Application of Information Theory for studying numerical competence in animals: an insight from ants

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Why from ants?
Ants possess sophisticated communication system and a high level of intelligence.

An anthill of red wood ants

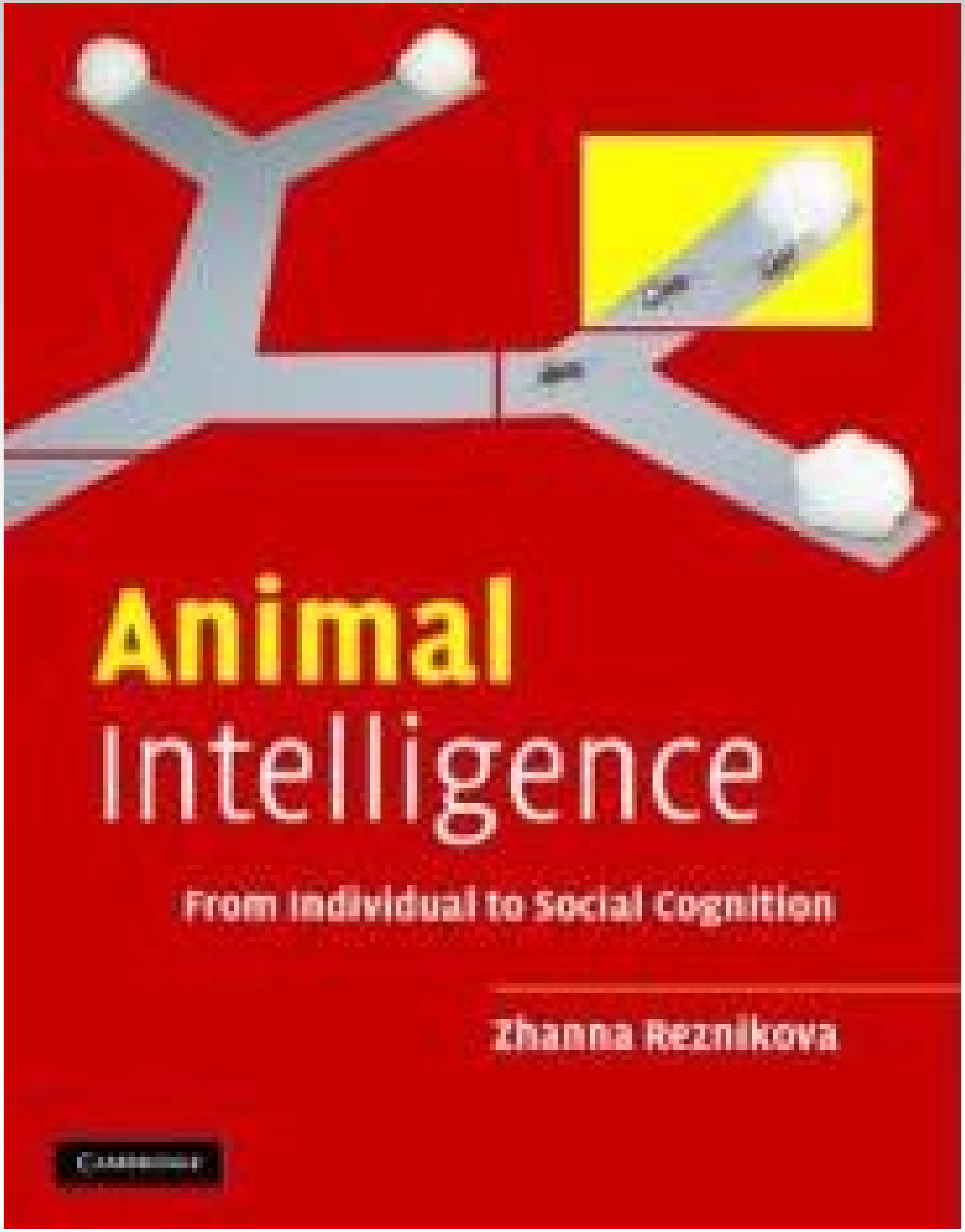
There are more than 12 000 ant species on Earth.
Only a few highly social species belong to the elite club of "cognitive specialists"

