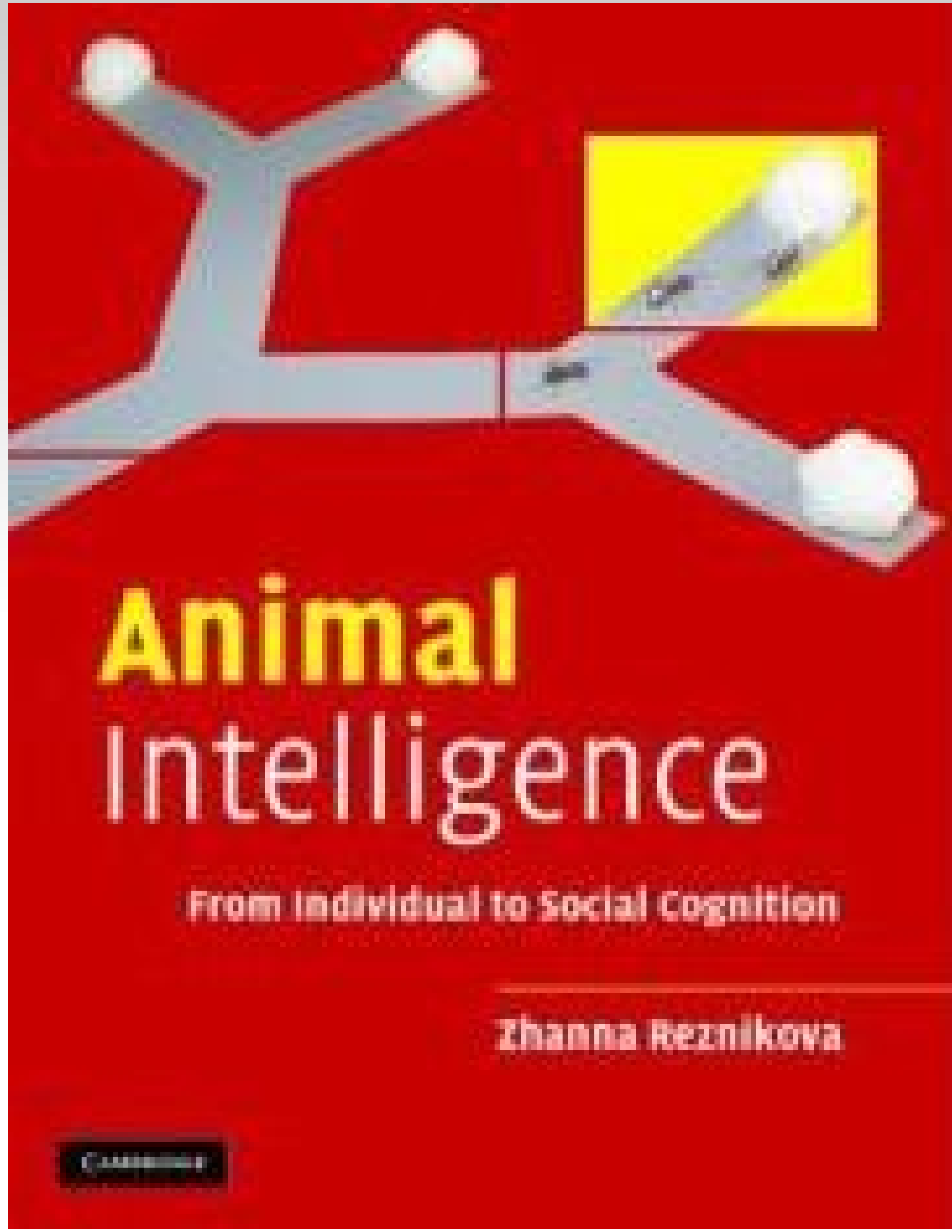
ANTS AND BITS

Zhanna Reznikova
Institute of Systematics and Ecology of Animals RAS and Novosibirsk State University
Boris Ryabko
Siberian State University of Telecommunication and Computer science; Institute of Computational Technology RAS

Thousands of works have been devoted to animal communication and intelligence.

The complexity of communication systems in animals is closely connected with their intelligence.



Three main approaches to the problem of animal "languages" exist:

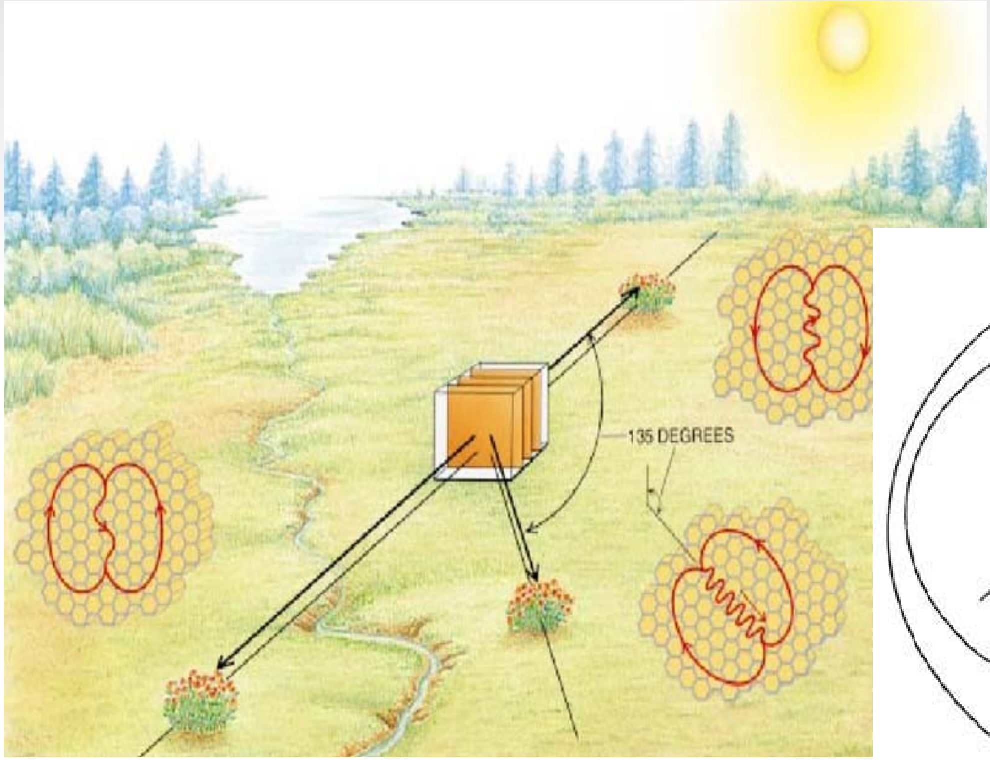
1) Direct decoding of signals:

