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RATE DIFFERENTIAL REINFORCEMENT IN MONKEY MANIPULATION

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A set of four manipulanda were presented to four Cebus monkeys, individually, and later in pairs. Step 1 provided an estimate of each S's probability of operating each item, while Step 2 determined whether pairing the items would disturb the ordinal relations among individual response probabilities. Both procedures provided information necessary for testing the assumption that a reinforcer is simply a contingent response whose independent probability of occurrence is greater than that of the associated instrumental response. Step 3 tested this assumption by again presenting pairs of items, but with one locked and its operation made contingent upon operation of the free item of the pair. The four Ss differed markedly in the extent to which the items produced different independent response probabilities, and correspondingly, in the extent to which the contingent pairs subsequently produced reinforcement. Confirmation of the present assumptions came primarily from one S, which differed substantially on the individual items, and showed five cases of reinforcement, all in the predicted direction. Further, reinforcement was shown by an increase in both contingency and extinction sessions. Finally, the response of intermediate probability reinforced the response of least, but not the one of greatest, probability, indicating that a reinforcer cannot be identified absolutely, but only relative to the base response.

The generalization that, of any two responses, the independently more probable one will reinforce the less probable one represents the major assumption of a recent model of positive reinforcement (Premack, 1959, 1961, 1962). This assumption was tested in the present experiments with the use of manipulation responses in monkeys. Basically, a two-stage procedure was used. First, estimates were obtained of S's probability of operating each of four different manipulanda. Second, the manipulanda were presented in pairs—one free, one locked—with operation of the locked item contingent upon operation of the free item. The model predicts that the contingency will increase the frequency of the free response, provided the independent probability of the contingent response is greater than that of the free response, and that the increase will be proportional to the independent probability of the contingent response.

In addition, that reinforcement is a relative, not an absolute property, follows from the model, as can be shown by applying it to three responses of different independent probabilities. Let A, B, C represent three responses of an organism with independent probabilities in descending order. If contingencies are arranged between all pairs of responses, the model predicts that A will reinforce both B and C; C will not reinforce either A or B, while B will reinforce C but will not reinforce A. Considered jointly, the reinforcement properties of A and C appear to corroborate the traditional absolute view: some events are, while others are not, reinforcers (*e.g.*, Skinner, 1938, p. 62). But the reinforcement properties of B controvert this view for, according to the model, B both is and is not a reinforcer, depending upon the relative probability of the referent response.

METHOD

Subjects

Four male Cebus monkeys—two cinnamon, two hooded capuchin—about 3½ yr old. None had experienced either food-contingent training or experimentally-induced food pri-

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vation, but all had had extensive previous experience with operant-level manipulation on items similar to those of the present experiments (*e.g.*, Premack and Bahwell, 1959). Throughout the present series, *S*s had free access to Purina monkey pellets and water, supplemented by a daily multi-vitamin sandwich. Testing was daily from approximately 12 to 1 pm, and food was replenished daily at approximately 4 pm.

Apparatus

A metal cage (40 x 30 x 27 in.) which both housed and tested *S*, and four manipulanda were used. Two normally closed ports in the front of the cage were equipped to receive any one or any pair of items; when inserted, the center of each item was approximately 16 in. from the floor of the cage. A lever (L), plunger (P), door (D), and horizontally-operated lever (H) were the items used. Constructed of stainless steel and ball bearing pivots by the University Science Instrument Shop, the items had operation distances of approximately 2½ to 3½ in., and force requirements ranging from approximately 35 to 55 gm.

The principal feature of each manipulandum was a solenoid operated lock that could be used to render any item inoperable. When pairs of items were given, either one could be locked and its release made contingent upon operation of the free item of the pair. Operation of the free item released the locked item, while operation of the previously-locked item restored its own lock, thereby reinstating the original contingency. Release of the locked item required both displacement and return to resting position of the free item. Previous work showed that if return-to-resting-position was not an explicit requirement, *S*s tended to hold the free item in its displaced position with one hand while freely operating the "contingent" item with the other hand.

Procedure

The four different procedures used are described separately in the appropriate results section. General procedure was the same in all test phases: either one or both of the panels were removed from the front of the cage, and either one or two items inserted and bolted to the cage. All sessions lasted 1 hr, and all were given daily, those within a test phase, and those between successive test phases.

RESULTS

Independent Rates

In the first test phase the items were presented individually with no restrictions upon responding. The four items were given to each *S* in a fixed and different order, and eight sessions were given per item; a total of 32, 1-hr sessions for the set of four items. The interval between sessions on the same item was 96 hr. Previous work (Premack and Bahwell, 1959; Premack and Collier, 1962) has shown that frequency of manipulation, in both rats and monkeys, is largely regulated by intersession interval (ISI); a sufficient ISI tends to maintain total output per item despite indefinitely many exposures to the item.

