

TOWARD EMPIRICAL BEHAVIOR LAWS I. POSITIVE REINFORCEMENT¹

DAVID PREMACK
University of Missouri

This account of reinforcement is based upon a generalization, not a theory. Few cases underly the generalization, but that which is generalized to are measurable properties of behavior.

If accurate, the present generalization will provide: first, an explanation of reinforcement; second, a criterion for evaluating the logical need for motivation constructs; and third, a possible basis for an empirical quantitative account of learning. This first paper, however, deals mainly with positive reinforcement. Learning, motivation, and the aversive case require independent treatment, though some reference to these topics will occur here.

THE RATE DIFFERENTIAL: A NECESSARY AND SUFFICIENT CONDITION FOR REINFORCEMENT

The account is based on the assumption that the nature of reinforcement can be discerned by taking two responses (Rs) of the organism, arranging both of the possible contingencies between them, and noting what differentiates between the contingencies in which reinforcement does and does not occur.

A hypothetical example is provided by using a rat, the bar press, and the ingestion of pellets. If by reinforcement we mean, for the moment, the

traditional increase in frequency of an R, the experiment will require two preliminary measures: (a) the rate of the bar press when the bar is available to the rat, which we will call the *independent rate* of bar pressing; and (b) the rate at which pellets are ingested when they are available to the rat, the independent rate of pellet ingestion.

Given the independent rates of both bar pressing and pellet ingestion, the experiment proceeds by arranging both contingencies: (a) the availability of a pellet contingent upon a bar press, and (b) the availability of the bar contingent upon the ingestion of a pellet. Consider that the former produces a rate of bar pressing greater than the independent rate, but that the bar contingent upon ingestion does not produce a rate of ingestion greater than that of the independent rate. What conclusions may be drawn as to the determinants of reinforcement?

Conclusions based upon the literature will include: need reduction, drive reduction, sensory stimulation, ingestive behavior per se, all combinations of the above. If, however, the conclusion is based solely upon the experimental outcome, it may read as follows: *Reinforcement results when an R of a lower independent rate coincides, within temporal limits, with the stimuli governing the occurrence of an R of a higher independent rate.*

A further consideration arises as a result of having measured the independent rates of both the bar press and ingestion. The rate at which pellets were ingested when contingent upon the bar press may approach the inde-

¹This paper was prepared during the author's tenure as a USPHS postdoctoral research fellow. Part of this paper was read at the Midwestern Psychological Association, Detroit, May 1958, in a symposium on reinforcement. I am deeply indebted to my wife, Anne James Premack, for her assistance with both the formulation and clarification of this account.

pendent rate of pellet ingestion; the two rates could not be equal in all cases because of the bar press itself, but the former might approach the latter as the limiting case. Now, if the above were so and each bar press were followed by the ingestion of a pellet, the rate of the pellet-contingent bar pressing would tend to equal the independent rate of pellet ingestion. As it turns out, the proportionality is not that simple; the independent rate of the higher R does *not* limit the contingent rate of the lower-rate R, etc. Nonetheless, the following possibility is of heuristic value: In the idealized case, the dependent or contingent or acquired rate of the lower-rate R tends to equal the independent rate of the higher-rate R.

Are these the only possible conclusions? They may be if only the one case is considered. But if we assign as great a weight to the negative as to the positive finding, and take an inductive leap, we may conclude as follows: *Any response A will reinforce any other response B, if and only if the independent rate of A is greater than that of B.*

This is the induction that will be examined here; not proved, the evidence to be presented is altogether insufficient, but examined for the definition of terms, implications, and, briefly, for quantification possibilities.

TEST METHODS

A test of this account concerns three main questions. First, is a rate differential a sufficient condition for reinforcement? Second, will the effectiveness of the differential vary as different variables constitute the rates of the Rs involved? Third, will the lower-rate R attain exactly the independent rate of the contingent higher-rate R? The latter is not incorporated in the quantitative version, but is retained here, so

as to consider performance factors that may disturb equality between the two Rs.

Tests of these questions require independent measures of both of the Rs involved, but few experiments provide this information. In runway studies there is no measure of the independent rate of the "runway R," no simple way of obtaining such a measure, and typically no measure of the R that terminates the run. Though the Skinner box provides in principle for measures of both Rs, in practice we have no measure of the higher-rate R, viz., ingestion, licking, or, more recently, rising up and sniffing the light source. Methods suited to the present questions are described below. Only the first is adequate, however, and after both are described, advantages of the one will be noted.

Rs Ranked Along a Rate Continuum

If the independent rates of several of an organism's Rs are determined in advance, the Rs can be ranked in terms of rate, and the account tested by arranging all possible contingencies between the ranked Rs. Let A, B, and C represent any three Rs, with independent rates in the order stated. It follows from the account that: A will reinforce both B and C, C will reinforce neither A nor B, and B will reinforce C but not A.

Support for the view of reinforcement as an absolute property is given by both A and C. Since A is and C is not a reinforcer, they exemplify the proposition that some stimuli are and some are not reinforcers—in a broader sense, that species are characterized by a set of stimuli which is and a set which is not reinforcing. The conclusion that reinforcement cannot be explained on the behavior level typically follows from this view, i.e., follows from, first, assigning reinforcement to

a set of stimuli, and then noting that the set cannot be physically characterized.