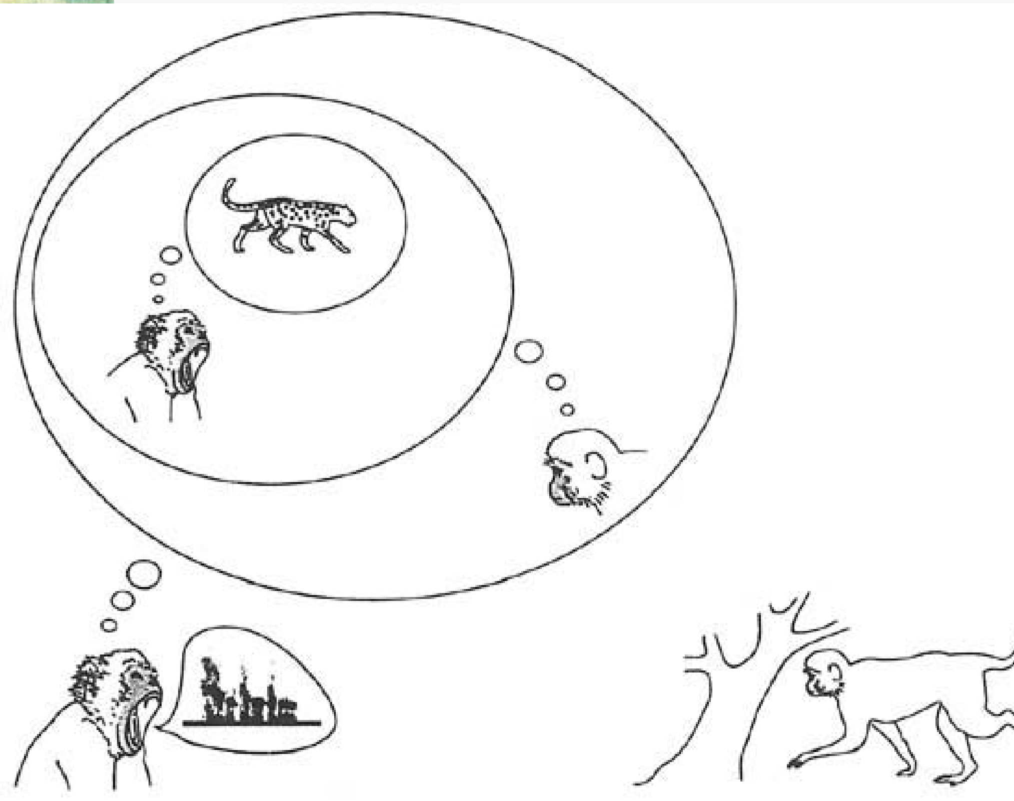
2) Designing artificial intermediary languages

3) The information theory approach (suggested by us)

Direct decoding of signals

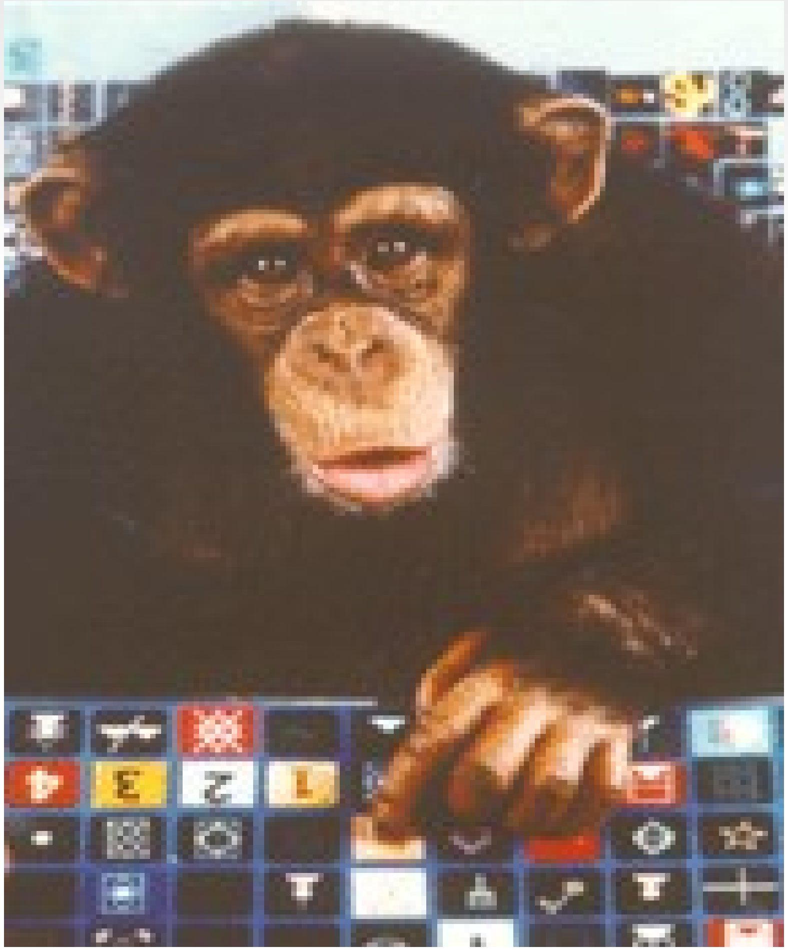
Only a few "words" of a few species have been decoded.





Intermediary languages are based on adapted human languages.

Natural languages of these species remain unknown!