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

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

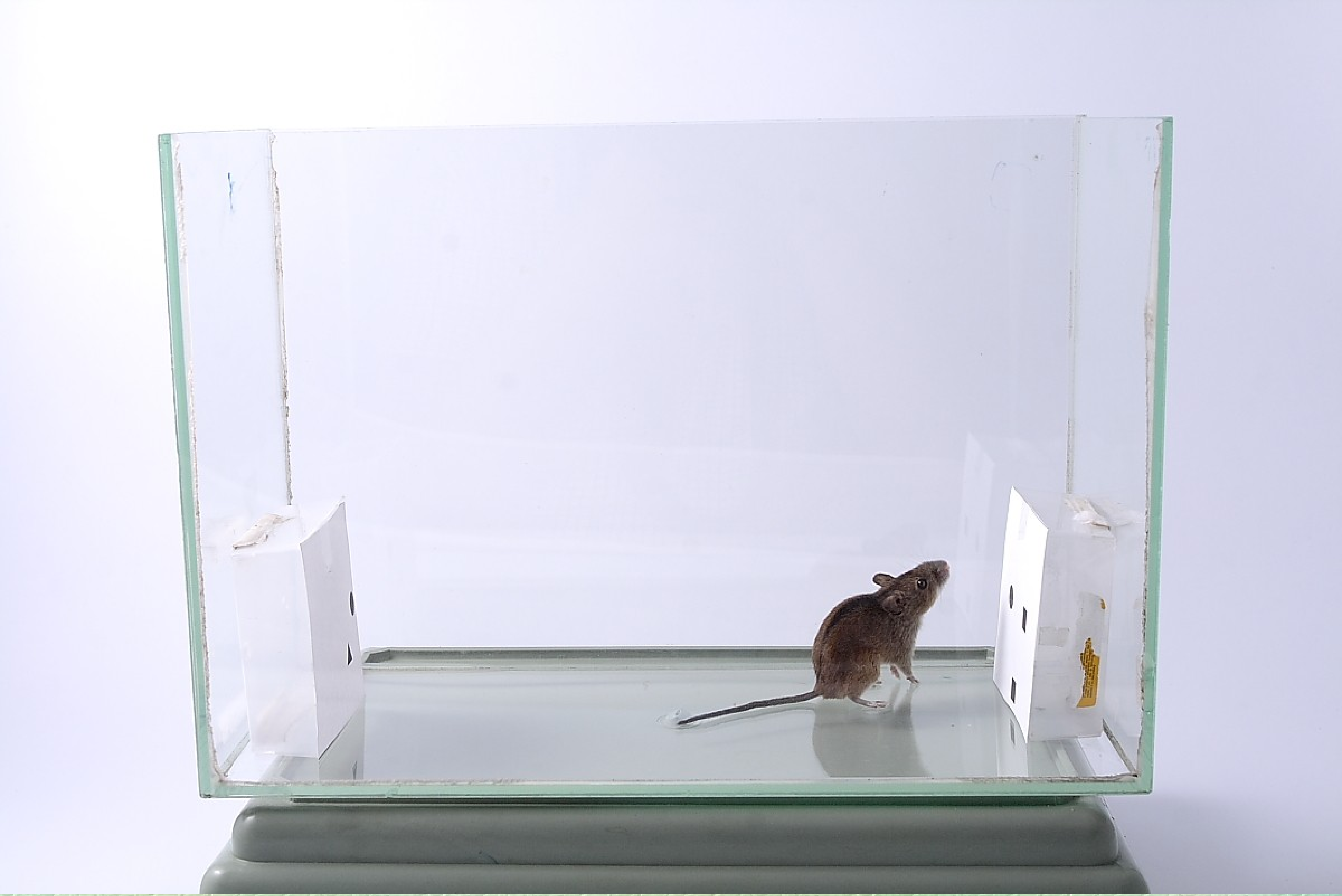
The complexity of communication systems in animals is closely connected with their intelligence.

Cambridge University Press, 2007



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

Only a few species are capable of enumerating beyond the traditional limit of precise number discrimination which is usually three to four items in animals



In our lab wild mice distinguish between 8 and 9 (2 vs.3 here)


2+3
2+2=?
NOAH
20 10

Recent studies have demonstrated many species as being able to judge about numbers

We are still lacking an adequate “language” of comparative analysis of numerical competence in animals.