The separate quadrants of Fig. 1 show the frequency with which each *S* operated each item on each of the eight sessions. The x axis identifies the item, the y axis gives frequency per session, and the separate numbered curves show the repeated measures. Marked individual differences may be seen in Fig. 1. Chicko

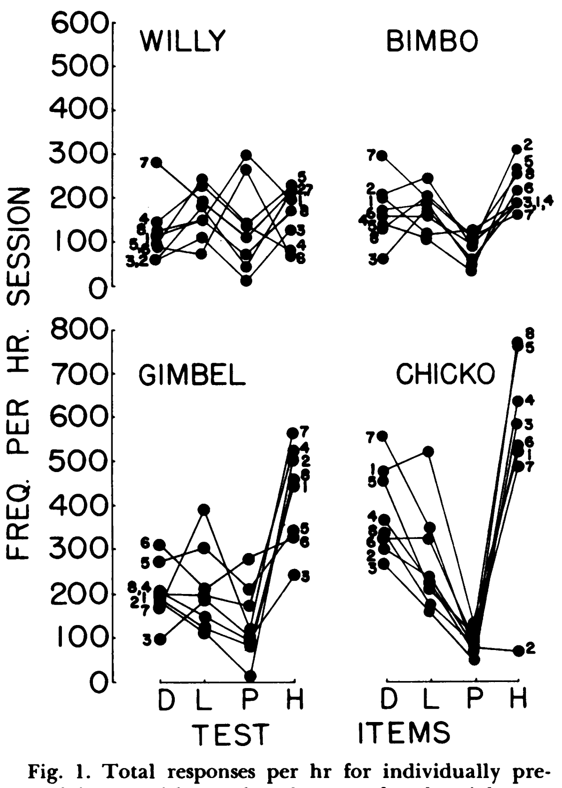

Fig. 1. Total responses per hr for individually presented items, with numbered curves for the eight sessions given per item.