Information Theory approach

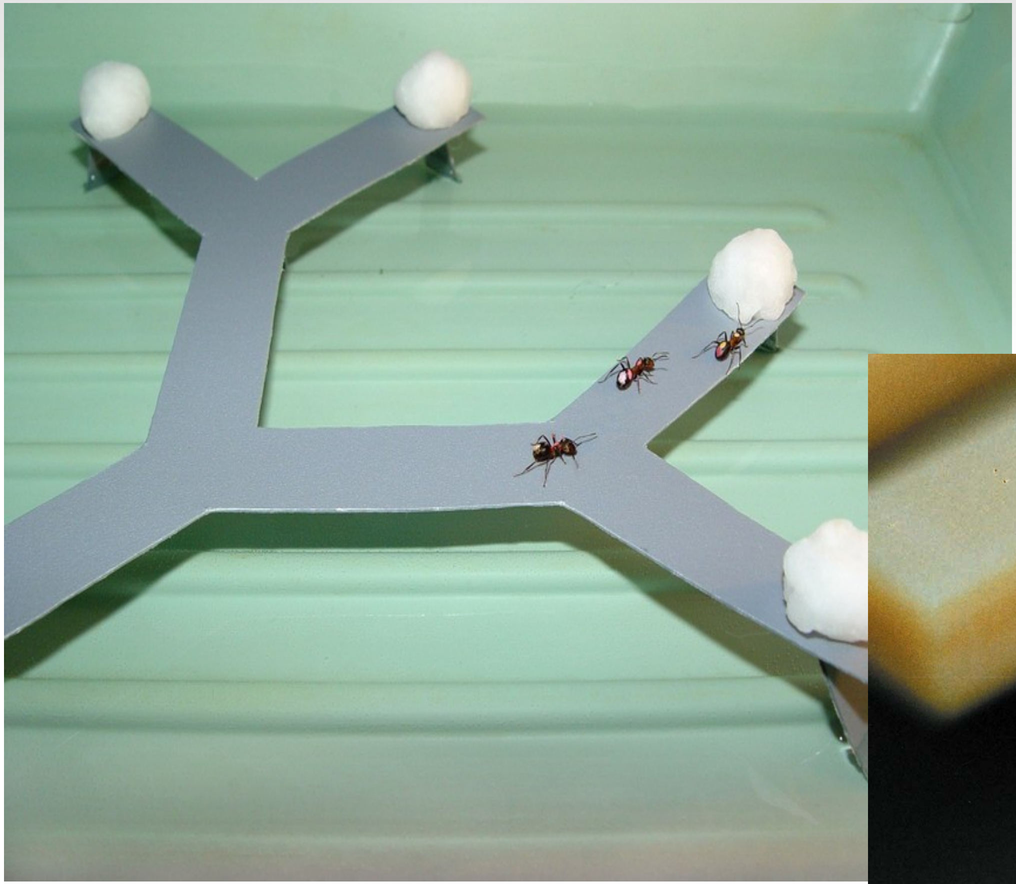
The main point: not to decipher signals
but to investigate the very process of information transmission by measuring time duration which the animals spend on transmitting messages of definite lengths and complexities.

First results were published in the 80th

Information Theory approach enabled us to:

(i) reveal distant homing in ants, that is, their ability to transfer information about remote events;
(ii) estimate the rate of information transmission in ants;
(iii) reveal that ants are able to grasp regularities and to use them for compression of information;
(iv) reveal that ants are able to transfer to each other the information about the number of objects;
(v) discover that ants can add and subtract small numbers.

Experiments with the *binary tree* and *counting mazes*



PART 1

Using Shannon entropy and Kolmogorov complexity to study communicative system in ants: The *binary tree* experiments


фото О.Б.Выгоняйловой

In red-wood ants small teams search for a certain leaf with an aphid colony within a tree crown.

Teams remain stable for several days and even weeks

The entropy-based approach demonstrates that:

► the set of messages ants are able to pass is huge (potentially unlimited)

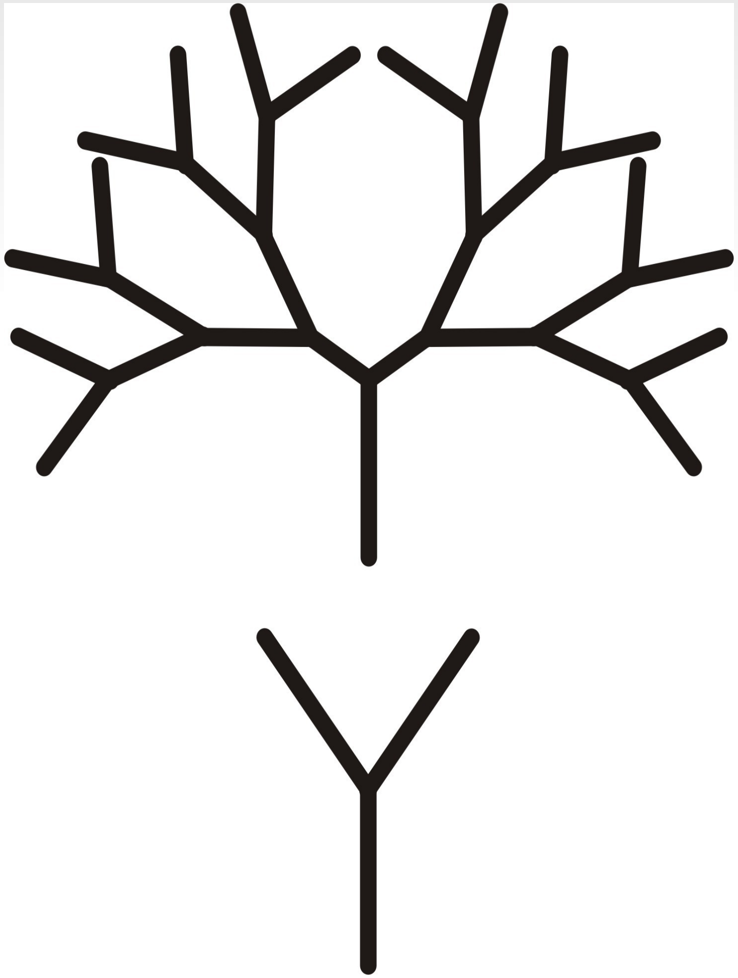
► the speed of transmission of information by ants is (approx.) 1 bit per minute

