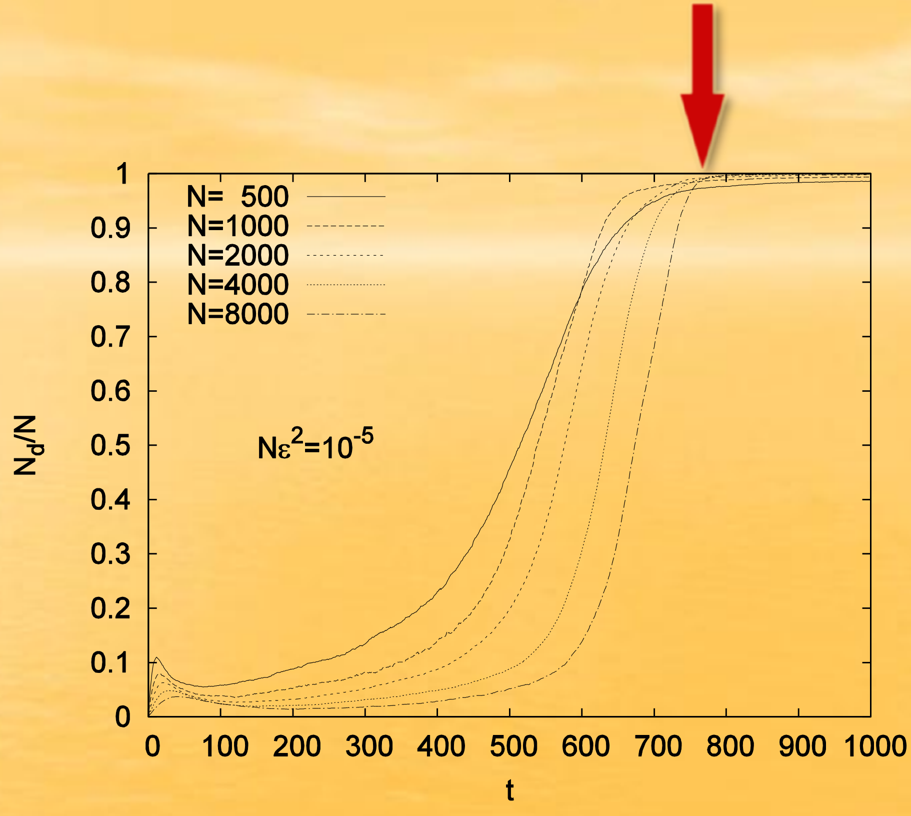


The time dependence of the number of languages L (logarithmic scale) calculated for several values of N and for $N\varepsilon^2 = 10^{-5}$. The inset shows the time dependence of the normalized number of languages L/N.

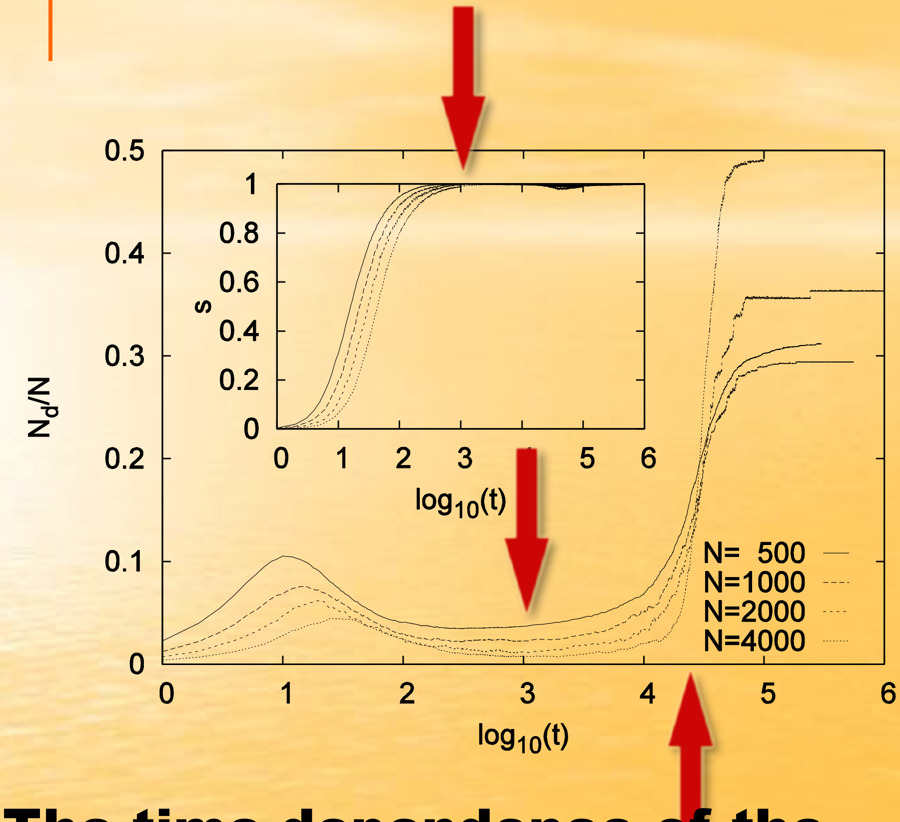


The time dependence of the success rate s calculated for several values of N and for $N\varepsilon^2 = 10^{-5}$.

