

*TWO UNLIKE PATTERNS OF RANDOM-RATIO
RESPONDING ASSOCIATED WITH DIFFERENT
EATING HABITS IN RHESUS MONKEYS¹*

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Four rhesus monkeys were exposed to an identical series of schedules that specified a uniform probability of reinforcement for every response. As probability was lowered slowly in 10 steps of 20 sessions each from 1.0 through 0.01, two distinct patterns of responding emerged. Two subjects showed high, pause-free response rates that increased with each successive reduction in reinforcement probability. The other two showed consistent post-reinforcement pausing at all probabilities, including 1.0, and substantially lower response rates that peaked at the moderate probability values of 0.04 and 0.03. This low-rate pattern was found to be correlated with a pre-experimental preference in the two subjects for mouthing and chewing food pellets one at a time, while the former high-rate, pause-free pattern was linked to a long-standing habit of "pouch feeding" in the other monkeys. These idiosyncratic collateral behaviors that differentiated the schedule performances appeared neither superstitious in origin, nor useful in the case of the low-rate monkeys.

It is becoming increasingly evident that many conditions other than those traditionally arranged by the experimenter ultimately determine the way in which reinforcement comes into contact with behavior and generates a characteristic schedule performance. A reinforcement schedule specifies the bare, minimally sufficient conditions under which certain responses can produce a reinforcer. Yet, the formal rules for obtaining reinforcement that define schedules are not the only determinants of the patterned performance of a subject working within those rules. Besides the traditional organismic variables, such as those implied by the concept of drive, theories about the behavioral control exerted by reinforcement schedules are according ever more formal recognition to the capabilities, competing history, and especially to the "other", non-measured behaviors that a subject either carries into, or develops during a scheduled performance (*e.g.*, see the notion of "non-R" or "R" behaviors of Schoenfeld and Farmer, 1970; and the term R_o , or the presumed reinforce-

ments available to alternative activities, of Herrnstein, 1970).

Often, the contribution of undesigned behaviors to the characteristic performance engendered by a schedule, that is, to the spacing and patterning of the selected operant in time, is noticed only if the former promote a more efficient adaptation to the schedule. For instance, on differential-reinforcement-of-low-rate (DRL) and fixed-interval (FI) schedules, collateral behavior may aid in the spacing of responses, ultimately increasing the efficiency of the performance (Laties, Weiss, Clark, and Reynolds, 1965; Segal-Rechtshaffen, 1963; Wilson and Keller, 1953; but see also, Zuriff, 1969). Besides preempting the designated response, and thus lowering its possible rate of repetition, overt stereotyped behaviors can also mediate responding on temporal schedules by becoming correlated with periods associated with different reinforcement probabilities, that is, by the behaviors themselves becoming discriminative stimuli.

However, the case of ratio schedules is quite different, regardless of whether they are defined in terms of a fixed, variable, or random number of responses (Ferster and Skinner, 1957; Brandauer, 1958). Here, a premium is placed upon a subject's making responses, not spacing them. So it is likely that any alternative behavior patterns that hinder rapid responding will be squeezed out during a sub-

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ject's pursuit of an efficient performance. On random- and variable-ratio schedules, particularly, idiosyncratic collateral behaviors are likely to be minimal, for such aperiodic schedule rules allow no fixed correlation to develop between either the spacing or number of responses and the occurrence of the reinforcing event. In fact, on random-ratio schedules, the probability of reinforcement for the designated response is the same at all times (Brandauer, 1958). Thus, it would seem improbable that any behavior, including the selected operant itself, would come under the strong control of behaviorally generated stimuli (Thompson and Grabowski, 1972, p. 80). On the other hand, since reinforcement sometimes serves to strengthen whole patterns of behaviors (Dews, 1966), any behavioral sequence that results in frequent occurrences of the selected response, whether evenly or peculiarly spaced in time, will be heavily reinforced by a random-ratio schedule and thus might persist.

The present data are an example of how some differing pre-experimental behavioral habits among four rhesus monkeys combined with a random-ratio contingency to produce two distinctive patterns of responding. Each pattern was maintained over many sessions and appeared to represent a blend of current contingent control with a long-standing, stereotyped eating habit.

METHOD

Subjects

Four naive male rhesus monkeys (*Macaca mulatta*) were studied. At the start of the experiment, Monkey 1 weighed 4.9 kg; Monkey 2, 3.2 kg; Monkey 3, 4.4 kg; and Monkey 4, 3.8 kg.