The Kolmogorov complexity – based approach shows that:

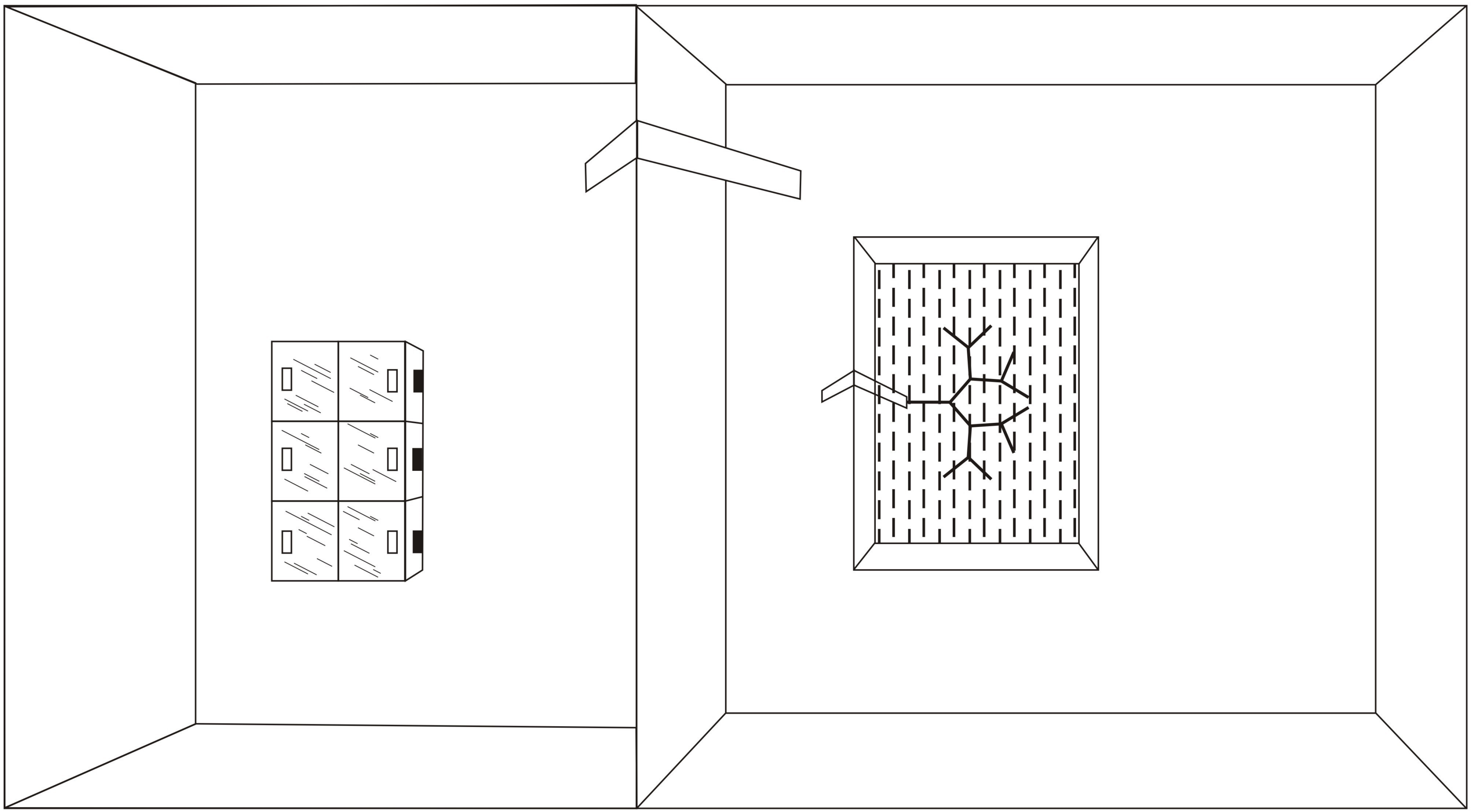
► ants can use simple regularities to compress information

Experimental paradigm

All you need is to ask ants to transmit several bits of information



The quantity of information (in bits), necessary for choosing the correct way in the maze equals *i*, the number of forks.

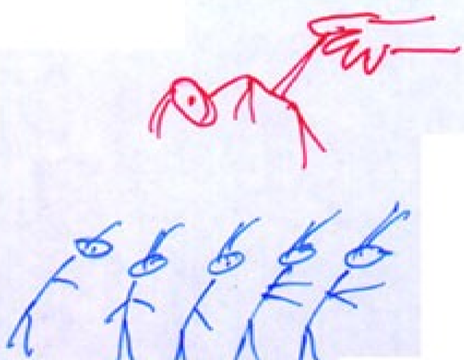


HOW ANT TEAMS WORK

A team
(4-8 ind)