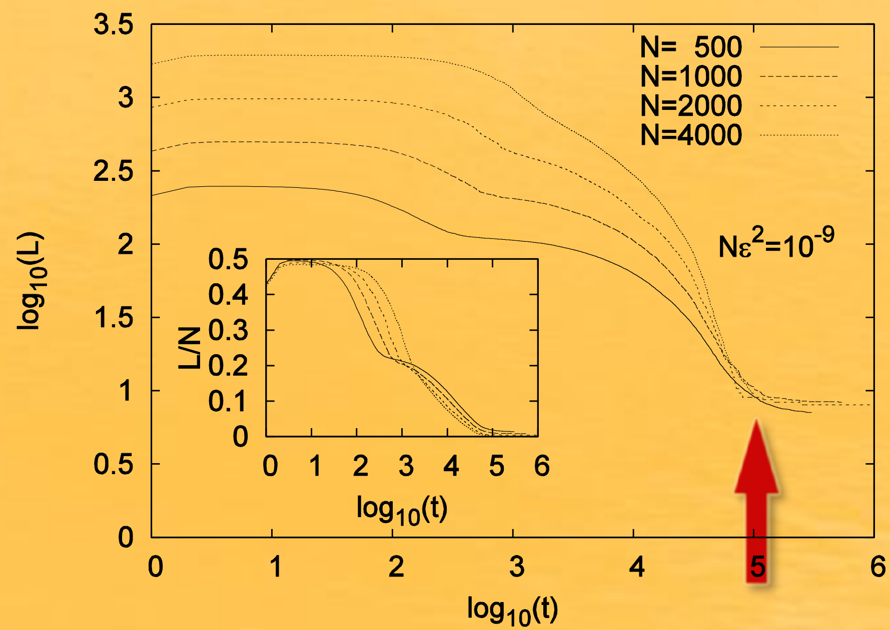
single-language regime



The time dependence of the ratio of agents that use the most common language N_d/N calculated for several values of N and for $N\varepsilon^2 = 10^{-5}$.

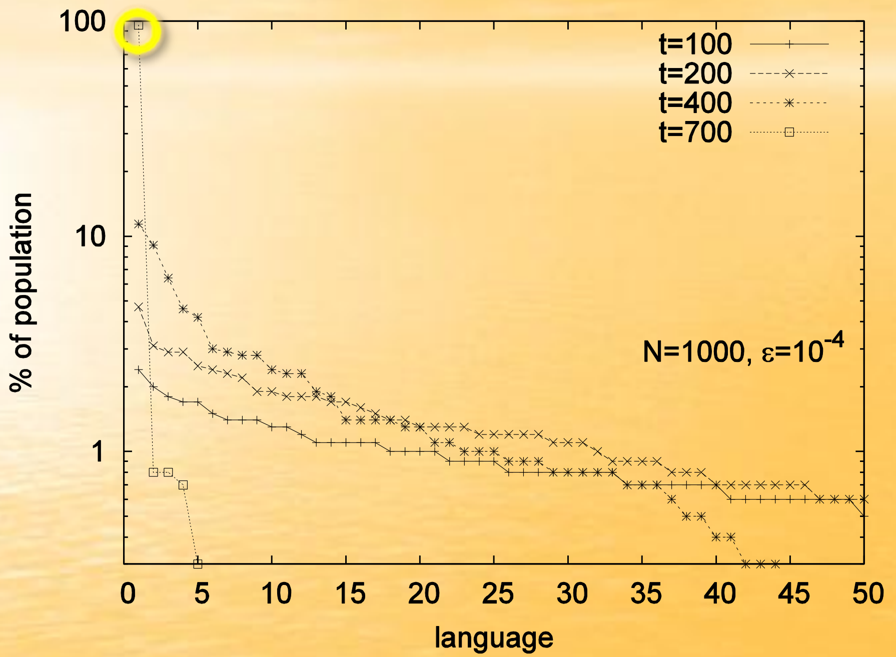


The time dependence of the number of languages L (logarithmic scale) calculated for several values of N and for $N\varepsilon^2 = 10^{-9}$. The inset shows the time dependence of the normalized number of users L/N.