The reinforcement properties of B suggest, however, that the absolute view is based upon failing to consider the rate of the would-be reinforcing R relative to the rate of the to-be-reinforced R. B shows this well since, if the account is accurate, B both is and is not a reinforcer. The reinforcement properties of B suggest, therefore, that "Is this stimulus a reinforcer?" requires the further question "With respect to what Rs?" (In the present terms, if the rate of the R governed by the stimulus in question is greater than that of the to-be-reinforced R, the stimulus can be used as a reinforcer.) But tests that use only one "instrumental" R or that deal solely with rat, ingestion, and usual laboratory parameters are unlikely to show the relativity; this combination assures that the independent rate of the ingestive R will exceed that of the "instrumental" R. Other combinations of species, Rs, and parameters demonstrate the relativity; one which permits reinforcing ingestion is shown in a later section.

The data to be reported here, however, are intended largely as a concrete example; they concern one subject and realize only part of the paradigm. The subject is a Cebus monkey, a species Klüver (1933) has described as being especially manipulative. The Rs ranked in terms of rate are all manipulation Rs; they were used to show the reinforcement of one "instrumental" R by another, i.e., to show that what makes an R "instrumental" is a rate less than that of the contingent R.

An apparatus has been devised which permits giving the subject a number of different manipulanda, either singly or in pairs. When used to determine the independent rate, the different manipulanda are given to the subject, one at

a time, under a standard test condition, and with no restrictions upon responding. When the manipulanda are given in pairs, either one can be locked and its operation made contingent upon the prior operation of the other and free manipulandum of the pair. Operation of the free member releases the locked member, and operation of the previously locked member restores its own lock. In this way a consistent schedule is arranged between operation of the free member and release of the locked member. Only one release of the locked member is provided by any number of operations of the free member.

A panel, which holds any one or any pair of manipulanda, is bolted to a port in the monkey's home cage, and all testing is conducted there. Testing is in home cage so as to approximate an environment in which unmeasured Rs are low and stable. The need for a low, asymptotic level of "competing" Rs is emphasized by this account; according to it, a competing R of an independent rate greater than that of the measured R can, by uncontrolled contingencies, reinforce the measured R.

The three Rs used so far are: lever pressing, operation of a horizontally hinged door, and the bin R in which the animal pushes back a light door mounted behind a hole and contacts an empty bin. The independent rates of these Rs were determined by giving the subject the appropriate manipulandum on five to ten 90-minute sessions. The subject was tested daily, but each item was given equally often daily, on alternate days and every third day, so that the mean intertest interval per item was about 48 hours. The long interval was used to maintain R-frequency per item at near maximum from test to test. The independent rate of manipulation Rs varies with several parameters, which will be noted

later, but may be kept relatively constant by the usual controls and by avoiding short intertest intervals which result in a cumulative decrement. For the parameters used, the mean frequencies were about 20 for the bin, 50 for the lever, and 100 for the door.

The tests described below followed, by 24 hours, the determination of the independent rates. Six of each kind were given daily in the order described, except for extinction, where only four were run. The tests concern only the door and lever. Because of presenting the same pair of manipulanda at only 24-hour intervals, an over-all decrement occurred. The reinforcement effect occurred despite the decrement.

First, when the subject was given the two manipulanda together, with no contingency between them, so that both the door and lever were free, the lower-rate R appeared to occur at less than its independent rate, while the higher R occurred at about its independent rate. For the six tests, the door averaged about 90, the lever about 36. Whether this kind of situation suppresses the lower-rate R cannot be evaluated because of the decrement associated with an intertest interval less than the one used to determine the independent rates. In the present series, however, this control condition served only to determine if presenting together previously unpaired manipulanda would produce an increment in the lower-rate R. That no increment occurred is the outcome important for the test series.

Second, the lower-rate R was made contingent upon the higher-rate R by now making operation of the lever contingent upon the prior operation of the door. The door averaged about 80, the lever only about 22. Because the higher-rate R tended to occur first and relatively often, the lower-rate manipulandum was actually free both from the

outset, and for most, of the test period. However, each lever press left the lever locked. Consequently, the subject could not respond to the lower-rate manipulandum in its customary "bursts," but could make closely spaced lever presses only by alternating higher-with lower-rate Rs. The alternation did not occur, however. Instead, after making a lower-rate R, the subject made varying numbers of higher-rate Rs, after varying intervals, and then returned to the lower-rate R after varying intervals. *Mainly, this lack of alternation between free and locked members demonstrates the failure of a lower-rate R to exert a controlling effect upon a higher-rate R;* it contrasts with the alternation which occurs when the rate differential is in the opposite direction, viz., from low to high. Finally, did the lower-rate R fail to reinforce the higher-rate R because the former did not follow the higher-rate R either sufficiently often or closely? This possibility cannot be ruled out, and finer tests of this point are needed. An important consideration for such tests, however, is that reinforcement is witnessed not by occurrence of an R, but by a rate of occurrence greater than the independent rate.