A scout

Information
Transmission



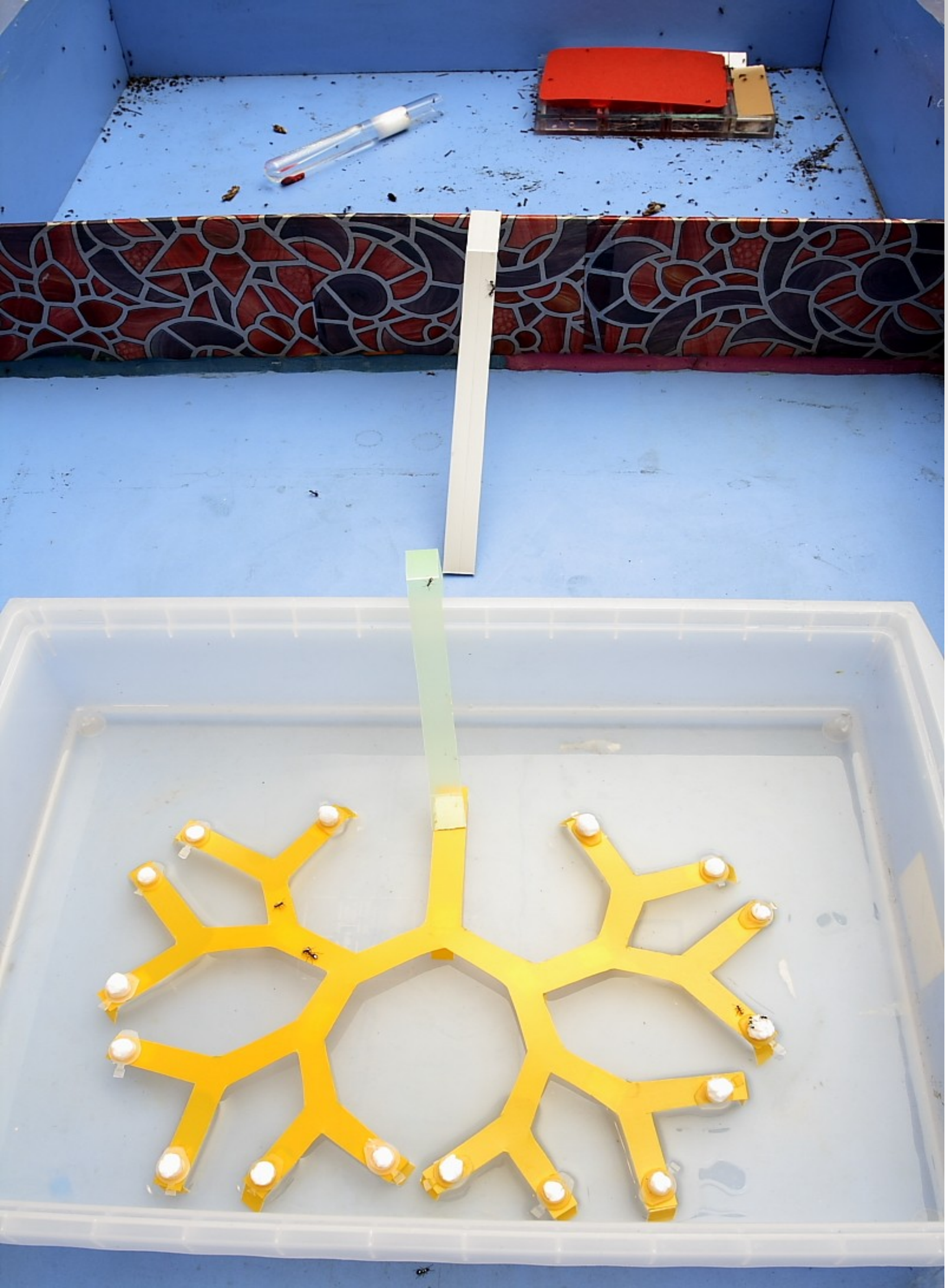
We have to search it
by ourselves …

Teams include one scout and three to eight foragers.

The scout attracts only members of its team to the food; foragers are not able to pass information.

Experimental procedure

1. We placed a scout on the trough
2. The scout returned to the nest on its own
3.The scout contacted its team (the duration of the contact was measured)
4. The scout was isolated
5. The foragers searched for the food themselves