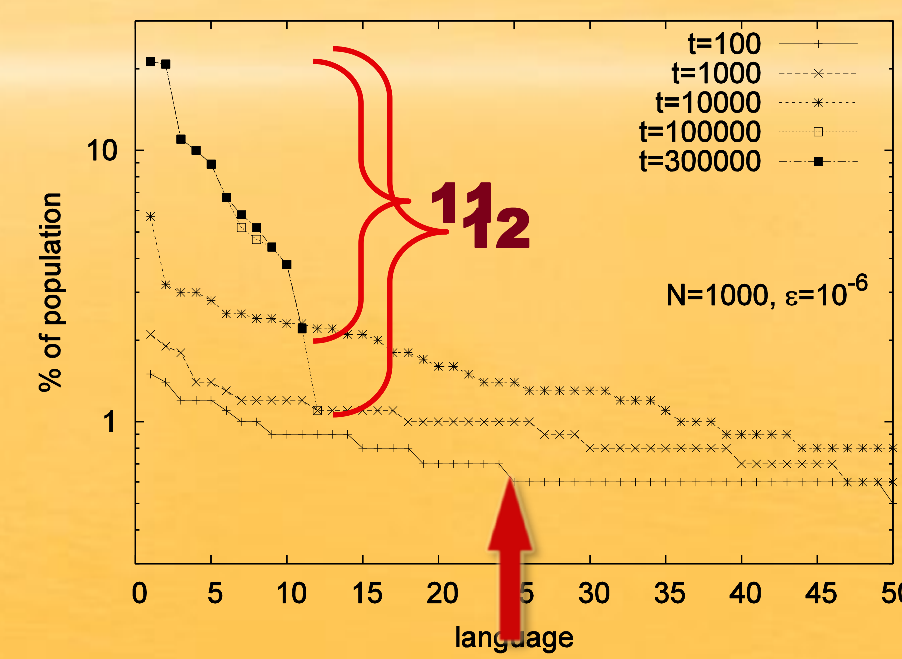
The time dependence of the ratio of agents that use the most common language N_d/N calculated for several values of N and for $N\varepsilon^2 = 10^{-9}$. The inset shows the time dependence of the success rate s.