Third, the rate differential was arranged from low to high by making the higher-rate door R contingent upon the lower-rate lever press. The lever press attained a mean frequency of about 120, which contrasts both with its original independent frequency (about 50) and with that of the door R (about 100). Thus the lower-rate R was not only increased but exceeded the independent frequency of the higher-rate R. On the first two tests the higher-rate R was notably reduced, though it attained its original independent frequency on the last two of the six tests. Three factors are notable

here. (a) Because of its contingent status, the higher-rate R could not occur in its usual "bursts"; this may account for the reduced rate on the early tests, and an accommodation to this factor, for the steady increase in the higher-rate R that took place across the six tests. (b) As the free R, the lever press could and to some extent did occur in "bursts," which may account partly for the fact that on all tests the number of lower-rate Rs exceeded the number of higher-rate Rs. An average of about 80% of individual lever presses were followed by a door R; this represents the alternation between the two Rs. The percentage did not increase across tests, though there were essentially no "bursts" of lever presses in any test not directly followed by a door R. Hurwitz (1958) has reported a case for rats and food-contingent bar pressing where, at an intermediate stage of training, bar presses exceeded pellets ingested, though the two Rs alternated with further training. The ultimate performance proportionality between the two Rs may be affected by the absolute rate of the higher R or by the difference between the rates of the two Rs. (c) Responding increased across this series of tests, in contrast to both test conditions above.

Fourth, extinction was run by removing the door from the panel, closing the port which the door had occupied with a blank, and giving the subject only the lever. This is the situation in which the independent rate was originally determined. As an extinction condition it is blunt: the stimuli governing the higher-rate R are grossly absent. Nonetheless, the subject pressed the lever at an elevated rate (78 and 56) on the first two sessions and then dropped progressively on the last two sessions to a level below the original independent rate.

While these data suggest that a rate differential is a sufficient condition for reinforcement, they have been reported as the most concrete means of describing a test method. Comparable tests are being extended to the greater number of Cebus now available.

Measuring Independent Rate in the Context of the Test

In contrast to the method described, where the independent rates are determined in *advance* of the contingency tests, a second method consists in measuring the independent rates in the context of the test. For example, the runway or choice-point can be combined with an apparatus that permits measuring the rate of the Rs that occur in the end boxes. Runway speed can then be examined for its relation to rate of end-box Rs, or choice-behavior for its relation to the difference between the rates of the Rs in the two end boxes. Since, however, this account is stated in terms of rate, it cannot treat either runway speed or percent turns. But even at the level of suggestion, data obtained with the second method may be misleading in their interpretation for this account.

When rates are determined during rather than before the contingency tests, the resulting data will relate *number* of higher-rate Rs to the dependent variable, e.g., number of end-box Rs to speed of the run. If we designate the "runway R" as A, and Rs that terminate runs for groups tested with different end-box items as B and C, the tests will contrast, say, $A \rightarrow BB$ with $A \rightarrow CCCCC$. In the first method, however, not more than one higher-rate R need follow a lower-rate R. In the manipulation case, for example, only one door R followed any lever press. Consequently, the contrast may be between $A \rightarrow B$ and $A \rightarrow C$, where A is a common lower-

rate R, and B and C are higher-rate Rs with independent rates determined in advance of the contingency tests. The first method emphasizes, therefore, as the second does not, that in order to produce an increment in the lower-rate R, only *one* higher-rate R need follow the lower-rate R.

In the light of this emphasis, the first method suggests further that one contingency, rather than repeated trials, between Rs of different independent rates will produce an increment in the lower-rate R. That is, if $A \rightarrow B + A \rightarrow B + A \rightarrow B$, etc., produces an increment in A, so will $A \rightarrow B$. In the manipulation example above, this suggests that *one* contingency between the lever press and door R will produce an increment in the lever press, the increment to be evaluated by comparing an extinction measure with the previously determined independent rate. Except as discontinuities are considered either at the level of number of contingencies or interval between contingencies, one contingency between one lower- and one higher-rate R would be considered to produce an increment in the lower-rate R.

Especially for quantification possibilities are these important considerations. If single contingencies are effective, then the differences between *mean* rates, which we are using here, can *not* be made the basis of reinforcement. That is, since the single R cannot have a mean value, a function relating changes in the lower-rate R to some relation between lower- and higher-rate Rs must employ R values other than mean rate. Considerations of this kind, however, concern learning rather than performance. For the data treated here mean rate will suffice; the measure may be viewed as an approximation of whatever R value may serve ultimately to permit the kind of function that is being sought.

REINFORCEMENT OF CONSUMMATORY Rs

It follows from this account that consummatory Rs are reinforcing, provided that a condition can be found in which the organism's rate of, say, ingestion is less than the rate at which it performs some nonconsummatory R. This rate relation, however, is the reverse of the one which obtains in the usual laboratory test. There the "instrumental" R is a noningestive R, the contingent R a consummatory R, and the rate relations such that the latter is substantially higher in independent rate than the former. The food deprivation, which is part of the usual test, assures a high independent rate of ingestion. Though it may also increase the independent rate of the "instrumental" R, the increment given the latter will not offset the advantage of the ingestive R, since particularly the maximum independent rate of ingestion will exceed that of the "instrumental" R. To use ingestion as the "instrumental" R, however, requires that it now have an independent rate less than that of the contingent and would-be reinforcing R. The ease of establishing this condition appears to vary with the species.

