

Choice in a continuous procedure*

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A pigeon lived in a situation in which all its food was obtained by pecking at two disks. The proportion of pecks allocated to either disk equalled the proportion of food obtained by pecks at the disk, confirming a well-known matching relation. The finding strengthens the view that the matching relation is an intrinsic property of the behavior of higher organisms.

All behavior involves choice, in the sense that when an organism is not engaged in one activity, it must be engaged in another. To understand the determinants of response frequency, therefore, one must study choice. A simple relation, the matching equation (Herrnstein, 1970), has been found to hold in a variety of choice situations. It states that the relative amount of behavior devoted to an alternative matches the relative amount of reward obtained from that alternative: $B_1 / (B_1 + B_2) = r_1 / (r_1 + r_2)$. For two alternatives simultaneously available, the relation reduces to equality between proportion of behavior (responses or time) and proportion of reward (number or duration).¹ Although first found for pigeons with two alternatives (Herrnstein, 1961; Catania, 1963), it has been demonstrated with three alternatives (Reynolds, 1963), and for rats and men, as well as pigeons (Shull & Pliskoff, 1967; Schroeder & Holland, 1969). It has recently been extended to situations in which only one activity is monitored, with all the alternatives unknown, and to situations in which the alternatives are presented successively rather than simultaneously (Herrnstein, 1970).

To what extent is this result of the laboratory applicable to behavior in more natural situations? Could it apply, for example, to pigeons foraging for food in the park? One objection to the laboratory research is that the responses studied are not the ones natural to foraging. The equation may hold for pigeons pecking at switches, but there are no switches in the park. There, pigeons either fly about to find food or sit and wait for people to bring it. Recent research has partially replied to this objection by showing that the matching relation holds for the activity of "sitting and waiting" (Brownstein & Pliskoff, 1968; Baum & Rachlin, 1969).

Another objection to extension of the matching relation is the unnaturalness of the laboratory regimen. Two aspects are particularly artificial. First, the conditions of

deprivation and satiation are peculiar. Pigeons and rats, for example, are generally maintained at 80% of their free-feeding body weights. They receive all of their food in a brief period of the day and are never allowed to satiate. Second, the brief period in the experimental situation is at once too significant and too insignificant—too significant because the animal receives virtually all of its food there, and too insignificant because it comprises such a small part of the animal's day and, hence, of its behavior.

All of these criticisms can be overcome in the laboratory by one change in procedure: having the animal live in the experimental situation. If it obtains all its sustenance from the apparatus, then it can be at full body weight or whatever body weight the conditions maintain. It can satiate itself when hungry and stop responding at the choice alternatives when sated. The 24-h situation can no longer be called insignificant or too significant. For the duration of the experiment, it is the animal's whole world.

A pigeon shut away in a box is obviously in a highly unnatural situation. Although this situation clearly differs in many respects from a pigeon's natural habitat, it can be construed as more natural than the usual laboratory situation in some respects. If the matching relation holds, then the credibility of extending it—at least to pigeons in the park—increases.

An important bonus in using a continuous procedure is the possibility of studying situations in which one alternative alone is sufficient to fulfill all of the animal's life requirements. Under such circumstances, distribution of behavior between alternatives is unnecessary. If the matching equation holds, this would strengthen the view that the relation is in no way constrained by the experimental procedure but is, rather, a property of the organism itself.

METHOD

The S was a male White Carneaux pigeon that had served in a variety of previous experiments. The experimental chamber was 12 x 12 x 16.5 in. high. Three walls

were aluminum, and one wall was clear Plexiglas. The ceiling, through which house illumination came, was translucent Plexiglas. A wooden perch in the shape of a square was mounted 4 in. above the floor and 3.375 in. from the walls. Two pairs of response keys, requiring a force of about 23 g and a movement of 0.5 mm to operate, were mounted 4 in. apart and 7.75 in. above the perch, one pair on each of two opposite aluminum walls. Below one pair of keys, 1.75 in. above the perch, was the opening of a Gerbrands grain feeder. Below the other pair, 2 in. above the perch, was the opening of a Gerbrands dipper feeder, the dipper of which was 3/16 in. deep and held about 0.5 cc of water. The keys above the water dipper were transilluminated with red light. The keys above the grain feeder were transilluminated with green light.

The pigeon lived in the experimental chamber for the duration of the experiment, about 7 months. The chamber was enclosed in a sound-attenuating lightproof box. Continuous white noise masked extraneous sounds. Houselights provided constant moderate illumination. The box was opened about once a month to check, clean, and weigh the bird.

The bird earned all its food and water by pecking at the response keys, two for food and two for water. The water keys alternatively produced a dipper of water for 3.65 sec at a 6-sec interval, initiated and terminated by pecks. This insured that the dipper had enough time to refill between water presentations and that responses were distributed between the keys, in preparation for future experiments on choice with water reinforcement. Pecks at the food keys produced occasional 3.65-sec presentations of grain according to two variable-interval schedules. All pecks produced a relay click as auditory feedback. The rates at which the keys could produce food were varied in such a way as to expose the bird to seven different pairs of alternatives: VI20-VI3, VI20-VI5, VI12-VI6, VI8-VI8, VI6-VI12, VI5-VI20, and VI3-VI20. Five of the pairs could produce a maximum total of 15 reinforcements per hour. The two pairs in which the alternatives differed most (3 vs 20 food presentations per hour) could produce a maximum total of 23 reinforcements per hour. Each situation was presented until performance appeared stable (about 2 weeks). In all conditions, a changeover delay insured that no reinforcement could occur less than 1.8 sec after a change of keys.

