COMMENTARY ON

Gifted Birds

ARISTOTLE was of the opinion that man is a rational animal because he can count. This may not seem to us a very impressive argument. Arithmetic is easier than it was in ancient times; the number system has been improved and better methods of calculation have been invented. We use machines which are far more proficient at arithmetic than even the cleverest human computer. It is not surprising, therefore, that arithmetic has lost caste. Bertrand Russell points out that "though many philosophers continue to tell us what fine fellows we are, it is no longer on account of our arithmetical skill that they praise us." [1]

Until recently, however, it was thought that man alone could count; now even this small remnant of pre-Darwinian eminence has been snatched from him. Everyone has seen performances by mathematically gifted horses and dogs (some of them also tell fortunes). But there is little ground for believing that these depressing animals have the faintest idea what they are doing when they stamp or bark out the correct answers to problems of arithmetic. Possessing an initial aptitude for learning commands, they merely obey signals given skillfully (and perhaps even involuntarily) by their masters.

The scientific experiments reported in the following paper by the noted zoölogist, Professor O. Koehler of the University of Freiburg, contain evidence of a different order. They seem to show that animals can be taught to count in the real sense of the word—to recognize differences between unequal groups of dots, or rows of marks, and to take action, to reason, on the basis of quantitative differences. Koehler's pupils have been birds; it is possible that other experimenters have achieved similar results working with dogs, seals, pigs or rats. Konrad Lorenz, the famous Austrian naturalist, has persuaded baby mallards to regard him as their mother by quacking like a duck; Karl von Frisch has demonstrated that bees communicate by a special kind of dance. The skill, imagination and extraordinary patience of these men is exhibited also by Koehler. His studies are important not alone for what they teach about animal behavior, but because they enlarge our understanding of the nature of thinking, of the number concept and of the psychological basis of mathematical reasoning. That is a good deal to learn from the behavior of jackdaws and budgereegahs. St. Francis would be pleased.

[1] Bertrand Russell, *Unpopular Essays*, New York, 1951, p. 72.

A rare bird.—JUVENAL

I heard the little bird say so.—JONATHAN SWIFT (Letter to Stella)

For there is an upstart crow . . .—ROBERT GREENE (1560–1592)

5 The Ability of Birds to "Count"

By O. KOEHLER

SO-CALLED "clever" horses and dogs, like the Loch Ness monster, appear from time to time. The masters of these animals are no doubt often sincere in their belief that their pets really display intelligence of the highest order; for they are quite unable to imagine that the animals can really perceive small involuntary signs and signals which tell them when the right answer has been reached, and so when they must stop barking or stamping, as the case may be. Yet it is now quite certain that that is precisely what these "clever" animals are doing. It was not the stallion 'Zarif' of Elberfeld who reproduced Descartes's "cogito ergo sum" in ill-spelt German, nor was it the dachshund 'Kuno' who answered the professor's question as to what creed he had with the words "Mine is yours!" No, these "clever" animals never solve any problems themselves; they only obey their masters' signs which, given at the proper moment, stop the barking or stamping by which they spell out their answers in code.

In the work here described all possible precautions have been taken to avoid the danger of self-deceit to which the owners of "clever" animals have succumbed in the past, and I hope we have been successful. At any rate, it will be evident from our account that the achievements even of the cleverest of our birds are insignificant compared with those alleged for the "clever" animals. But whereas the performances of the latter are spurious we hope we have proved conclusively that the achievements of our birds are examples of true learning and in no way dependent on clues, voluntary or involuntary, given by the experimenter.

During training and "spontaneous" experiments (see below) the observer and the bird were always separated by a partition so that the experimenter was never seen by it; while at work he was able to watch it through the viewfinder of a cine-camera fitted into the wall. Moreover, when a deterrent was required in conditioning, it was only one degree of punishment and this was always the same. It was thus impossible for the experimenter inadvertently to give signs by means of the punishing apparatus since the latter functioned along all-or-none lines.