In the rat, and perhaps the rodents generally, the difficulty begins with the fact that ad lib. maintenance does not lead to a rate of ingestion which is less than the independent rate of the common and engineerable nonconsummatory Rs. The momentary rate of the rat's ad lib. eating session is unusually constant (Baker, 1952), and this constant tends to be higher than the maximum independent rate of, say, the bar or light-contingent bar press, at least for those values of food, bar, and light intensity which we have tried. While there may be a low-rate food and high-rate light intensity which together will yield a reversal of the customary rate

relations between ingestive and non-ingestive Rs, we have not found the values.

Moreover, reducing the ad lib. eating constant by a deprivation technique does not facilitate the reinforcement of eating. By first depriving the rat of food, a low eating rate can be obtained; following deprivation the rat does not eat at a constant rate, but under some circumstances begins at a value greater than the ad lib. constant and terminates at a very low value (Baker, 1952). However, when the terminal eating rate is low, the independent rates of the other Rs may be equally low. And if satiation effects are broad, reducing the rate of all Rs, little reinforcement of any kind will be possible.

Other techniques may work. For example, the wheel turn which, in the rat, has a substantially higher independent rate than the bar press, and which Kagan and Berkun (1954) have shown to reinforce the bar press, may serve to reinforce ingestion. But the difficulty of finding stimulus pairs and parameters which will provide the desired rate relations in the rat comments merely on a species peculiarity of the rat.

Measures on a Cebus monkey indicate that parameters can be found under which the monkey operates some manipulanda at a rate greater than that at which it ingests most foods. Beyond the Cebus, however, the child may be the ideal subject. For certain age levels and socioeconomic classes, the desired rate relations appear to obtain within the parameters of the child's daily life. The study described below shows that a reversal of the usual laboratory rate relations between eating and noneating Rs can be obtained with the child and, that when it is, eating is reinforcing.

A pinball machine (PBM), rewired for continuous operation, and a candy

dispenser, the two placed side by side, comprised the experimental arrangement. A PBM was used instead of the simpler devices in use with the monkeys, since the present purpose was less to analyze manipulation than to obtain as high a manipulation rate as possible. Candy consisted of constant-size chocolate bits, delivered one at a time by a conveyer belt into a dish each time the child ate the piece in the dish. Thirty-three children, the entire first-grade class of a public school, served as subjects. Their average age was 6.7 years.

Each child was tested twice, the first serving to determine the subject's relative R frequency to the candy and the PBM, and the second as the test of the hypothesis. Both tests lasted 15 minutes and used the same materials; the second was given three to four days after the first.

On the first test, both the candy and PBM were unrestrictedly available. The child was led to a position midway between the two devices and told, "We have two games here; you can play both of them as much as you like." After demonstrating both devices, the experimenter said, "I'll be back here sitting down," and then retired behind a one-way viewing screen. Sixty-one per cent of the children made more PBM responses than they ate pieces of candy. In Table 1, they comprise the larger group labeled "manipulators"; those labeled "eaters" represent the 39% who ate more pieces of candy than they made PBM responses (three ties which occurred were scored as "eaters").

On the second test, the availability of candy and the PBM were made subject to either of two contingency relations, E-M or M-E. For E-M, each operation of the PBM was contingent upon the prior ingestion of a piece of candy, whereas for M-E, each piece of candy was contingent upon the prior

operation of the PBM. Both the "manipulators" and the "eaters" were randomly divided, and half of each main group tested under E-M and half under M-E. For "manipulators" E-M was the experimental condition and M-E the control; the reverse held for the "eaters." What characterizes both experimental conditions is that the higher-rate R is contingent upon the lower-rate R ("manipulators" must eat to manipulate; "eaters" must manipulate to eat). Control conditions make the higher-rate R freely available, as in Test 1, and thus provide a

measure of changes in the lower-rate R which may occur independent of the rate-differential contingency.

Like the magazine-trained rat that responds to the inoperative magazine rather than pressing the bar, "manipulators" in the experimental condition "fiddled" with the inoperative PBM, ignoring the candy, while "eaters" stood by the empty dish, ignoring the PBM. Consequently, because of the time-limited session, instructions were used to establish the first contingency (defined as a PBM response followed by the ingestion of candy, or vice versa, regardless of the time between the two responses). If three minutes elapsed without a response, the experimenter said, "Remember, there are two games." If this failed, he then said, "I wonder what would happen if you ate a piece of candy? Played the PBM?" according to whichever was appropriate. Once a contingency occurred, nothing further was said.

The results are shown in Table 1 in terms of the increase in the number of lower-rate Rs from the first to the second test. For "manipulators" this is the increase in number of pieces of candy eaten; for "eaters," increase in number of PBM responses. As may be seen in Table 1, control-condition increments are small compared with those for the experimental condition, and the mean differences within both main groups are significant at less than the 1% level of confidence. In both cases, a rate-differential contingency increased the frequency of the lower-rate R: While candy reinforced manipulation for the "eaters," the PBM reinforced eating for the "manipulators."

More elegant demonstrations with nonverbal organisms are needed, but the above results suggest that the uniqueness of consummatory Rs does not consist in their unreinforcibility.