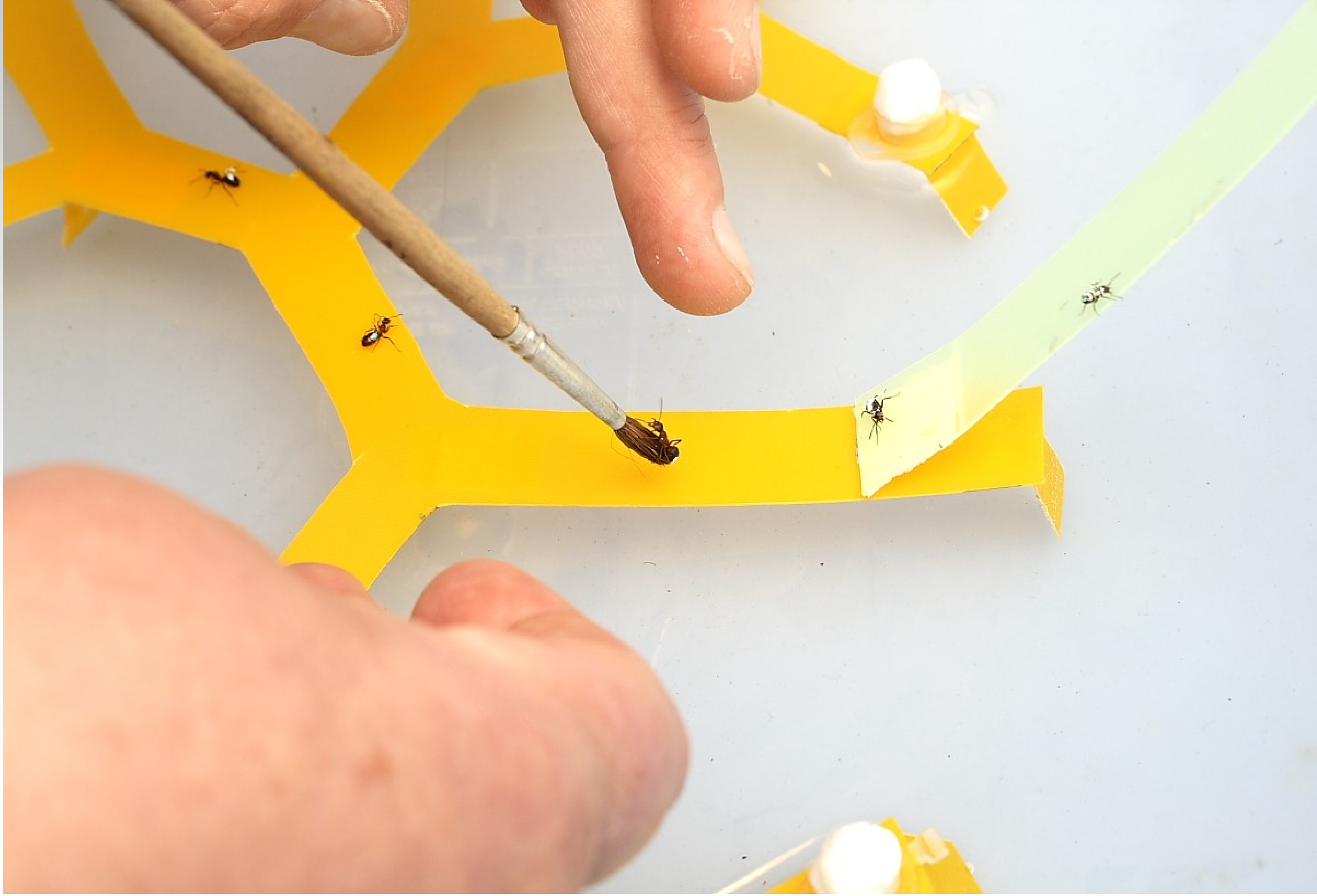


A laboratory arena is divided into two sections: A smaller one containing a nest, and a bigger one with an experimental system.

A “binary tree” is placed in a bath of water

A bridge ended with a “trample”

Ants were individually marked with colour paint



A scouting ant was placed on a leaf with a trough

Returning to the group, the scout contacted one to four foragers in turn. The duration of the contact was measured in seconds.

To avoid the use of an odor track, the “binary tree” was replaced by an identical one when the scout was contacting its group.

After the scout had contacted its team, it was isolated for a while, and the foragers had to search for the food by themselves.

In different years we cooperated with **335** scouts and their teams.

Each scout took part in tens of trials.

Estimating the rate of information transmission in ants

338 trials for 2,3,4,5 and 6 forks.

H_0 : Ants find the "right" leaf randomly

H_1 they find the goal thanks to obtained information

The probability of a chance finding of the correct way with ***i*** number of forks is $(1/2)^i$.

H_0 was rejected.

In <u>control experiments</u> uninformed foragers spent 10-15 time more to find a feeder than informed ones.

We assumed that the duration of the contacts between the scouts and foragers $t = ai + b$

i is the number of forks,

a – the time to transmit one bit ,

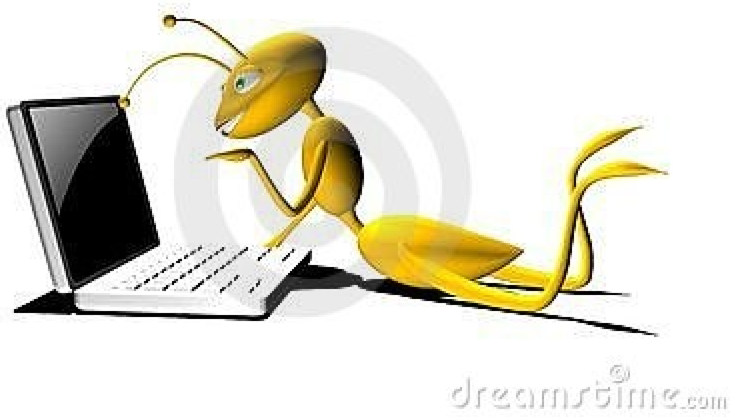
b - a constant

(ants can transmit information not related directly to the task)

In three ant species the time a to transmit one bit is 0.74, 1.09 and 1.19 min.
(about 10 times larger than in human communication).

The potential productivity of ants language is high

In a tree with six forks the total number of different routes is at least $2^6=64$.



Kolmogorov complexity and data compression in the ant language

Ants can grasp regularities of the "text" and use them to optimise and shorten their messages.

They spent half the time for transferring the information about "regular" sequences of turns (such as "RRRRRR" or "RLRLRL"), as compared to shorter but "random" sequences, such as "RLLRL".

ANTS CAN COMPRESS INFORMATION

Duration of transmitting information (in sec) from scouts to foragers (no.1-8 regular turn pattern; no. 9-15 random turn pattern)

No	Sequences	Mean Duration(sec.)	SD	Numbers of trialss
1	LL	72	8	18
1	RRR	75	5	15
2	LLLLL	84	6	9
3	RRRRR	78	8	10
4	LLLLLL	90	9	8
5	RRRRRR	88	9	5
6	LRLRLR	130	11	4
8	RLRLRL	135	9	8
9	LLR	69	4	12
10	LRLL	100	11	10
11	RLLR	120	9	6
12	RRLRL	150	16	8
13	RLRRRL	180	22	6
14	RRLRRR	220	15	7
15	LRLLRL	200	18	5

The ants began using regularities to compress only quite large “texts.”

They spent from 120 to 220 sec. to transmit information about random turn patterns on the maze with 5 and 6 forks and from 78 to 135 sec. when turn patterns were regular.

There was no essential significance when the length of sequences was less than 4.

Part II.

numerical competence: an insight from ants

Numerical competence is one of the main intriguing domains of animal intelligence.

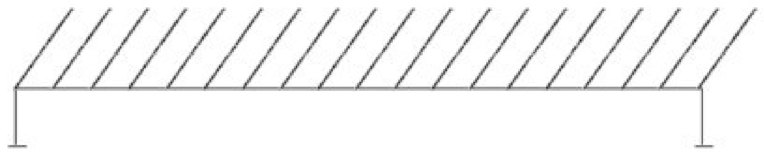
We suggested a new experimental paradigm which is based on ideas of information theory and is the first one to exploit natural communicative systems.