Apparatus

Each monkey was permanently restrained in a Plexiglas primate chair enclosed within an individual sound-attenuating booth. A response lever was mounted on the waistplate of the chair, 15 cm directly in front of the monkey. The lever could be activated by exerting a dead-weight force of 275 to 330 g through a 1.5-cm excursion, a total minimum work requirement of approximately 44×10^4 ergs (0.044 J). Water was available to the monkey at all times and was delivered in 0.75-sec squirts of 5 ml each through a spout mounted 10 cm to

the left of its head. The monkey could obtain water by pressing a clear plastic nose key located next to the spout, on a one-press, one-squirt basis. Aside from one piece of fruit offered three times a week, all food was earned during sessions in the form of Dietrich and Gambrill 750-mg, whole diet pellets. They were delivered through a chute located opposite the water spout, and a 1-sec tone feedback accompanied every pellet delivery. The main houselight was a 6-W fluorescent bulb mounted on the rear wall directly behind the subject's head. The only other light in the chamber was provided by two small incandescent pilot lamps that illuminated from behind both the water key and an identical, but inoperable, key located next to the pellet chute on the other side of the monkey's head. Twenty-four hour behavioral scheduling and recording were accomplished with a mixture of relay and transistor equipment located in an adjacent room.

Procedure

Initially, every response on the lever produced a pellet of food. The acquisition of this response required no shaping and took from three to five days. Next, the availability of food was restricted to two 1-hr periods each day that were signalled by turning off the main houselight. Thereafter, a schedule of two sessions per day, the first from 9 to 10 a.m. and the second from 5 to 6 p.m., remained in effect seven days per week throughout the experiment.

All four monkeys were exposed simultaneously to an identical sequence of random-ratio schedules that specified a uniform probability of reinforcement for every response. Reinforcement was controlled by a high-speed flip-flop, and a reinforcer was delivered whenever a response happened to coincide with a particular one of two states of the flip-flop. Consequently, the probability of reinforcement was determined by the proportion of time the flip-flop spent in that state. The net result was that each response (and therefore all inter-response times) had the same probability of producing a pellet. This method of instrumenting the random-ratio contingency produced a schedule identical to the time-correlated, or limited-availability, schedules devised by Schoenfeld, Cumming, and Hearst (1956). The probability of reinforcement (P) was progressively decreased in blocks of 20 sessions each

from 1.0 (continuous reinforcement) to 0.5, 0.3, 0.2, 0.1, 0.07, 0.04, 0.03, 0.02, and 0.01, a total of 200 sessions. Because the food earned by Monkeys 3 and 4 at $P=0.03$ was judged

sufficiently meagre as to be potentially harmful to health, these two subjects were run for only five sessions each at the two lowest P values, or for a total of only 170 sessions.