TABLE 1
INCREASE IN LOWER RATE RESPONSE FROM
FIRST TO SECOND TEST

Manipulators	
E-M (Exp.)	M-E (Control)
Increment in number of pieces of candy eaten per subject	
16	0
16	4
19	19
22	0
14	5
14	10
28	0
19	0
26	7
81	a
\bar{X} 25.5	\bar{X} 5
Mdn. 19	Mdn. 4

Eaters	
M-E (Exp.)	E-M (Control)
Increment in number of PBM responses per subject	
10	5
8	0
7	0
1	0
16	7
9	0
16	
\bar{X} 9.4	\bar{X} 2
Mdn. 9.0	Mdn. 0

* Child absent on Test 2.

They may be distinctive in the high rates which they attain relative to the other Rs, though the rate relations possible for the different Rs appear to vary with the species. For example, Lorenz (1957, pp. 129-175) has noted that stalking in certain predators commonly attains, in present terms, an independent rate greater than that of ingestion. As a survival mechanism, perhaps there may be, however, a number of parameters in all species under which the independent rate of ingestion exceeds that of the other Rs.

Finally, the above study is of interest for its suggestions concerning the relativity of reinforcement. That species are *not* characterized by a specific set of reinforcing stimuli, and that this mistaken absolute view has resulted from failing to consider the rate of the would-be reinforcing R *relative* to that of the to-be-reinforced R, are main suggestions of the study. Indeed, that reinforcement is not only a relative property but, in some instances, a reversible one is also indicated. For example, there would seem little doubt but that with sufficient food deprivation "manipulators" would become "eaters" and, consequently, that the R which had been "instrumental" could be made reinforcing, and vice versa. A comprehensive treatment of both the relativity and reversibility is reserved for a later paper. Here the main point is simply this: Any stimulus to which the species responds can be used as a reinforcer, provided only that the rate of the R governed by the stimulus is greater than that of some other R.

"DRIVE"

Effect of the Intertest Interval

While the broad effects of food deprivation are apparently unique, the effect of the interval between feeding sessions *specifically* upon ingestion may

represent a general function, one holding for the independent rate of any movement and the interval between occurrences of the movement.

For example, Butler (1957) has shown visual-contingent responding in the rhesus monkey to increase with deprivation for visual stimuli. Hill (1956) has reported wheel turning in the rat to increase with the confinement interval. For independent groups of rats tested at intervals of 12, 24, and 48 hours, Premack, Collier, and Roberts (1957) found both the bar press and light-contingent bar press to be increasing functions of the intertest interval. For the same group of rats rotated through five intertest intervals ranging from 3 to 48 hours, and tested eight consecutive times at each interval, Premack (1958) found the light-contingent bar press to be an increasing function of the interval. Finally, Premack and Bahwell (in press) found lever pressing in a Cebus monkey to be a generally increasing function of deprivation for the lever. Given the same lever on 252 half-hour sessions, an equal number of sessions at about 15-, 39-, and 65-hour intervals, the monkey responded 4,109 times; significantly most often at the largest interval; and showed no decline across the about 5-month test period. Continued examination of species movement may reveal differences in temporal parameters, but a common increasing function for independent rate of all movement and deprivation for the stimuli upon which the movement depends.

As to the general effects of food deprivation, some parallel may possibly be found in depriving the organism of *any* behavior which, like ingestion, has a high independent rate and is recurrent throughout the organism's life. For a nonconsummatory R, the wheel turn tends to have these charac-

teristics in the rat. Slonaker (1926) has reported that rats turn a continuously available wheel at a substantial rate during about two-thirds of their life. Moreover, the decrement in the wheel turn reported to occur across repeated tests (Hill, 1956) does *not* distinguish the wheel turn from ingestion. We have found rats to ingest significantly more of a new food on the first than on succeeding days; when shifted from ad lib. lab food to Gaines dog meal, rats ate a mean of 19.98 grams the first day and only 14.19 grams by Day 14 ($p < .01$, $F = 2.41$, df 13/143); across days decline has been found also for Noyes pellets. On the basis of these parallels, Premack and Premack (1958) studied ad lib. food consumption as a function of deprivation for a continuously available activity wheel. When deprived of the wheel, rats ate significantly more than they had when the wheel was available and than a control maintained without the wheel. In two replications, grams intake attained a maximum on about the third post-wheel deprivation day, and intake did not return to baseline for about 14 days.

What seems most likely to distinguish food deprivation from deprivation for stimuli governing noningestive Rs are the different relations within the stimulus classes. Let A, B, C, and D subsume the members of the food class. Though no data can be found on this point, it seems probable that organisms deprived of the class, and tested on, say, A, would ingest more of A than a control maintained on B, C, and D, and tested on A. In the case of nonfood stimuli, however, depriving for increasing amounts of the stimulus class appears to *reduce* the over-all response level. Ochocki and Premack (1958) maintained one group of rats in the colony, another group in light-tight, sound-treated icebox hulls,

and tested subgroups of both main groups on the light-contingent bar press at intervals of 3, 12, and 48 hours. While responding was an increasing function of the intertest interval for both main groups, frequency was significantly lower at all intervals for the stimulus deprived group.