After thorough conditioning we made so-called "spontaneous" experiments in which no punishing apparatus was used at all. In these experiments the animal was left entirely to itself and the results recorded automatically, so that all possibility of clues from the investigator was ruled out. Such procedure is, of course, fundamentally different from the process of circus training, where learning continues all the time in front of the spectators. We never see the animal perform alone but are always shown the trainer and animal in co-operation. Our birds learn many tasks without any punishment, merely by self-conditioning. That is by omitting unsuccessful movements and in such cases there is therefore no difference between training and spontaneous experiments; in fact every experiment is spontaneous. Many spontaneous experiments were made by the birds *in complete absence of any human being.* They were left alone with their task in the big garden while the experimenter was occupied far away in the house. He could not see the birds, neither could the birds see him. Then, perhaps after an hour, he would come back and find the problems solved. Thus even telepathic communication between man and animal, if such be a possibility, is excluded. Nevertheless, the results obtained under such conditions with the observer absent were often amongst the best. Nearly all the problems solved by the birds in spontaneous experiments were recorded automatically by cinema. The total length of film required to record such successful solutions has amounted to about 3 Km. Unfortunately the vast majority of this documentary evidence was destroyed by fire during the war, and only four films made for teaching purposes were rescued. Parts of these are what you see to-day. These four films refer only to experiments already published with full statistical details. There remain from the old series, records of experiments of about ten more ravens and one gray parrot, Jake, still to be published. Now we have commenced work again with parrots, magpies and some other species.

It may be asked why we take all this trouble with a problem which is apparently without biological significance since we know no example of any wild bird counting in its normal state? Though this is so, I believe nevertheless the problem is of interest in regard to the old question of the origin of the human *language.* In spite of Revesz' (1946) most valuable book, I believe it is true to say that apart from our experiments, comparative psychology has no evidence to offer towards the solution of this problem. This present congress has given example after example of striking similarities between human and animal action at the lower levels of sensation, orientation, locomotory mechanisms, instinctive behaviour, releasing patterns, social behaviour, moods and learning. Only language appears to be a technique peculiar to man. It therefore seems worth while to suggest as a working hypothesis that all the characteristics which make for the tremendous difference between human and animal behaviour are the consequences of this one human prerogative, viz. language. It is only man that has given *names* to things, ideas, relations, etc. The human child *learns* words just like a parrot; but after having learnt the first few words it may at once form new sentences with them, sentences which express some true relation, which express wishes and which later ask questions. This ability to form new sensible sentences is not learnt in the ordinary sense; on the contrary, this capacity to make reasonable use of learned words is *innate* in the child. This innate capacity is the greatest, indeed the decisive prerogative of man over all animals. As far as I know, no animal has ever learnt to make a similar use of words.

The question arises, however, how it is that our words are fit to be used for forming true sentences, for speaking, ordering and asking; in short, why our language fits our surroundings and why it is of more use than the warblings of a bird. I will try to answer this question by giving an example. *Our birds did not count,* for they lack words. They could not name the numbers that they are able to perceive and to act upon, but in actual fact they learn to *"think unnamed numbers."* The difference between birds and ourselves is perhaps best shown by an instance personally known to me, of how a child learned to count. When nearly four years old, she had learnt the words, one, two three up to seven in the right order and she had learnt to read the figures. She was taught this during a very short time by a reliable friend of the parents who assured them that the lesson had been restricted to exactly these two things (seven words and seven figures, both in the right sequence and co-ordination); nothing more than this was taught. Some days later the child, in the presence of her mother, saw a tram coming, and said, "Look, there comes the three and it has three cars; that fits." It was route No. 3 and the tram had three cars; three was the figure she had read; three cars was the sum of three similar objects, which she had seen and counted. When she further remarked that the figure fits the sum, then that fits meant *"number,"* in the sense that the figure seen and the sum of the objects seen had in common the number *named* three. As a philosopher might say, she had grasped practically the idea of *named numbers*. There is of course nothing abnormal in this. It is merely one example of the innate capacity of every normal human child for using learnt words and at once, without any further learning process, applying them in the right sense; in this instance for counting everything and for calculating without the least instruction. The child had no further contact with her former teacher and the parents themselves gave no further instruction. Indeed they deliberately avoided doing so, but nevertheless she could produce sentences like the following: "I see six is five with one more," "Two and five, I can do that: three (one), four (two) . . . , . . . , seven (five), seven, is right." The parents never encouraged the child and she soon dropped this game. Two years later in school she did not remember her early achievement in mental arithmetic and began to learn counting and, like her schoolmates, with the help of her fingers.