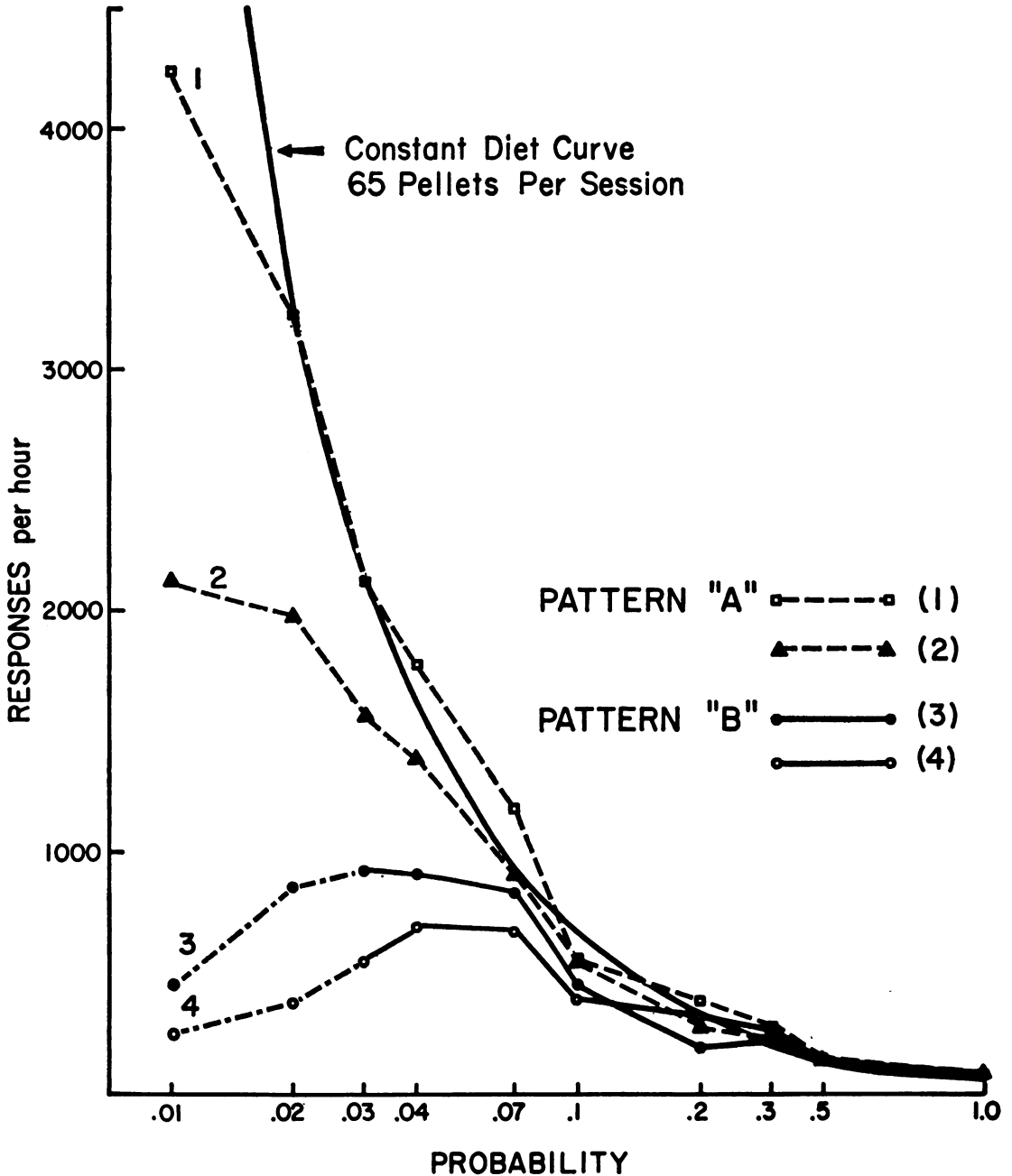


Fig. 1. Response rates of four monkeys, as numbered, exposed to successively decreasing probabilities of reinforcement (plotted on semi-logarithmic axes to save space). Constant diet curve projects response rates that were required to maintain reinforcement level averaged by all subjects at $P=0.5$. Each point represents the mean of five sessions. These were the final five of 20 sessions each at every P value, except for the lowest two of Monkeys 3 and 4 (joined by dashed-plus-dotted lines), when only five sessions were scheduled.

RESULTS

Figure 1 indicates that as P was reduced from 1.0 through 0.04, hourly response rates of all subjects increased with each new value of P , thereby at least partially offsetting the progressively more stringent work requirements. However, with further reductions in P through 0.01, only Monkeys 1 and 2 continued to show upward adjustments in their response output. Monkeys 3 and 4 exhibited maximum response rates at the moderate P values of 0.03

and 0.04 respectively, and thereafter showed a systematic decline in rate as P approached 0.01.

The mean food intake for all subjects at $P = 0.5$, virtually a free-feeding condition, was 65 pellets per session hour or 130 pellets per monkey per day, a diet equal to approximately 409 Kcal per day. To maintain this level established during the twenty-first through fortieth sessions, a subject needed only to adjust its responding in later sessions to the successive jumps in the random-ratio requirement in a manner indicated by the constant