"Drive"

Whereas in the Hull-Spence system, hours of food deprivation is related to D, and D ultimately to performance, in this account hours of food deprivation is first examined for its effect upon the independent rate of ingestion. Subsequently, the independent rate of ingestion is examined for its effect upon lower-rate Rs that lead to ingestion. Though tradition has set the ingestive case off, by calling it "drive" or "motivation," in this account the effect of the ingestive contingency does not differ in modus operandi from that of *any* higher-rate R—manipulative, locomotive, or sensory—upon the paired lower-rate R.

Of the paradigms which can be used to test the reinforcement generalization, the one most relevant to the usual "drive" study is the following: The *same* higher-rate R, when at different values of independent rate, is made contingent upon a common lower-rate R. Thus, in the customary "drive" study the higher-rate R for all groups is ingestion, and the differences in hours of food deprivation represent possible differences in the independent rates of ingestion for the several groups. This paradigm contrasts with one in which *different* higher-rate Rs are made contingent upon a common lower-rate R, but the prediction made by the reinforcement generalization is the same for both paradigms, viz., the increment in the lower-rate R will be greater, the greater the independent rate of the contingent higher-rate R.

Because the intervening variable approach has dominated the field, little data relevant to this account can be found. The literature shows two separate approaches: (a) determinants of the independent rate of ingestion, and (b) effect of hours of food deprivation upon food-contingent Rs. Tests of this account require that the two approaches be united in the same study.

Consider as a typical "drive" study one in which several groups are differentiated in terms of hours of food deprivation and tested on the same food-contingent, lower-rate R. To convert this study into a test of this account requires two measures, both of which are omitted by the intervening variable approach. First, we require the effect of hours of food deprivation upon the independent rate of ingestion, and second, the effect of hours of food deprivation upon the independent rate of the R that is to be used as the "instrumental" R. Food deprivation may affect the rate of the "instrumental" R *before* it has been made food-contingent in the study, and the effect may be different for the several groups. Moreover, for certain deprivation procedures, hours of food deprivation may affect differently the "instrumental" and ingestive Rs.

A recent study by Birch, Burnstein, and Clark (1958), coupled with a less recent one by Bousfield and Elliott (1934), approximates the methodology of measuring, first, the effect of the independent variable upon ingestion and, second, the effect of the ingestive contingency upon the lower-rate R. Together they also provide a bit of information as to whether the effect of hours of food deprivation is the same for the "instrumental" and ingestive Rs.

In both studies essentially the same independent variable was used. Rats were first maintained for protracted periods on a fixed deprivation schedule

and then tested at varying hours after their last feeding. The studies differ in terms of their dependent variables. In what amounts to an extinction measure, Birch et al. found that number of approaches to the empty feeding device was greatest at the previously scheduled feeding time, less for times both greater and less than the scheduled feeding time. Bousfield and Elliott considered the effect of the same variable upon ingestion itself. They found the rate of ingestion, as well as grams intake, to be greatest for the group tested at the scheduled feeding time, less for groups tested at all other times. Thus, the relation to hours of food deprivation was the same, both for the extinction measure of the food-contingent R and the independent rate of ingestion. And in neither case was this the monotonic increasing relation that has been shown, with other deprivation procedures, to hold for grams intake and hours of food deprivation (Lawrence & Mason, 1955).

Birch et al. next tested runway speed as a function of the same variable. On the first trial, *before* a run had led to ingestion, speed and hours of food deprivation were not significantly related, though there was an indication of increased speed with greater deprivation. However, on the second trial, *after* a run had led to ingestion, runway speed was greatest for the group tested at the scheduled feeding time, less for groups tested at all other times. Thus, while comparison of the first-trial results with those by Bousfield and Elliott suggests that, for this deprivation procedure, hours of food deprivation may affect differently the ingestive and "instrumental" Rs, once the "instrumental" R had led to ingestion it was related to hours of food deprivation in the same way as was the independent rate of ingestion. Taken in sum, these results suggest that the independent

rate of ingestion is itself the direct determinant of changes in ingestion-contingent lower-rate Rs, in contrast to hours of food deprivation, which acts merely to affect the independent rate of ingestion, as well as possibly the independent rate of the "instrumental" R. Moreover, when compared with the manipulation example, they suggest that the effect of a higher-rate ingestive R upon the paired lower-rate R does not differ in *modus operandi* from that of a higher-rate manipulation R upon the paired lower-rate R.

Birch et al. placed only two pellets in the runway end box; if one had been used, we would predict the same group differences. The assumption here, as noted earlier, is that an increment in the lower-rate R, that is some function of the relation between the mean rates of the lower and higher Rs, can be produced though only one higher R follows the lower R. An increment occurred in the lever press, for example, though only one door R followed any lever press. Mean rate is being used as an approximation, however. If contingency changes in the lower-rate R are to be calculated directly from pre-contingency measures of both lower- and higher-rate Rs, it is already evident that R values other than mean rate will be required.

The broad effects of both food deprivation and satiation are unique, but these distinctions notwithstanding, the ingestive case is subsumed by the reinforcement generalization on the following grounds. First, a rate produced by food deprivation does not differ in its reinforcement effect from a rate produced by any other operation. Second, the *modus operandi* of the ingestive contingency is the same as that of any higher-rate R. Third, the shape of the function for increments in ingestion-contingent lower-rate Rs and hours of food deprivation is directly predict-

able from the function for the independent rate of ingestion and hours of food deprivation. If further study bears these considerations out, then for the inferences of the intervening variable approach there may be substituted measurement of the independent rates of the lower- and higher-rate Rs.