Not even the cleverest of our birds showed inborn capacities like that. But they did learn *unnamed numbers* which were presented to them by two principal methods: (i) simultaneous presentation and (ii) successive presentation. The hypothesis here put forward is that man would never have started counting, i.e., to name numbers, without the following two prelinguistic abilities which he has in common with birds. The first of these abilities is that of being able to compare groups of units presented *simultaneously* side by side by seeing numbers of those units only, excluding all other clues. This problem was presented to birds in quite different ways, starting with only two groups of edible units (grains of corn, fruit, pieces of meat, etc.), the two groups different by one unit only, and at the other extreme rising to choice according to pattern (N. Kohts). A raven, named Jacob, and a gray parrot named Geier were presented with five small boxes covered with lids bearing 2, 3, 4, 5 and 6 spots each respectively—the key being a lid with one of these numbers of spots lying on the ground in front of the boxes. Both birds learned to open only that one of the five lids which had the same number of spots as the key pattern. As a control of the experiment everything was changed in a random manner from one experiment to the next. There were 15 positions of the five boxes and very many different positions of the key pattern; the number of units in the key pattern changed with each experiment and there were five places for the "positive" number of spots on a lid corresponding to that of the key. Moreover there were 24 permutations of the four negative numbers. Also the relative situation of the spots of one group and with Jacob only, the size and form of those spots was changed with absolute irregularity. In the final series of experiments, for each trial I broke afresh a flat plasticine cake into pieces of highly irregular and broken outlines, the size of a piece varying from 1 to 50 units of surface area, and I always took care to make the general patterns of the positive number on the lid as unlike as possible to that of the key pattern. In an experiment such as this I hope that any clue foreign to the problem was excluded, and yet Jacob solved the problem by choosing the positive lid according to the only item which was not changing through all the experiments, i.e. the number of spots equal to that of the particular key pattern presented.

The second ability with which we are concerned is to estimate, i.e. to remember numbers of incidents following each other and thus to keep in mind *numbers presented successively in time,* independent of rhythm or any other clue which might be helpful. Here again many different methods were employed. At first birds were trained to eat only "x" grains out of many offered without any help being given from a figure. For instance, if a hundred or more grains are given in a big heap, one grain touching many others, there are no figures at all for no gaps are to be seen between them (in the budgerigar film you will see birds trained to eat only two or three grains out of a big heap). Another task was to eat only "x" peas which were rolled into a cup, one after another, at intervals ranging from 1-60 seconds. Here again there are no figures at all; the peas are delivered as if by a slot machine, one by one, so the pigeon never sees more than one pea in the cup. The bird always has the same view and there is absolutely no visible clue for distinguishing the last permitted pea from the first forbidden one. The same applies to opening lids of boxes standing in a long row until "x" baits have been secured; since the baits were arranged in the boxes in 20 or more distributions from one experiment to the next, the number of the lids to be opened is constantly changing. For instance, if the bird is trained to take five baits it may have to open any number of lids between one and seven. The bird thus opens lids up to 5 baits, i.e., it "acts upon five," but the number of lids it has to open to get five baits changes with each experiment. Still more remarkable is the fact that birds learned to master up to four problems of this kind at the same time. For instance, a jackdaw learned to open black lids until it had secured two baits, green lids up to three, red lids up to four, and white lids until it had secured five baits. Similarly budgerigars learned to "act upon two" when the experimentor said "dyo dyo dyo" and upon three (take only three grains from the heap) when he uttered the words "treis treis treis . . .". A similar result could be obtained with a bell indicating two and a buzzer indicating three.

Since, as far as we could see, all external clues were carefully excluded in this experiment, only an inner token can have been responsible for the birds ceasing action when the number was reached. Here we are forced to use psychological terms. It seems as if the bird does some inward marking of the units he is acting upon, sometimes those supposed "inward marks" show themselves in external behaviour in the form of intention movements. Thus a jackdaw, given the task to open lids until five baits had been secured, which in this case were distributed in the first five boxes in the order 1, 2, 1, 0, 1, went home to its cage after having opened only the first three lids and having consequently eaten only four baits. The experimenter was just about to record "one too few, incorrect solution," when the jackdaw came back to the line of boxes. Then the bird went through a most remarkable performance: it bowed its head once before the first box it had emptied, made two bows in front of the second box, one before the third, then went further along the line, opened the fourth lid (no bait) and the fifth, and took out the last (fifth bait). Having done this it left the rest of the line of boxes untouched and went home with an air of finality. This "intention" bowing, repeated the same number of times before each open box as on the first occasion when it had found baits in them, seems to prove that the bird remembered its previous actions. It looks as if after its first departure it became aware it had not finished the task, so it came back and started again, "picking up", with intention movements, baits it had already picked up in actuality; when, however, it came to the last two boxes, which by mistake it had omitted to open on its first trip, it performed the full movements and thus completed its task.