RESULTS AND DISCUSSION

Figure 1 summarizes the basic result. The filled points are data from

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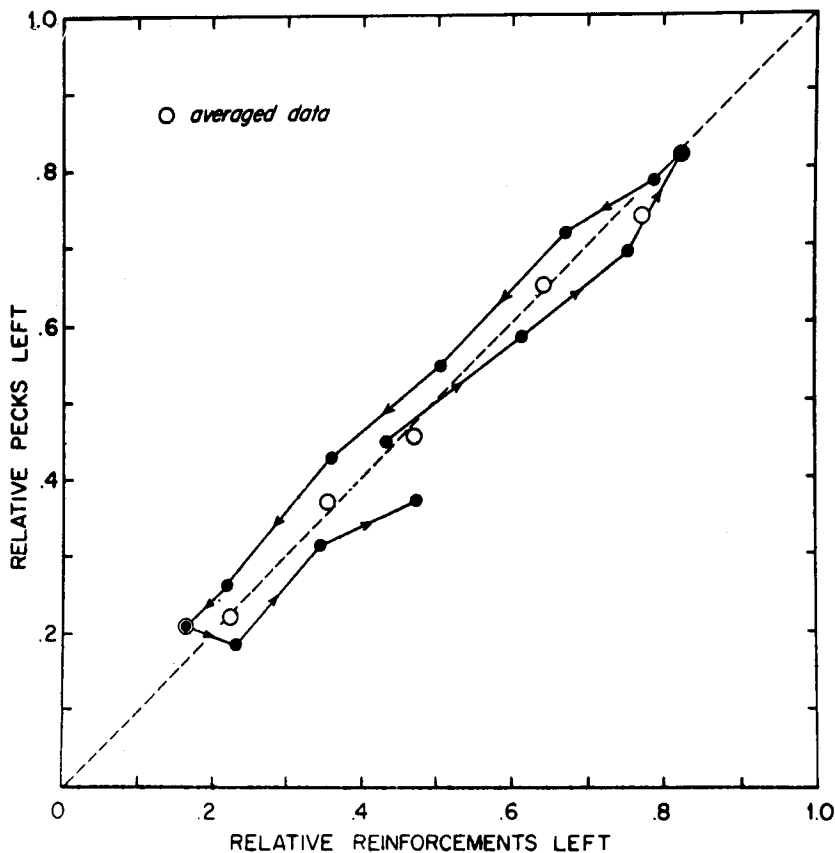


Fig. 1. Distribution of behavior as a function of distribution of reward. The ordinate is the proportion of pecks made at the left of two response keys. The abscissa is the proportion of food presentations obtained from pecks at the left key. The diagonal line represents the matching relation. The arrows show the order of conditions.

the last 5 days of each condition. The matching relation (diagonal line) is well confirmed.

The spread of points around the matching line indicates that order of presentation of the conditions influenced performance. When the proportion of reinforcements on the left was increasing, the choice proportions tended to fall short of matching. When the proportion of reinforcements was decreasing, the choice proportions fell above matching. This order effect, known as *hysteresis*, may result from too rapid a change of conditions, which would have prevented complete stabilization of performance. The averages of the determinations from the ascending and descending series (open circles), however, fall close to the matching line.

There was some interaction between choice and relative reinforcements. This can be seen in the different abscissa values for the same condition in the ascending and descending series of conditions. In general, however, the degree of interaction was slight, as would be expected. As long as

response rates at both keys exceed a minimal level, the obtained and programmed proportions of reinforcements will be close.

Since the bird often failed to respond for many minutes at a time, the obtained rate of reinforcement fell short of the maximum attainable. The average was 10.8 reinforcements per hour (range: 9.1 to 12.7 reinforcements per hour). The average response rate (total for both keys) was 590 pecks/h (range: 377 to 851 pecks/h). Neither rate of reinforcement nor response rate varied systematically with the changing conditions. Although the bird's free-feeding body weight was 502 g, after the first 2 months its weight stabilized at about 460 g (range: 456 to 472 g). It is difficult to guess why the experimental conditions produced a lower stable body weight than that obtained in the pigeon's home cage. An activity cycle may have limited food intake. Whatever the cause, its effect was to produce satiation—that is, to halt responding in the face of continued opportunity to feed—at a reduced body weight.

Although the matching relation was clearly replicated with this pigeon, I am studying additional pigeons to determine the role of activity cycles and the changeover delay. Initial results with another bird support the matching relation.

The matching relation obtained was in no way forced by the procedure. Choice was unconstrained in two important senses. First, the number of pecks actually required for the reinforcements obtained was a negligible portion of the number of pecks emitted. Out of approximately 590 pecks/h, only about 11 produced reinforcement. The remaining 579 pecks (98%) could have been distributed in any manner. Their conformity to the matching relation is produced by the pigeon, rather than by the apparatus.

The second sense in which choice was unconstrained is novel in this procedure. In previous experiments, organisms maximized the rate of reinforcement by distributing behavior between alternatives. Since the pigeon in the present experiment was allowed to satiate itself, it imposed an upper limit on obtained rate of reinforcement. In some of the conditions (the extremes of relative reinforcements), the bird could easily have reached the obtained rate of reinforcement by responding at only one of the alternatives. It could have ignored the less advantageous alternative, but it did not. The adherence to matching probably resulted from maximization of rate of reinforcement during periods of food-getting, the bird's self-imposed sessions with the food keys. It may have been more economical, in the sense that the distribution of behavior kept the sessions shorter. Economical or not, however, the pigeon's conformity to the matching relation, under these conditions, where any distribution was unnecessary, further strengthens the view that the relation is a basic property of choice in higher organisms, the result of a phylogenetic history of selection.

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performance measures. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 517-527.

NOTE

1. Although this relation is superficially similar to probability matching, Herrnstein (1970) has pointed out that it is not only different from, but also incompatible with, probability matching.