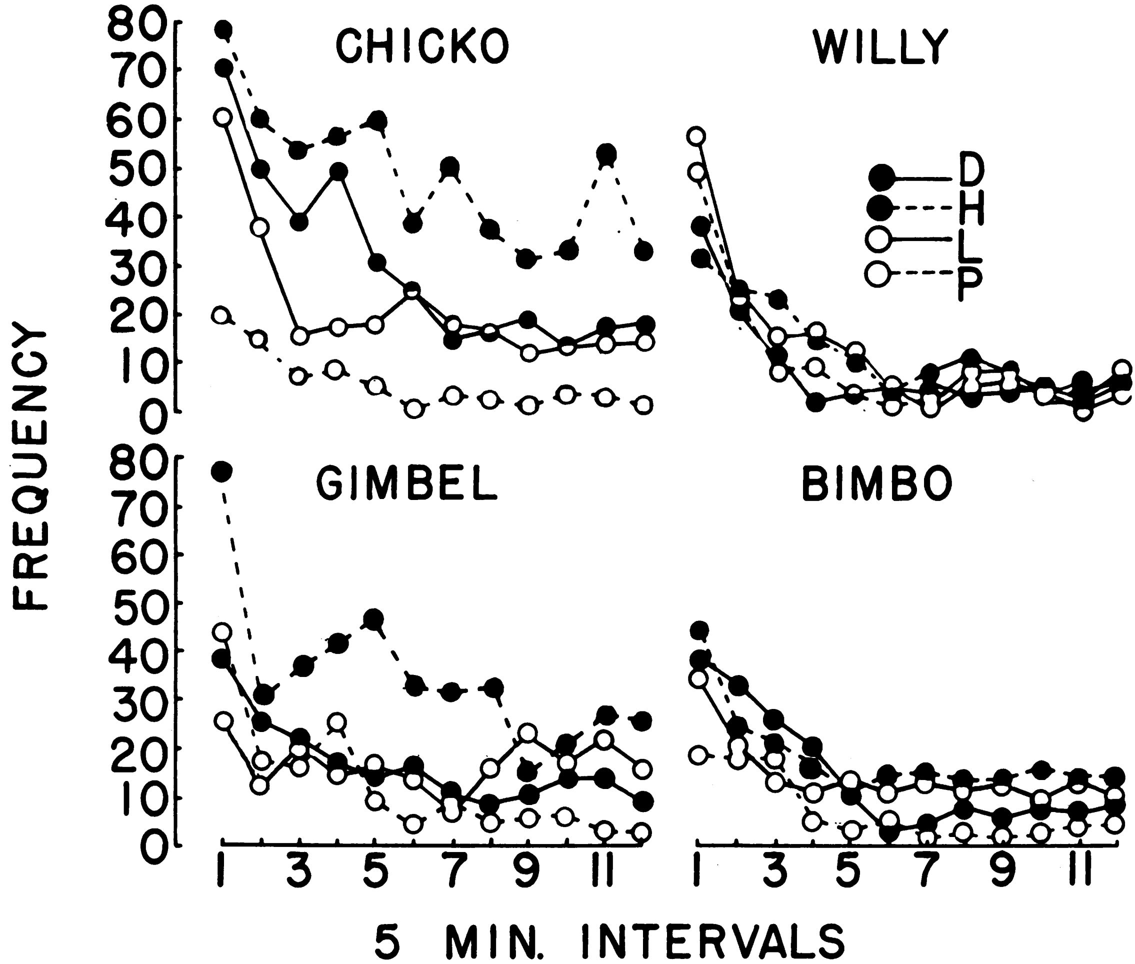

Fig. 2. Within-session responding for individually presented items. Frequency per 5-min interval averaged over all eight replications, with item as the parameter.

and Willy depict the two extremes, the former showing clear and consistent preferences, the latter essentially no preferences, coupled with a generally low response level.

Figure 2 shows mean response rate per 5 min interval averaged over all eight sessions. The characteristic within-session decrement may be seen, as well as the different decelerations of the several items. All *S*s except Willy showed at least one preference, but only in Chicko were these large and consistent.

Table 1 gives total frequency per replication averaged over all items; total frequency varied nonmonotonically, but did not decline, with replications. Thus, although responding declined within each session (see Fig. 2), the 96-hr inter-item interval provided for complete between-sessions recovery.

Table 1
Total Frequency per Replication for Individually Presented Items

	Replications								
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*Total*
Chicko	1623	1219	1044	1273	1518	1268	1444	1344	10,733
Gimbel	832	942	613	1080	1128	1130	1233	887	7,845
Bimbo	641	864	499	613	561	629	783	704	5,294
Willy	765	509	315	590	706	508	814	523	4,730

Independent Rates of Pairs

In the second test phase, *Ss* were presented with pairs of items, again with no restrictions upon responding. The six pairs generated by the four items were presented to each *S* in a fixed and different order, and four sessions were run per pair, a total of 24, 1-hr sessions for the set of six pairs. Testing was daily, but the interval between sessions on the same pair was 144 hr, and that between sessions on the same item was an average of approximately 40 hr.

The main purpose of this procedure was to determine whether pairing the items would disturb the ordinal relations among the individual response probabilities, in particular, reverse their rank order. If pairing were to have such an effect, then, because in the contingency situation *S* confronts pairs of items, predictions as to which items will reinforce which others would have to be made in terms of the rank order among pairs (for an actual case, see Brownstein, 1962).

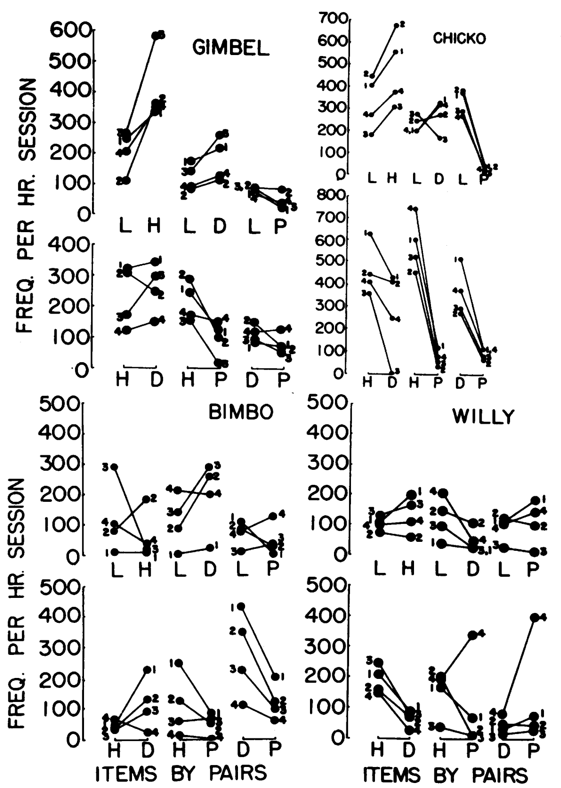

Fig. 3. Total responses per hr for paired items, with numbered curves for the four sessions given per pair.

Figure 3 shows total responses per session made on each item of a pair on all of the four replications. Differences between *Ss* on individual items reappear. For example, in the case of Willy, no pair differed appreciably, whereas for Chicko, in five of six pairs, ordinal relations among members of pairs were consistent over all replications. Moreover, the inconsistent pair consisted of the two items that differed least on individual presentation.

