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ANT APTITUDE FOR THE TRANSMISSION OF INFORMATION ON THE NUMBER OF OBJECTS

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SUMMARY

A series of experiments demonstrating the ant's ability to count at least up to 60 is described. We consider that the ability to count and to communicate effectively, based on language behaviour, demonstrate the existence of intellect in ants. We also consider the theory of superorganisms in the light of data, based on studies of ant intelligence.

INTRODUCTION

The ability of elementary reasoning in animals, i.e. their ability to abstract, to extrapolate, to count, to plan their behaviour, and to use the experience gained in new situations, has long been a matter of interest to ethologists.

K. von Frisch (1914, 1923) was the first to use the method of associative training of social insects. Tere have been many studies of the high mental capability of social insects and the complexity of their communication. G Mazokhin-Porchnyakov and his co-workers have convincingly demonstrated the aptitude of social insects for logical operations (Mazokhin-Porshnyakov, 1968; Mazokhin-Porshnyakov et al., 1984).

But there are conflicting opinions among ethologists on aspects of the intellectual behaviour in social insects. MacFarland in "Animal behaviour" (1985) says that the modern state of knowledge does not suggest psychic capacities in the honeybee, as that seems fantastic. The concept of the Superorganisms, forgotten in the sixties and seventies, now has been revived. B. Hölldobler and E. Wilson suggest in their monograph "The Ants" (1991), that this concept be resurrected given the present state of knowledge and that it should be possible to extend the analogs of the structural parts of the colony of social insect on to organs and tissues. The modern version of this concept is based on the complex integration of the insect community, which is related to simple ontogenetic processes, since the complex system appears to consist of very simple elements.

One of the ways to progress in this field is to investigate the most pronounced manifestation of the ability of reasoning, namely, language behaviour. The dances of the honeybee, described by K. von Frisch (1923, 1965), are the most complex of the known forms of insect communication. According to Menning (1979), "the world should admit that information as a symbolic form is available not only to man, but to such a modest creature as the honeybee".

Our paper describes experiments concerned with the ant's aptitude for transmitting information on the number of objects, in our case up to 60. We have not investigated individual capacities, but have performed experiments on the communication system of the whole colony.

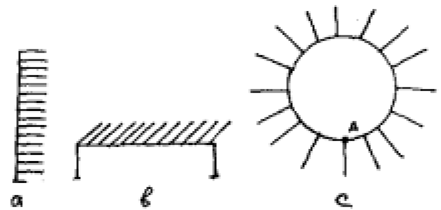

Fig. 1 The setups: a vertical trunk (a), a horizontal trunk (b), and a circle (c).

MATERIALS AND METHODS

The experiments were performed in 1984 - 1985 and 1988. Ants lived in the 2x2 m laboratory arena, in a transparent nest. The colonies consisted of 800 - 2000 specimens. All experimental ants were marked with coloured labels and fed once every three days only in the experimental setup. The experimental setups, consisted of a long "trunk" with equally spaced branches, made of matches or thin boards. Each branch ended in an empty trough, except for one filled with syrup. The time needed for a scout to transmit information on the number of the food- containing "branches" was determined. The foragers of the species investigated (*Formica polyctena* Foerst.) separated into teams of 5-8 specimens, each with one scout. As soon as the scout found food, it informed the forageing team. We placed scouts on the branch with the trough containing food, and the scout returned to the nest on its own. Sometimes the scout contacted its team at once, and the group began moving towards the setup. In this case, after the scout contacted the foragers, we isolated the scout and the foragers had to search for the food by themselves. But more often, after the scout returned to the nest, it left it and returned to the trough alone. Sometimes it made errors and only found the food-containg trough after visiting some empty ones. Then it returned to the nest again, contacted the team, and either remained with the team or left it. In the first case, the scout was isolated, while in the second case, we performed the experiment repeatedly. Sometimes the scout had to make up to four trips before it could mobilize the foragers. In all cases of mobilization, we measured the duration (in seconds) of the contact between the scout and foragers in the nest. We considered the beginning of contact to occur when the scout touched the first forager ant, while we took the end of contact to be the moment when the nest was abandoned by the first two foragers. Contacts were followed often by numerous antennal movements. Scouts contacted one to four foragers in turn, sometimes two simultaneously. When the scout repeatedly returned to the trough alone, we measured each of its contacts with foragers. Only the duration of the last contact, followed by the foragers' abandonment of the nest, was taken into account.

During contact of scout and forager in the nest, the experimental setup was exchanged for a similar one to avoid the use of an odour track by the ants. During the experiment, troughs were placed on the branches at random: in the first series (Table 1), the food was in branch N10; in the second one, in the branch N40; etc., so that up to 4 teams active that particular day were working on a given branch. Foragers of other teams were not permitted to visit the experimental setup during this series. The design of the experiments permitted us to control differences in the duration of information transmission on the number of the branch.