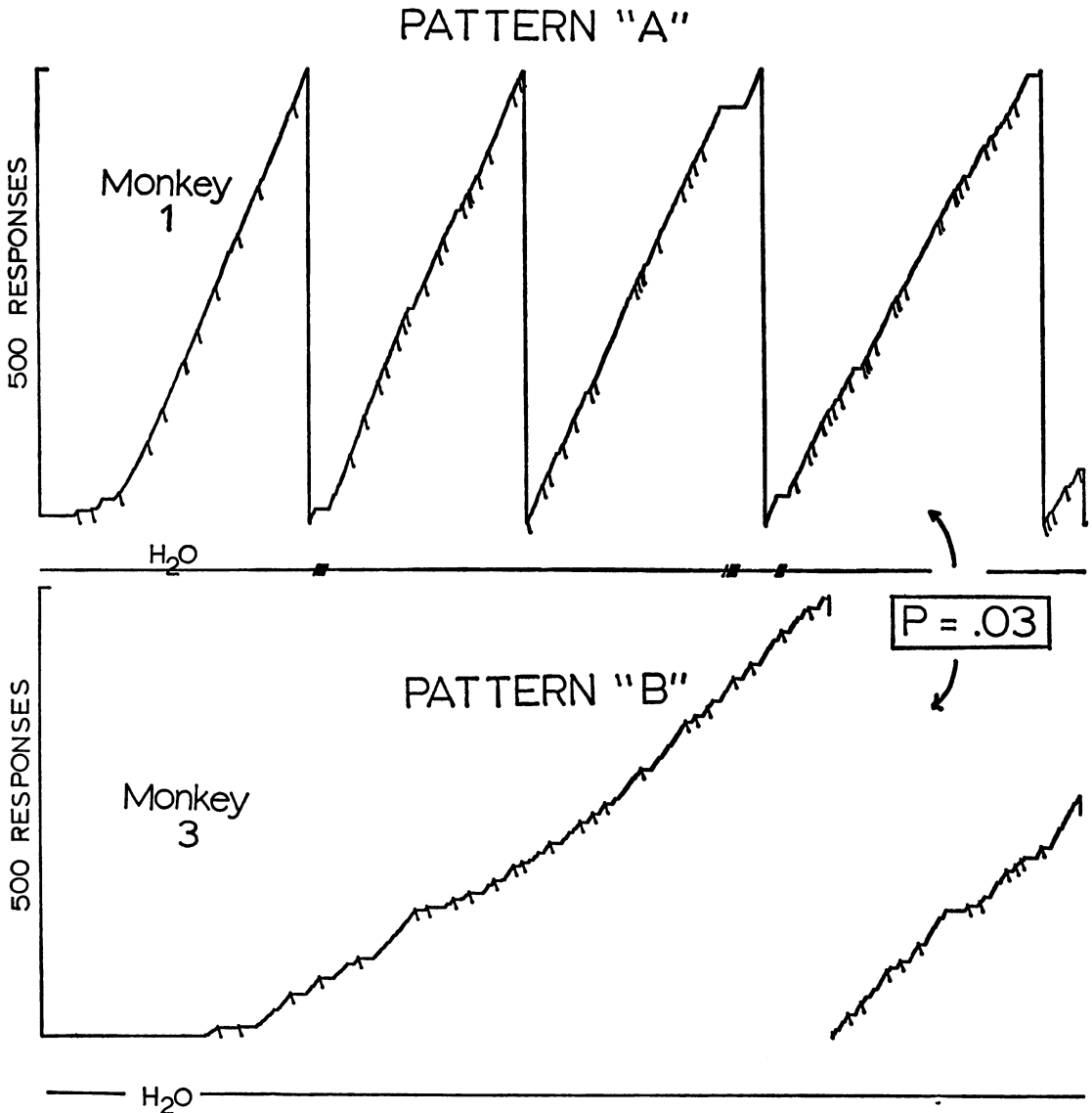


Fig. 2. Cumulative records of Monkeys 1 and 3, which displayed differing patterns of random-ratio responding during their final sessions at $P = 0.03$. Reinforcements are indicated by downward deflections of the response pen. Drinks of water are shown by the event marker beneath each curve. Every record is 60 min long.

diet curve projected upon Figure 1. Since all food was earned exclusively during sessions, response rates, and consequently reinforcement rates, were inversely related to deprivation level. The further an individual's response rate departed from the ideal curve, the greater the influence of deprivation to speed responding and to return the performance towards the curve. In light of this relation, the failures of Monkeys 3 and 4 to continue to adjust their response rates beyond the relatively mild random ratios of 33 and 25 responses per reinforcement, respectively, seemed unusual.

In addition to the divergence in overall response rates, two distinct patterns of random-ratio responding emerged among the four subjects, as evidenced in their cumulative records. One (Pattern A) was typified by high, steady rates of lever pressing with few, or no, pauses following reinforcements. This pattern was displayed by the subjects, Monkeys 1 and 2, that in Figure 1 consistently increased their response rates as the probability of reinforcement was made more intermittent. Figure 2 (top) presents, as an example of Pattern A, the last session of Monkey 1 at $P = 0.03$. As this record indicates, when pauses did occur in Monkey 1's responding, they (a) were usually uncorrelated with reinforcements, (b) some-

times involved collateral drinking, and (c) were always followed by an abrupt resumption of a high rate of response. By contrast, Monkeys 3 and 4 displayed substantially lower, uneven rates of responding that were correlated with frequent post-reinforcement pauses (Pattern B). The lower half of Figure 2 presents as an example of Pattern B, the last session of Monkey 3 at $P = 0.03$. This P value was selected as a point of comparison in Figure 2, since it was the lowest P value at which all four subjects received 20 sessions of exposure.