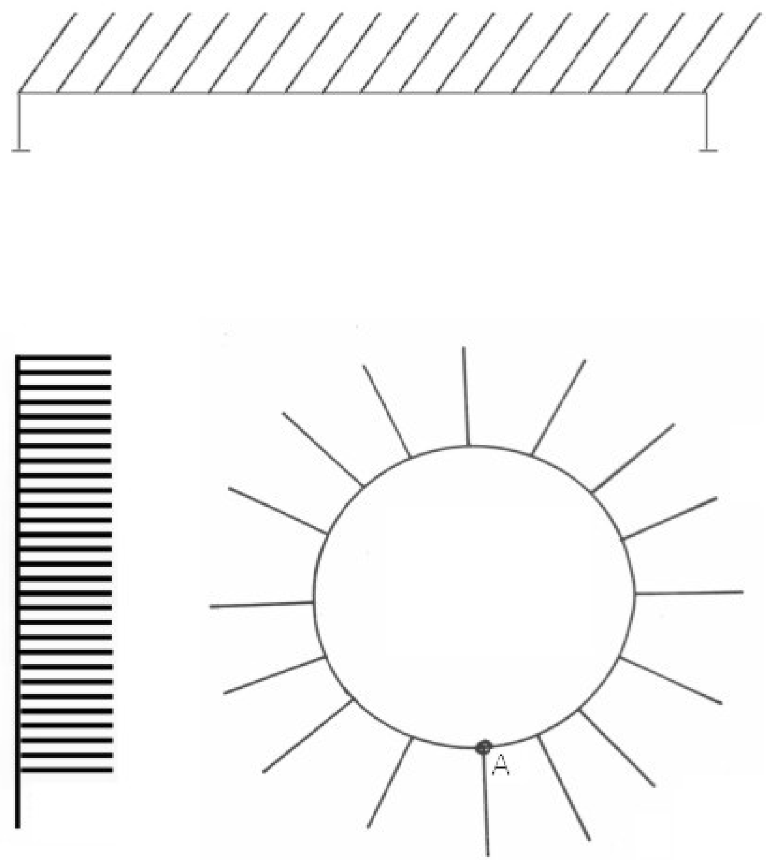
We suggested a new experimental paradigm which is based on ideas of information theory and is the first one to exploit natural communicative systems.

This approach revealed that:

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

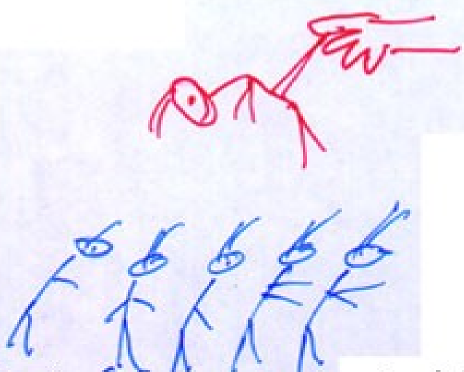
(2) They can add and subtract small numbers.

Experiments with counting mazes



The main idea is that we can judge how ants represent numbers by estimating how much time scouting ants spend on “pronouncing” numbers, that is, on transferring information about index number of branches

HOW ANT TEAMS WORK



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.

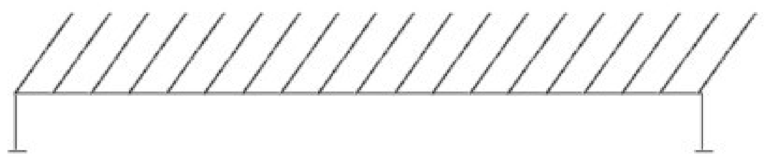
Experimental procedure

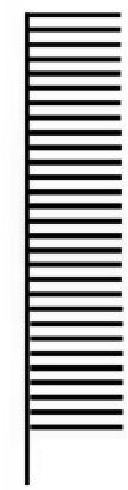
1. We placed a scout on the trough
2. The scout returned to the nest on its own
3. The scout contacted its team (the duration of the contact was measured)
4. The scout was isolated
5. The foragers searched for the food themselves