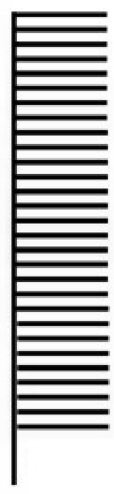
This approach revealed that:

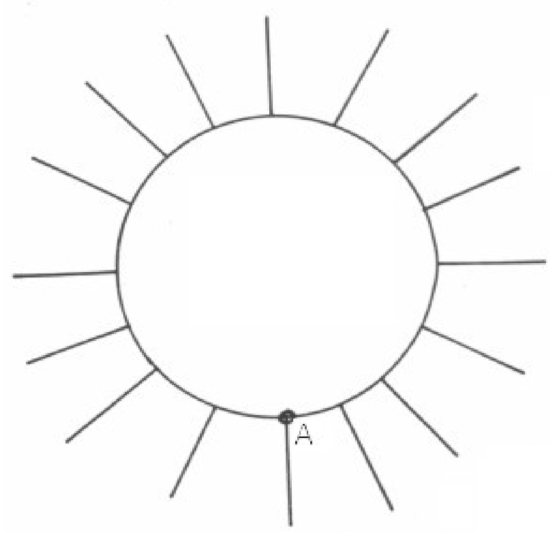
(1) Ants are able to pass information about the number of objects within thirty.

(2) They can add and subtract small numbers.

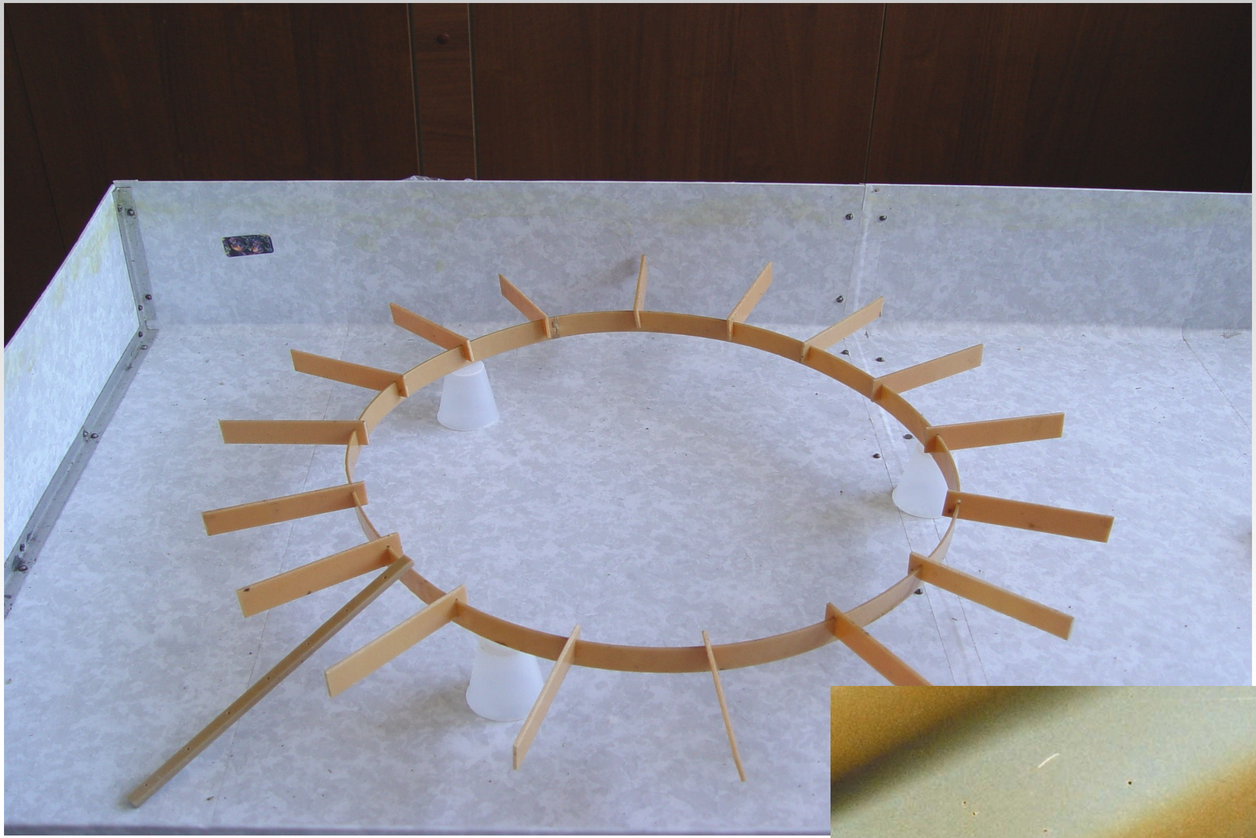
We measured the duration of time spent by a scout for the transmission the information about the number of the branch containing food.







Counting mazes: a circle and



a horizontal trunk (an ant team has just arrived to an empty brunch)

Ants can transfer information about numbers

From 2 laboratory colonies, 32 scout-foragers teams worked in three kinds of counting mazes.
From 152 trials in 117 cases the team immediately found the goal.

$t = ai + b$ for different set-ups
i -the index number of the branch
t- the duration of the contact between the scout and the foragers

The values of a and b are close and do not depend either on the lengths of the branches or on other features of set-ups.

The likely explanation is that ants can evaluate the number of the branch and in the sequence of branches in the maze and transmit this information to foragers.

Presumably, a scout could pass messages not about the number of the branch but about the distance to it or about the number of steps and so on.

Even if ants operate with distance or with the number of steps, this shows that they are able to use quantitative values and pass on exact information about them.

In some human languages numbers are represented in a similar way.

1=finger

2 = finger,finger....

14 357 108 893 872$=?

Mundurucus Indians (2005)

Ants can add and subtract small numbers

A fundamental idea of information theory: The more frequently a message is used in a language, the shorter is the word or the phrase coding it.

Four ant colonies; a horizontal trunk with 30 branches.

Each experiment was divided into three stages, at each of them the regularity of placing the trough on branches with different numbers was changed.

Three stages of the experiment:

I: the branch containing the trough was selected randomly, with equal probabilities for all branches. The probability of the trough with syrup being placed on a particular branch was 1/30. This did not differ from previous experiments.

II: two “special” branches A and B were chosen (N 7 and N 14; N 10 and N 20; and N 10 and N 19 in different years) on which the trough with syrup occurred with the probability **1/3** for “A” and “B” (and **1/84** for each of the other 28 branches).

III: the number of the branch with the trough was chosen at random again.

At the first stage (random selection of a branch containing food) the dependence was close to linear.