A clue into the possible origins of the two distinct styles of random-ratio responding may exist in the earlier performance records of the same subjects at $P = 0.5$. The top record of Figure 3 demonstrates that Monkey 1, which later developed high, sustained response rates on the more intermittent P values, showed on this richer feeding schedule a clear-cut preference for obtaining its pellets in clusters of several at once. On the other hand, Monkey 3 in the lower half of Figure 3 displayed consistent pausing after individual reinforcements, even at this early stage in the experiment. This subject rarely began working towards its next pellet until the first had been consumed.

This correlation of the pattern of early eating at the value of $P = 0.5$ with the eventual

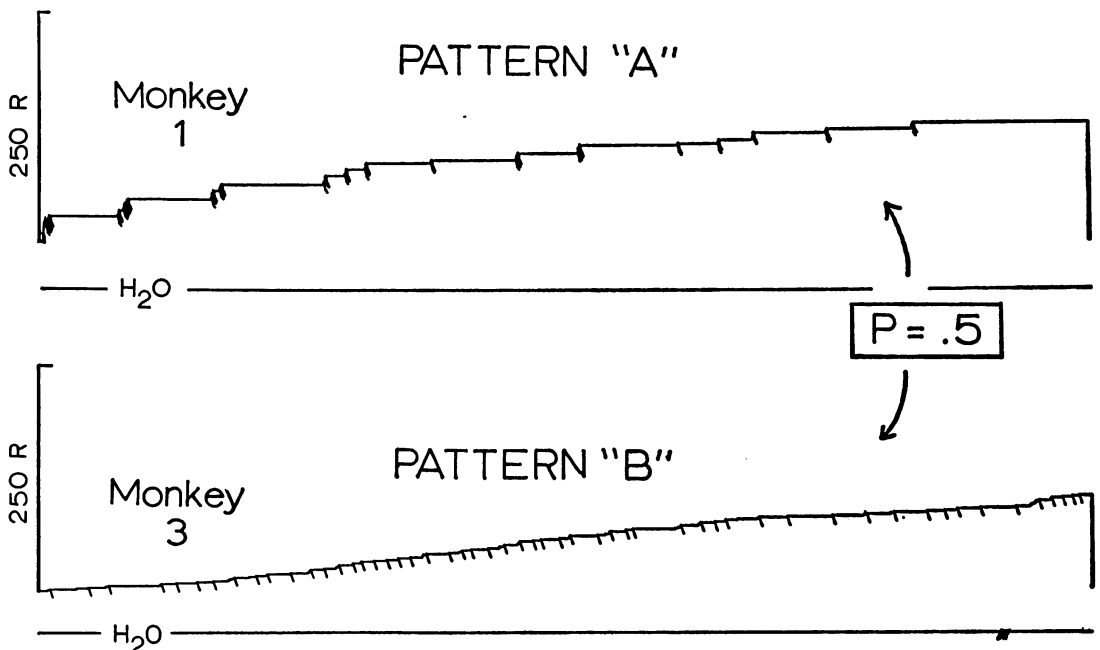


Fig. 3. Cumulative records for the final sessions at $P = 0.5$ for the same monkeys shown in Figure 2. These records were recorded 60 days (120 sessions) earlier than those in Figure 2.

style of random-ratio responding at more intermittent P values also held for the remaining two subjects. Figure 4 shows that Monkey 2, which like Monkey 1 responded in clusters at $P = 0.5$ (bottom record), also developed the high, steady, pause-free response rate at $P = 0.03$ (top), described above as Pattern A. On the other hand, Figure 5 shows that Monkey 4, which like Monkey 3 began the experiment with a spaced pattern of eating (bottom), developed instead the broken, low-rate pattern of responding at $P = 0.03$, labelled Pattern B.

DISCUSSION

The principal finding of this study was that a monkey's accustomed manner of eating when food was available on a virtual free-feeding basis was predictive of later patterns of responding on more intermittent random-ratio

schedules. Two monkeys that exhibited an initial preference for earning and gathering food pellets in clusters of several at a time, later produced response rates that were a monotonic increasing function of the random-ratio requirement. Two others that spaced their pellet intake more evenly, failed to follow increments in the random-ratio with higher response rates beyond moderate values.