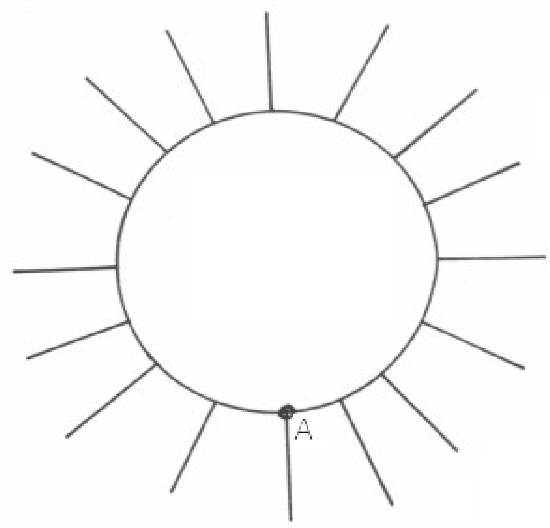
Ants were individually marked with colour paint

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

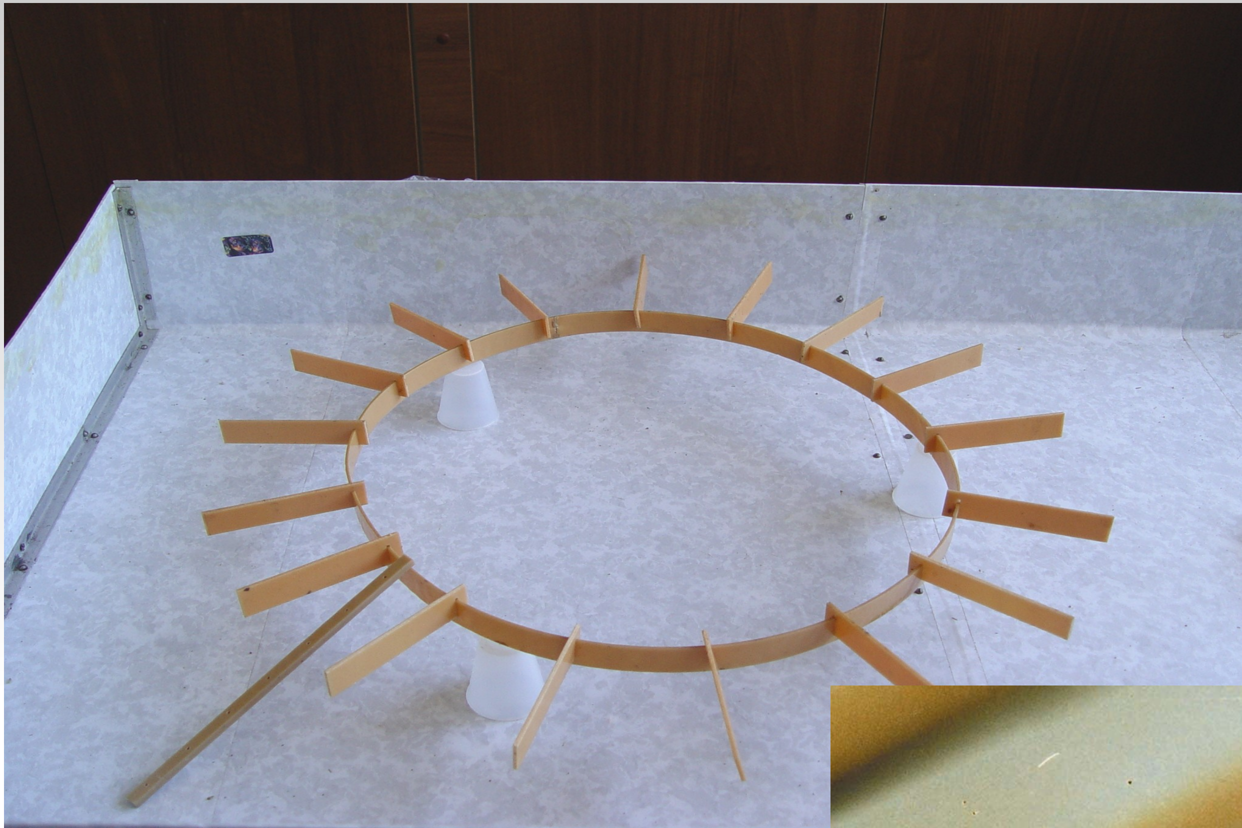
We measured the duration of time spent by a scout for the transmission the information about the number of the branch containing food.







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 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

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

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

Information theory is not only excellent mathematical theory bur many of its results can be considered Nature laws.

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Ants May Be Math Wizards of the Animal Kingdom

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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