single-language regime

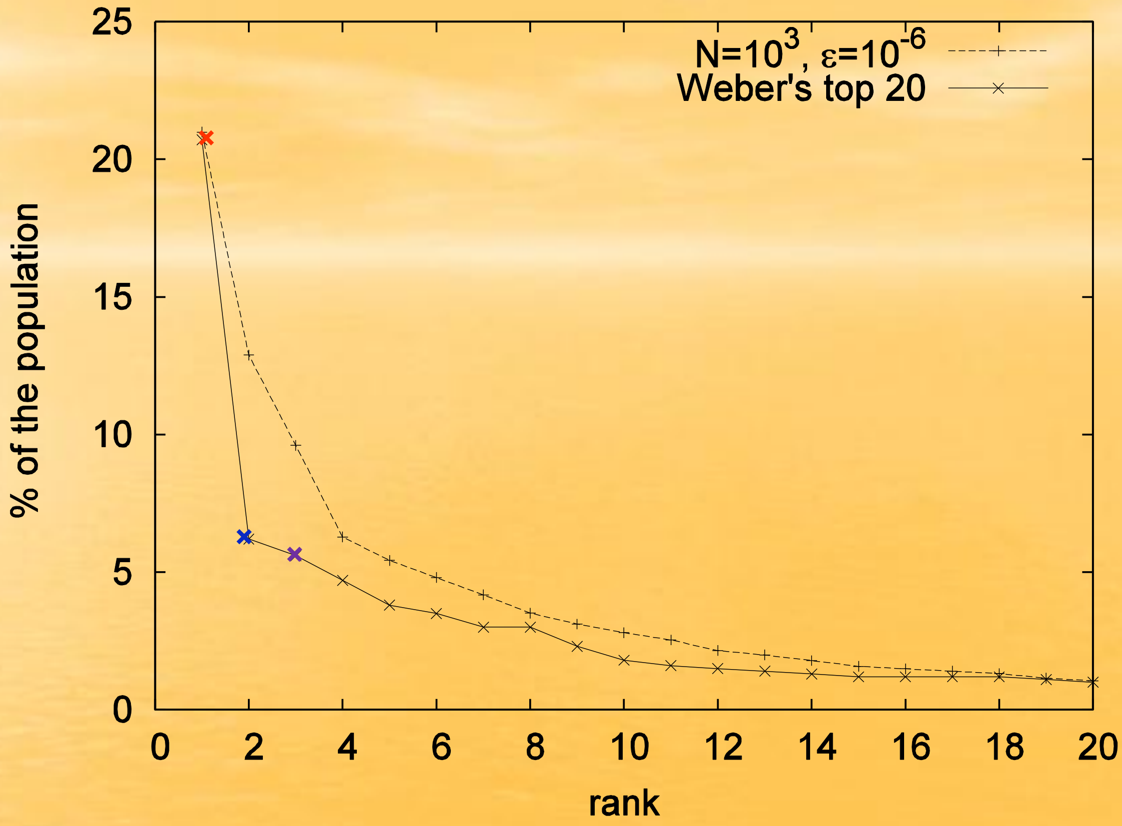


The percentage of population constituted by the users of the 50 most common languages, calculated for $N = 1000$ and $\varepsilon = 10^{-4}$.

multi-language regime



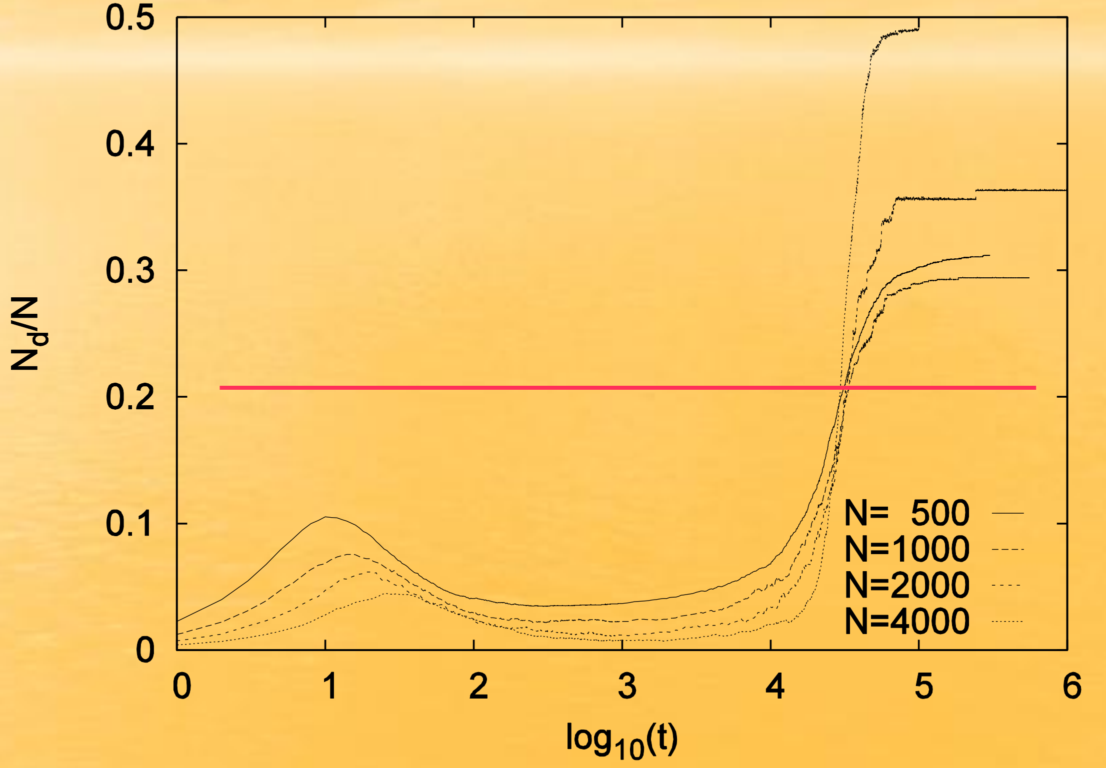
The percentage of population constituted by the users of the 50 most common languages, calculated for $N = 1000$ and $\varepsilon = 10^{-6}$.



The fraction of the population constituted by the users of the 20 most common languages, calculated for a multi-language regime and compared with Weber's statistical data (Weber, 1997).

The first three languages according to Weber are:

Chinese (20.7% of the population, i.e., $1.1 \cdot 10^9$ speakers), English (6.2%, $3.2 \cdot 10^8$), and Spanish (5.6%, $3.0 \cdot 10^8$).


0.5
0.4
0.3
0.2
0.1
0
N_d/N
0
1
2
3
4
5
6
$log_{10}(t)$
N= 500
N=1000
N=2000
N=4000

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