It is most interesting that these early patterns of responding, noted at $P = 0.5$, also correspond to two different stereotyped eating habits that are usually distributed unevenly among laboratory colonies of rhesus monkeys. The majority of rhesus monkeys, even when individually caged, have been characterized informally by animal handlers as "pouch feeders". Like Monkeys 1 and 2 in the present experiment, when presented with dry chow, they will quickly mouth and store

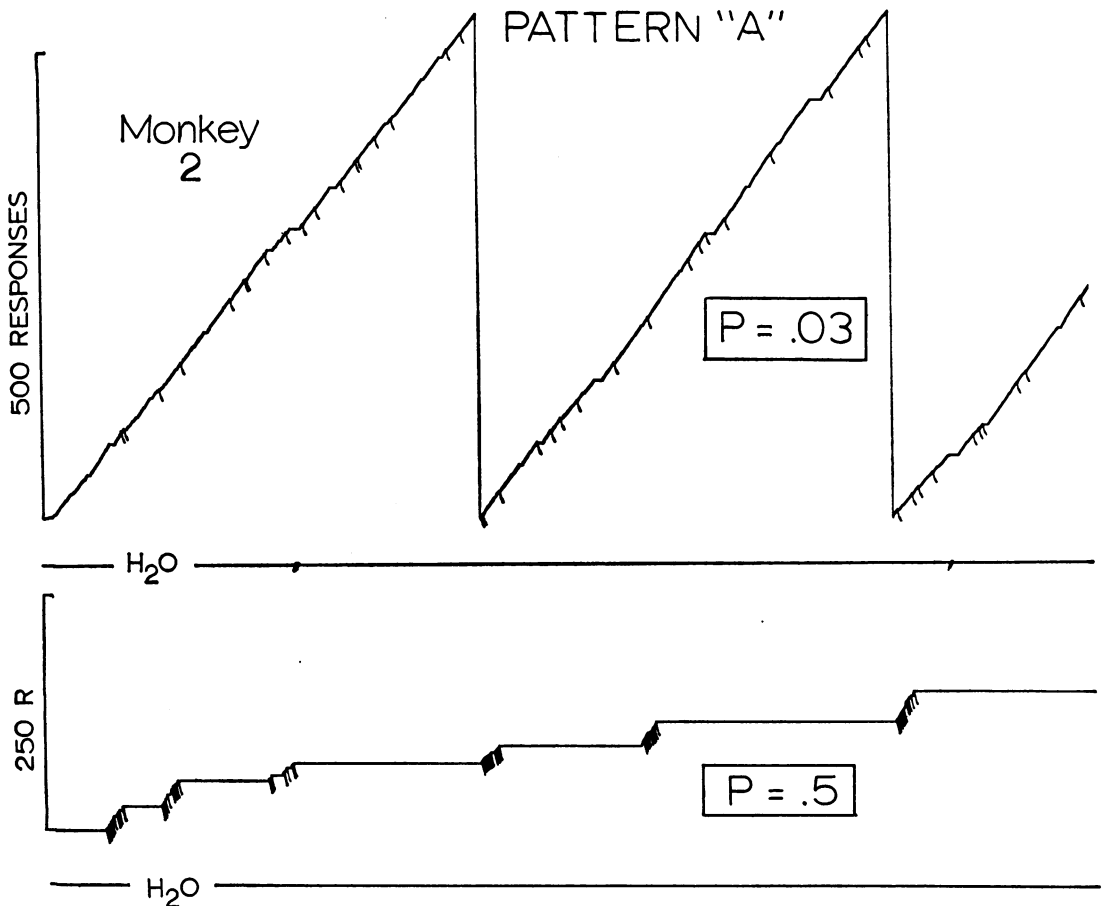


Fig. 4. Cumulative records for the final sessions at $P = 0.03$ (top) and 0.5 (bottom) of Monkey 2, whose patterns of responding at both values resembled those of Monkey 1. This is described as Pattern A in the text.