RESULTS AND DISCUSSION

A number of scouts turned out to be unable to transmit the correct information on the number of the food-containing branch: some foragers, after being contacted by these scouts, failed to find the correct path at once; their "incapable" scouts were removed from the setup.

Groups which successfully found the way to the trough did not show any significant differences in the duration of information transmission of the number of branch, and thus the data for all teams were combined. Note that of the 26 teams which participated in the experiments, scouts of 19 teams successfully transmitted the information on the branch number and that 7 teams failed to do this. Fifteen series of experiments with five scouts and their teams were performed in the setup with vertically distributed branches ("vertical trunk", Fig.1a). To study whether the duration of information transmission of the branch number depends on the branch length as well as on the distance between branches, we carried out a similar series of experiments (16 in total) on the vertical trunk with branches five times longer and twice as far apart. To exclude the dependence of the duration of information transmission on the form of the setup, its spatial orientation, etc., 30 experiments were performed on the horizontal setup ("horizontal trunk", Fig. 1b) and 38 on the circular setup "circle" (Fig.1c).

Ants came to point A on the circle and to the initial point of horizontal trunk via a bridge (the setup was mounted in a cuvette with water to avoid the ants moving in a straight line). Data were obtained as for the "vertical trunk", i.e. setup 1 (Table. 1).

Twenty six teams (5 in 1984 and 21 in 1985) worked in four setups. In total, the teams abandoned the nest after they were contacted and moved towards the trough 130 times. Note: we specially removed the scouts. In 99 cases the team immediately found the correct path to the trough, without making the wrong trips to empty troughs.

In the remaining cases, ants came to the empty troughs, and began looking for food by checking neighbouring branches. We did not include these cases later in the data. In all experiments (31 in total), foragers failed to find the food-containing trough when "incapable" scouts were working. Such scouts were experimentally removed from the working part of the arena.

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Table 1. The results of experiments in the "vertical trunk 1".

Exp. number	Date	Number of food-cont. branch	Duration of scout-forager contacts	Working team number
1	10.XII.	10	42	I
2	10.XII.	10	40	II
3	10.XII.	10	45	III
4	14.XII.	40	300	II
5	14.XII.	40	280	IX
6	17.XII.	13	90	II
7	17.XII.	13	98	I
8	17.XII.	28	110	III
9	17.XII.	28	120	X
10	19.XII.	20	120	X
11	19.XII.	20	110	III
12	19.XII.	35	260	III
13	19.XII.	35	250	X
14	23.XII.	30	160	I
15	23.XII.	30	170	III

Since all setups had no less than 25 branches the probability to find the correct trough randomly is less than 1/25. Thus, the ratio we obtained experimentally can only be accounted for by information transmission from scouts. We note that the probability of finding the food-containing trough randomly in 90 cases out of 130 is less than 10^{-10}.

In addition, ants, including scouts, placed in the setup, without having information on which trough contained food, usually failed to find the food, even though they actively searched for it.

Data obtained on the setup "vertical trunk 1" are shown in Table. 2. The relation between the number i of the branch and the duration t of the contact between scout and foragers is linear and described by the equation $t = ai + b$. The coefficient of correlation between t and i is high (Tabl. 2). These parameters were also measured for other setups (Table 2).

On the "circle", the food-containing branch was numbered from the point A counting clockwise, because in all cases the foragers moved only in this direction, even when the counter-clockwise path was much shorter; we do not know the reasons for this.

Table 2. Values of correlation (r) and regression (a, b) coefficients.

Type of setup	Sample size	Maximum number of branches	r	$a \pm \sigma a$	$b \pm \sigma b$
Vertical trunk	15	40	0,93	7,3±4,1	-28,8±0,51
Vertical trunk	16	60	0,99	5,88±0,44	-17,11±0,65
Horizontal trunk	30	25	0.91	8,54±1,1	-22,2±0,6
Circle	38	25	0,98	8,62±0,52	-24,4±0,61

It is interesting that on the "vertical trunk" after contact with the scout foragers climbed quickly to the upper end of the trunk, and then slowly returned to the food-containing branch; thus we numbered the branches starting from the upper end of the trunk.

We can conclude that, ants are capable of at least limited counting and that their "language" allows them to transmit numbers. The fact, that the dependence of the length of time t to transmit information on the number i of the branch is well-described by the equation $t = ai + b$. The similarity between the values of a and b for the various numbers i is suggestive of the ant's ability to transmit information about the number of the branch.

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