The simplest explanation that I have to offer for this inner marking is that it may consist in *equal* marks as if we were to think or give one nod of the head for one, two for two, and so on. This I propose to call *"thinking un-named numbers."* On the contrary, the most prodigal assumption which one could make and one which, I believe, is unnecessary, would be that the bird did the marking by *inequal* or *qualitatively different* marks in fixed order, as if we think 1, 2, 3, 4, 5, or alternatively a phrase of five different syllables. That of course would be *named numbers*, in other words, real counting. If my simplest assumption, that of equal marks, be true, one might expect that an *anticipated* punishment during the process of acting up to "x" for instance, would be without effect. Thus one might expect that if in the course of being trained for five the bird was punished after having taken two grains, it would continue to act upon five; and that is indeed what the pigeons did. But budgerigars and still better, jackdaws, were able to adhere to a new order inculcated by only one anticipated punishment, and one jackdaw adhered to this new order for a long series of spontaneous experiments before finally returning to the old higher value of "x." Notwithstanding this result, I hesitate to accept this more prodigal assumption, because I have only this one experiment pointing in that direction. All other tests indicate the contrary. Thus there is no sign of "number intelligence" at all, no obvious progress of learning ability as in the case of children, but if the marks were quite equal, according to our first assumption, it is hard to understand how the jackdaw could grasp the new lower number at once, indicated by only one anticipated deterrent which occurs quite without warning. Perhaps the assumption of purely *quantitative* differences between the marks which are qualitatively identical, would serve the explanation; for instance, a crescendo of expectancy of punishment or in the case of self-conditioning without punishment, a decreasing avidity for the baits as the bird passed along the line of marks.

Pigeons and budgerigars were hopelessly upset by changes in experimental conditions during training for a problem, whereas jackdaws grasped the transposition at once. One bird, after having learnt to open the lid with three spots and not touch the lid with four spots, was presented with three and four mealworms moving on the lids instead of spots. The film shows the first presentation of this new kind of clue in a spontaneous experiment. The bird is anxious and hesitates a long time, but finally it goes straight to the three mealworms and leaves the four alone, and instead of opening the lid it eats the mealworms from it without opening it at all. To summarise: a given species of bird would show the same ability of grasping unnamed numbers where they are presented simultaneously or successively, but the ability differs with the species. Thus with pigeons it may be five or six according to experimental conditions, with jackdaws it is six and with ravens and parrots, seven.

Similar tests of the same ability have been carried out with man. In this case the groups of figures are presented tachistoscopically by lantern slides, shown simultaneously and carefully timed so that while they may be fully seen the time is too short for counting to take place. It is remarkable that, when this is done with human beings, the limit of achievement is of the same order as that shown by birds. Thus few persons reach eight and many, like pigeons, get no further than five. As to the second ability, experiments are still being carried out, but as far as we can see there is no expectation that man can achieve better results than the birds provided named counting is excluded. This similarity of the limit in both abilities, as in the six species including man, seems to be a most important fact, and we can hardly assume such a correlation to be due to chance. For ourselves, the two abilities, to grasp unnamed numbers presented simultaneously (differentiating between groups seen side by side) or successively (acting upon "x"), have in common only the absolute idea of unnamed numbers. Since birds do not speak and have names neither for things nor numbers, we must ask whether a bird may not learn to associate the two abilities. This can be decided in two ways, first by testing the power of action upon seen numbers and second by choosing a certain seen number equalling a number just acted upon. We are working along both these lines. As to the first, there has been one positive result. After many failures a jackdaw learned to take two mealworms out of a circle containing many if there were two points in the centre of the circle, and four mealworms if there were four points.

Two pre-linguistic faculties common to some species of birds and to man have been demonstrated. "Unnamed thinking," which I would like to suggest may be common with us. Our "brainwaves" are very often wordless. We often quite suddenly perceive correct solutions of problems with which we have been striving for a long time before we have decided we will name them in one language or another by a formula or a sketch. Very many ideas come to us in wordless form, just as most of the ideas which an animal may grasp; the difference merely is that we can recount it afterwards in words and animals cannot. Fighting, playing, courting, etc., in both animals and man may have many items in common, items which probably are wordless, that is, in both cases.

This attempt may encourage more research towards the detection of "unnamed thinking" in other directions. The question "what is it enables our language to fit nature as it does?" may perhaps be partly answered by pointing to forms of pre-linguistic thinking which higher animals and man have in common. So far we seem to have found two of them.

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