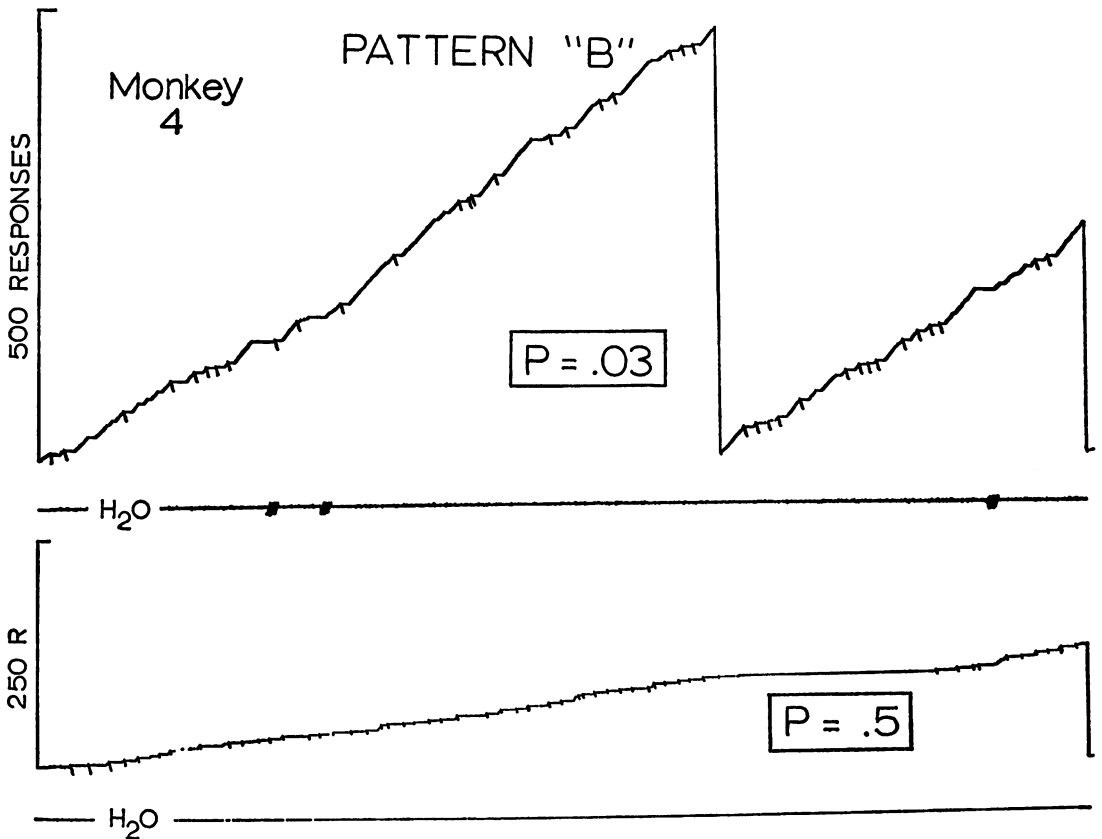


Fig. 5. Cumulative records for the final sessions at $P = 0.03$ (top) and 0.5 (bottom) of Monkey 4, whose patterns of responding at both values resembled those of Monkey 3. This is described as Pattern B in the text.

large quantities of pellets in their jowls for later chewing and swallowing. Other monkeys (for which no parallel characterization exists, although J. Dardano² has suggested that they be called "dainty chewers") routinely chew and swallow each new piece of food before seizing the next. The present four subjects probably carried these different habits into the experiment, and were observed to exhibit them afterwards in their home cages. On two occasions, about a month after the experiment, each subject was offered a metal cup containing 10 banana-flavored Purina lab chow pellets, each weighing approximately 4 g. As expected, Monkeys 1 and 2 stuffed all the pellets in their mouths rapidly and within 20 sec on both occasions had retreated to the back of their cages. Monkeys 3 and 4 emptied the cups over a matter of minutes.

Among primates, cheek, or buccal, pouches

are found only in a subfamily of Old World monkeys, the Cercopithecinae, which includes besides macaques, patas monkeys, guenons, mangabeys, baboons, and others. In these species, cheek pouches are correlated with a simple form of stomach, for in the subfamily Colobidae, where cheek pouches are lacking, a specialized sacculated stomach invariably occurs (Hill, 1966). It is not clear why some species possess pouches, and others not. They occur in both terrestrial and arboreal macaques (Jay, 1965). Nor is it clear why, within a species that possesses cheek pouches, certain individuals will consistently use them to store food for safe-keeping or transport, while others will not. For instance, Hall, Boelkins, and Goswell (1965) concluded from observations of free-ranging patas monkeys and baboons that only subordinate young adult males commonly distend their pouches with food, with "still protected juveniles or infants and most of the adult males and females rarely doing so" [p. 27]. Con-