COMMENSURABILITY OF BEHAVIOR UNITS

In the tests of independent rate described earlier, the subject was simply given test items under a condition that was the same for all items. No restrictions were placed upon the items, the subject determined its own units of responding, and the records, as measured, consisted of a succession of manipulanda operations, ingestions of food units, and, in some unreported work, succession of wheel revolutions. No criterion for dividing these behavior segments was provided. In effect, each segment of unrestricted responding was divided by the anthropomorphic unit, e.g., "lever press," "pellet ingested," etc. Though, at this stage, the main justification for these R units is that the comparisons "worked," in retrospect it is possible to make explicit the assumptions underlying the choice of units and thus to provide a formal criterion for selecting the R unit by which to count the independent rate of any segment of unrestricted responding.

The assumption which is here applied to all behavior segments generated by unrestricted test items is that each segment contains what might be called a smallest possible unit (spu). *The spu is defined as that unit which gives the same amount of responding as is given by free responding, when in fact stimulus restrictions force the organism to respond by spu.*

In the ingestive case, spu would seem to amount to the intact chain,

i.e., to a combination of seizes, bites, chews, and swallows which is recurrent throughout the unrestricted segment, though make-up of the combination may vary with the organism, as well as with degree of food deprivation, size of pellet, consistency, etc. To treat the intact ingestive chain as the spu amounts to considering that: if stimulus restrictions forced the organism to respond by discrete chains, in equal periods of stimulus availability, it would ingest essentially as many pellets as when pellets were free and it responded by its characteristic multiple of intact chains. Tests of this assumption can be made by more complex procedures than were used here; they would involve variously restricting both the number of food units available at any one time and the intervals between their availability. However, the contingency situation itself amounts in part to such a test, since there the occurrence of the lower-rate R imposes intervals between multiples of the organism's free responding units. Consequently, if the single intact chain were made the contingency unit, and the asymptotic amount of pellets ingested in that situation tended to equal the amount ingested in tests of unrestricted responding, evidence would exist for treating the intact chain as the spu.

To perform the above test requires a knowledge of the number of intact chains that occur per pellet or multiple of pellets. Since pellets vary as to size, in order to count the unrestricted ingestive segment by intact chains the pellets would have first to be calibrated in terms of the organism's R units. The independent rate for the segment of unrestricted ingestion would then amount to: number of pellets ingested per unit time by number of chains per pellet or multiple of pellets. Though calibration will make some occasion for

the direct observation of behavior unavoidable, calibration is unavoidable; if the experimenter's stimulus-effect measurement unit were simply equated with the R unit, the independent rate of the segment could be made to vary with the choice of food units.

Seizing, biting, chewing, etc., cannot be used to count the independent rate of the unrestricted ingestive segment, except as the correlation between certain of these units and the intact chain is known. In the context of unrestricted ingestion, it may be expected that the smaller units do not occur at their independent rate. Seizing may be affected by biting, biting by chewing, etc., though to determine which reinforce which others would require testing various combinations of them in isolation of the rest, insofar as that is possible. When tested in isolation, each of the smaller units would be expected to stabilize at some value of independent rate, but in each case at values less than that of the intact chain.

In the context of unrestricted ingestion, certain of the smaller units appear to occur multiply within the chain, and thus at a rate greater than that of the intact chain. The within-chain arrangement may be such as to schedule ratios of certain of the smaller units with respect to others; for example, a number of chews may antecede a swallow. But that the within-chain rate of all such units is dependent, not independent, could be shown, presumably, either by testing them in isolation or, what would amount to the same thing, by making any one of them the contingency unit. As contingency units, seizing or biting or chewing, etc., would be expected to fall short of their within-chain rates. And, in general, when the rate of the contingency unit does not approach the rate at which the same unit occurred when the unit was a part of the segment of unre-

stricted responding, there is evidence that the segment was not counted by the spu, but by some unit of dependent rate.

The manipulation case reported suggests that single operations of the manipulanda may comprise the spu for segments of unrestricted manipulation. Both rats and monkeys appear to manipulate in "bursts," i.e., by multiples of lever presses, etc. Nonetheless, when the Cebus was given the door in contingent status, and thus restricted to discrete operations of the door, the immediate and substantial reduction in the door Rs was transient. By the fifth contingency test, the door R had reacquired its original rate, though it was then limited to discrete occurrences in contrast to the multiples characteristic of unrestricted manipulation.

An essential parallel between intact ingestion and manipulation chains may possibly be shown as follows: for manipulanda which yield different independent rates of operation, *contacts* to the same inoperable manipulanda may vary little and in all cases stabilize at independent rates substantially less than those for operations. Indeed, in the Cebus the generally high manipulation rate may make it possible to schedule, say, lever presses with respect to lever contacts. Though species may adapt to disrupted multiples of intact chains, the adaptability cannot be thoroughgoing. Instead, for repeated tests at the same intertest intervals, different movements of the species may be expected to stabilize at different independent rates. Work of this kind would further the brilliant, pioneer investigations by Schiller (1952) concerning species-specific movements in the chimp, and the relevance of these movements to what has been called insight.