At the third stage: (1) the information transmission time was very much reduced, (2) the dependence of the information transmission time on the branch number was non-linear, with a depression in the vicinities of the "special" points (for ex.,10 and 20)

An example: The first stage – branch N 11 – 70 -82 sec
branch N 1 - 8-12 sec

The third stage – branch N 11 5-15 sec
branch N 1 – the same

Ants have changed the mode of presenting the data.

The number of the branch	Distance to the nearest special branch	Times of transmission of information about the branch
26	6	35, 30
30	10	70, 65
27	7	65, 72
24	4	58, 60, 62
8	2	22, 20, 25
16	4	25, 8, 25
16	4	25
22	2	15, 18
18	2	20,25,18,20
15	5	30, 28, 35, 30
20	0	10, 12, 10
6	4	25, 28
16	4	30, 25

We calculated the coefficient of correlation between the time for transmission of a message about the trough *i* and the distance from *i* to the nearest "special" branch.

The correlation coefficient (*r*) in the experiments with different "special" branches

Sample size	Numbers of "special" branches	*r* for the first stage of the experiments	*r* for the third stage of the experiments
150	10,20	0.95	0.80
92	10, 19	0.96	0.91
99	15	0.99	0.82

Coefficients have high values and they differ significantly from zero.

The scout's message consisted of two parts: (1) a “number” (a “name”) of a “special” branch nearest to the branch with the trough and (2) how many branches away is the desired branch from the “special” one. This is the number which had to be added or subtracted in order to find the branch with the trough.

The numbers of the “special” branches (for ex.,10 and 20) played a role similar to that of the Roman numbers V and X.

The time is shorter when the branch is closer to any of the “special” ones.

Ants were forced to develop a new code in order to optimise their messages.The usage of this new code has to be based on simple arithmetic operations.

CONCLUSION

- Information theory can be used to study natural communication systems.

As an example, we show that ants can:

- transfer information
- compress information
- change the way they represent information
- add and subtract small numbers

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04/12/2011

Ants can solve simple arithmetic problems and communicate numbers to their colony brethren, according to a new study in the journal *Behaviour*. While birds like pigeons ace math and non-primate humans like chimpanzees do OK, ants may have the most precise mathematical skills.

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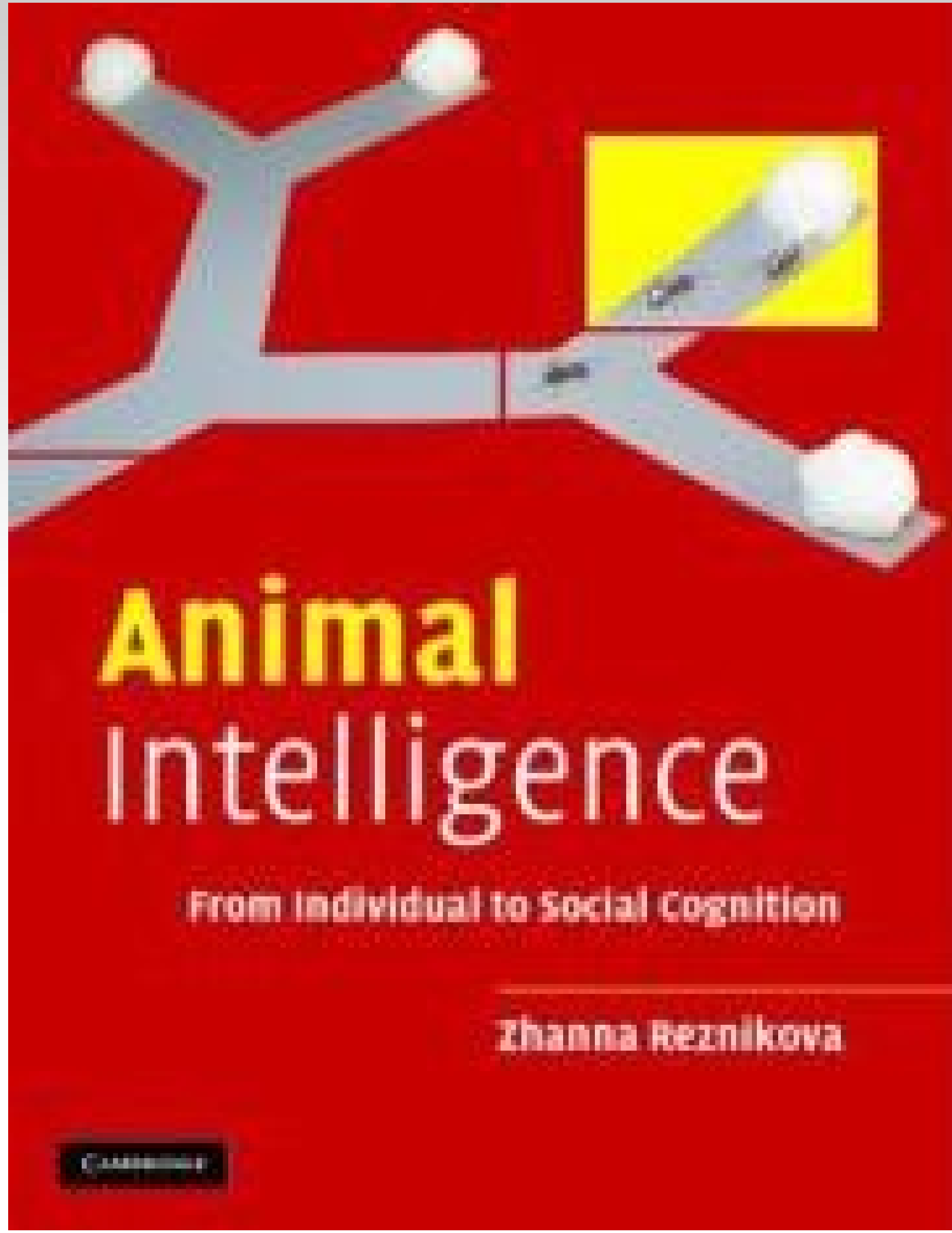

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