²Personal communication.

versely, Bertrand (1969) observed among stump-tail macaques (*Macaca speciosa*) that not only low status animals, but "dominants, who could keep the food tray as long as they pleased, also crammed their pouches" [p. 31]. An interesting possibility suggested by Charles Southwick³ is that rhesus monkeys may develop different feeding habits in relation to their habitat. Monkeys from village, roadside, temple, and urban habitats that obtain considerable food from people or through pilferage (Singh, 1969) characteristically display short, active, competitive feeding bouts during which the cheek pouches are stuffed. On the other hand, monkeys from forest areas in India are primarily grazers, moving slowly through the natural vegetation, feeding on buds, berries, fruits, and young leaves (Singh, 1969). Southwick notes that the feeding sessions of forest monkeys appear relaxed and quite prolonged compared to those of monkeys living around people and engaged in competition for a more limited food supply.

Whatever the origins of these different eating habits among monkeys, it seems clear from the records at $P = 0.5$ that both Monkeys 3 and 4 entered the experiment with a predilection for inserting "chewing" pauses after reinforcements. These apparently became trapped by the schedule, for later they developed some of the characteristics of post-reinforcement (or pre-ratio work) pauses, in that they appeared from the cumulative records to become longer as the ratio requirement was raised (Farmer and Schoenfeld, 1967; Griffiths and Thompson, 1973). On the other hand, Monkeys 1 and 2 learned to "eat on the run" and never displayed significant post-reinforcement pausing despite random ratios as high as 100. Thus, those pre-experimental behaviors that became locked into the schedule and that accounted for the divergent performance patterns, were neither superstitious in origin, nor, in the cases of Monkeys 3 and 4, were they useful mediating sequences. In this sense, these observations differ from O. R. Lindsley's account of superstitious bowing by dogs during variable-interval performance (cited by Laties, Weiss, Clark, and Reynolds, 1965) and from the many descriptions of spontaneous response chains that arise when subjects are forced to delay or space their responding (e.g., Blough, 1959;

Hodos, Ross, and Brady, 1962; Laties and Weiss, 1963; Laties, Weiss, Clark, and Reynolds, 1965; Zuriff, 1969).

Despite the intrusion of these collateral behaviors, the functions relating response rate to probability of reinforcement shown in Figure 1 resemble those originally reported by Brandauer (1958) for pigeons. As in the present experiment, Brandauer exposed his subjects to a series of random-ratio schedules arranged in order of increasing intermittency, from $P = 1.0$ to 0.00167. Over a moderate range, response rates increased with lower values of P through a maximum at $P = 0.02$ for two birds and 0.01 for another. Yet, Sidley and Schoenfeld (1964) constructed a similar function, using a separate group of pigeons for each value of P , and found little relation between response rates and reinforcement probability. Their curve appeared flat, with no maximum within the range of $P = 1.0$ to 0.0068, although they argued that had they used still lower values of P they would have produced a maximum, for if P is made very small, responding doubtlessly will extinguish. In the present study, different monkeys displayed peak response rates at a variety of P values, from 0.04 and 0.03 for Monkeys 4 and 3, respectively, to projected values for Monkeys 1 and 2 that would have to equal, at least, or perhaps exceed in intermittency, the lowest P employed, 0.01. If individual pigeons were to exhibit a similarly diverse population of peaks, this might explain how a carefully executed group average curve, like Sidley and Schoenfeld's, could possess a different shape than the individual functions of which it was presumably composed (Estes, 1956; Sidman, 1952).

Farmer and Schoenfeld (1967) also suggested that the seemingly fundamental function that relates the rate of a response to the probability of its reinforcement actually reflects just a shortening of post-reinforcement pauses at lower P values. They demonstrated that response rates corrected for such pauses did not vary when each of two pigeons was exposed in mixed order to a wide range of different P values. Thus, they reasoned, under these conditions, the response-rate function for random-ratio schedules essentially reflects a subject's reapportionment of time-spent-responding and time-spent-pausing. However, this two-state analysis does not seem to fit the

³Personal communication.

monotonic increasing functions found in the present study, particularly those of Monkeys 1 and 2, whose pausing was exceptionally infrequent at P values lower than 0.07 and, hence, contributed little to the continued rise in the hourly response-rate function beyond that value. Rather, the cumulative records and some interresponse-time distributions from sampled sessions of all subjects suggested that the response-rate curves reflected joint changes in rate-while-responding and time-spent-pausing.

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