In locomotion a blind, empirical approach is necessitated by the relative

absence of anthropomorphic units coupled with the difficulty of observation. With the rat and the activity wheel the spu may possibly be found by testing across a series of decreasing stimulus restrictions. Starting with a small fraction of a revolution, the distance the wheel is made available on any one operation may be gradually increased, until a per operation distance is found which, in equal periods of wheel availability, yields a total distance of use equal to that for the unrestricted wheel. If such a unit exists, then the independent rate of the segment for unrestricted wheel turning would amount to: number of revolutions per unit time by number of spu's per revolution or multiples of revolutions. This technique would accommodate differences in wheel diameters, and would not require topographical calibration of the measurement unit.

A different and more general approach to the problem of determining the independent rate for behavior segments lacking in anthropomorphic units has been suggested by MacCorquodale.² In brief, the method consists in first ranking Rs that are easily counted. Provided the reinforcement generalization holds across the group of ranked Rs, their rate continuum is then used to locate the independent rate of arbitrary units taken from behavior segments that are difficult to count.

Finally, that rate is a property common to disparate movements and that a method may possibly be found for assigning but one value of independent rate to any segment of unrestricted responding are themselves of little consequence. Advantages depend upon using the common property as the basis for a function, for only then do the disparate movements become commen-

² K. MacCorquodale. Personal communication, November 1958.

asurable in terms of their values for the common property.

The function that is entailed by the reinforcement generalization is nonspecific, though within the limits of that function there is a definite commensurability between the different Rs. Because the generalization treats a rate differential as a sufficient condition for reinforcement, ranking the Rs of an organism in terms of their independent rates should permit predicting which Rs will reinforce which others. Only the R with the highest independent rate should be a universal reinforcer, only the lowest R fail to reinforce any other R, while those intermediate on the continuum should reinforce all those below themselves and be reinforced in turn by all those above. Moreover, all Rs of like independent rate would be equal; they would reinforce the same lower-rate Rs and be reinforced in turn by a common group of higher-rate Rs. The function is nonspecific, however, in that it does not permit specifying the dependent rate that will be attained by the lower-rate R. And what is being sought is the function that will permit calculating dependent rate from measures of the independent rates of the two Rs involved in any instance of reinforcement.

REFERENCES

- BAKER, R. A., JR. A study of the feeding behavior of laboratory animals. Unpublished doctoral dissertation, Stanford University, 1952.
- BIRCH, D., BURNSTEIN, E., & CLARK, R. A. Response strength as a function of hours of food deprivation under a controlled maintenance schedule. *J. comp. physiol. Psychol.*, 1958, **51**, 350-354.
- BOUSFIELD, W. A., & ELLIOTT, M. H. The effect of fasting on the eating behavior of rats. *J. genet. Psychol.*, 1934, **45**, 227-237.
- BUTLER, R. A. The effect of deprivation of visual incentives on visual exploration motivation in monkeys. *J. comp. physiol. Psychol.*, 1957, **50**, 177-179.
- HILL, W. F. Activity as an autonomous drive. *J. comp. physiol. Psychol.*, 1956, **49**, 15-19.
- HURWITZ, H. M. B. A source of error in estimating the number of reinforcements in a lever-pressing apparatus. *J. exp. Anal. Behav.*, 1958, **1**, 149-152.
- KAGAN, J., & BERKUN, M. The reward value of running activity. *J. comp. physiol. Psychol.*, 1954, **47**, 108.
- KLÜVER, H. *Behavior mechanisms in monkeys*. Chicago: Univer. Chicago Press, 1933.
- LAWRENCE, D. H., & MASON, W. A. Food intake in the rat as a function of deprivation intervals and feeding rhythms. *J. comp. physiol. Psychol.*, 1955, **48**, 267-271.
- LORENZ, K. The conception of instinctive behavior. In C. H. Schiller (Ed.), *Instinctive behavior*. New York: International Univer. Press, 1957. Pp. 129-175.
- OCHOCKI, F. J., & PREMACK, D. The joint effect of stimulus deprivation and the intertest interval on the frequency of light-contingent bar pressing. Paper read at Midwestern Psychological Association, Detroit, May 1958.
- PREMACK, A. J., & PREMACK, D. Increments in ad libitum eating as a function of deprivation for wheel-turning behavior. Paper read at Midwestern Psychological Association, Detroit, May 1958.
- PREMACK, D. Deprivation-performance function for light-contingent bar pressing as determined by the number of consecutive tests per deprivation interval. Paper read at Midwestern Psychological Association, Detroit, May 1958.
- PREMACK, D., & BAHWELL, R. Operant level lever pressing by a monkey as a function of intertest interval. *J. exp. Anal. Behav.*, in press.
- PREMACK, D., COLLIER, G., & ROBERTS, C. L. Frequency of light contingent bar pressing as a function of the amount of deprivation for light. *Amer. Psychologist*, 1957, **12**, 411. (Abstract)
- SCHILLER, P. VON. Innate constituents of complex responses in primates. *Psychol. Rev.*, 1952, **59**, 177-191.
- SLONAKER, J. R. Long fluctuations in voluntary activity of the albino rat. *Amer. J. Physiol.*, 1926, **77**, 503-508.

(Received July 22, 1958)