Although both of the above procedures raise independent questions, they serve here as prerequisites for tests of the present assumptions. To determine whether a more probable response will reinforce a less probable one requires being able to differentiate between more and less probable responses. Ideally, it requires ordering a large set of responses in terms of their independent probabilities. The failure of all but Chicko to approximate this requirement reflects a principal difficulty of the procedure—finding items on which *Ss* will differ. This difficulty is instructive, however, for although there are few rules to guide the search, there is the suggestion that *S* may itself be a critical variable. If this is even approximately true, important practical consequences may follow. Subjects that differ little in probability of responding to the constituents of their environment will, according to the present model, be proportionately limited as to their reinforcement possibilities. For example, differences among the four *Ss* on the present set of items lead to the prediction that, when the items are paired contingently, Willy will show few if any reinforcement effects, Chicko a number of such effects, and the other two *Ss* an intermediate number; the number being proportional to the number of differences shown among the individual response probabilities.

Contingency Tests

In this procedure the items were again presented in pairs, but now one item was locked and its operation made contingent upon operation of the free item. A continuous reinforcement schedule was used which, at the same time, ruled out storage or multiple responses on the contingent item. That is, at least one free response was required between any two contingent responses.

The six pairs of items generated 12 possible contingency pairs, since in this procedure the same item can serve both as a free item on one occasion and as a contingent item on another. Chicko and Gimbel were tested on nine, and Bimbo and Willy on five of the 12 possible pairs. For each pair, a block of four daily contingency sessions was given, followed by a block of four daily extinction sessions. In extinction, the contingent item was removed, the port was closed as in the original procedure, and only the previously free item was given. On five of the nine pairs on which Chicko was tested, the contingent response had a higher independent rate than the free response, and these five cases were replicated completely, including the alternating blocks of contingency and extinction sessions. Over the course of the present procedure, Chicko received 112 daily, 1-hr sessions.

Maintaining a 24-hr ISI over as many as four 1-hr sessions, as in the contingency procedure, typically produces a cumulative decrement in total manipulation responses per session. Thus, any increments produced by contingency training occurred despite an ISI which by itself would be expected to produce a lower independent rate than that of the 96-hr ISI of procedure 1.

Contingency Results

The outcome for the four *S*s differed in a manner generally predictable from their independent rate records. Main results are summarized in Table 2, which gives mean frequency per session averaged over all of the independent rate, independent rate of pairs, and contingency sessions, respectively. The pairs are listed in the order in which they were presented during contingency training. Chicko, after receiving the nine pairs in the order shown, was retested on the first five pairs, again in the order listed.

Rather than showing a reinforcement effect on any of the five pairs, Willy declined on all items. The over-all decrement would be expected on the following grounds: with no countering incremental effect of reinforcement, the 24-hr ISI of contingency training should produce a lower rate than the 96-hr ISI of the independent rate procedure.

Bimbo and Gimbel showed one strong and two weak incremental effects, respectively. Further, in neither *S* did any less-probable response increase any more-probable response. However, several more-probable responses failed to reinforce less-probable ones, most notably the P ⊃ H case in Gimbel. Also, success and failure of reinforcement bore no evident relation to magnitude of the differences among pairs shown in the independent rate procedures.

The clearest predictions possible are those for Chicko, who differed substantially and consistently on five of the six possible pairs. An immediate indication of the confirmation

Table 2
Comparison of Average Frequency per Session of the Free Response Alone (IR), in a Pair (IR-P), and in the Contingent Pair (C)

	Chicko				*Gimbel*		
Item	*IR*	*IR-P*	*C*	*Item*	*IR*	*IR-P*	*C*
P (H)	78	68	243	P (L)	131	40	152
P (D)	78	93	214	L (H)	207	200	224
L (H)	270	326	342	H (L)	424	414	318
P (L)	78	40	246	P (H)	131	89	82
D (H)	382	274	467	D (H)	201	259	148
L (D)	270	233	245	P (D)	131	78	105
H (P)	543	584	382	L (D)	207	119	94
D (P)	382	369	298	H (D)	424	230	206
H (D)	543	459	424	D (P)	201	115	161

	Willy				*Bimbo*		
Item	*IR*	*IR-P*	*C*	*Item*	*IR*	*IR-P*	*C*
D (H)	121	63	57	L (D)	178	111	230
L (D)	177	124	112	P (D)	85	118	77
P (H)	136	109	95	D (L)	175	193	121
H (P)	167	147	83	P (H)	85	42	22
L (H)	167	100	120	H (L)	225	59	83

of the main predictions is shown in Table 2. In all cases where the independent probability of the contingent response was greater than that of the free response, there was an increase in the free response (1-5); all other cases led to a decrement (6-9). In mean frequency per session, increments in the free response ranged from 22.2% to 211.5% and decrements from 9.2% to 37.4%.

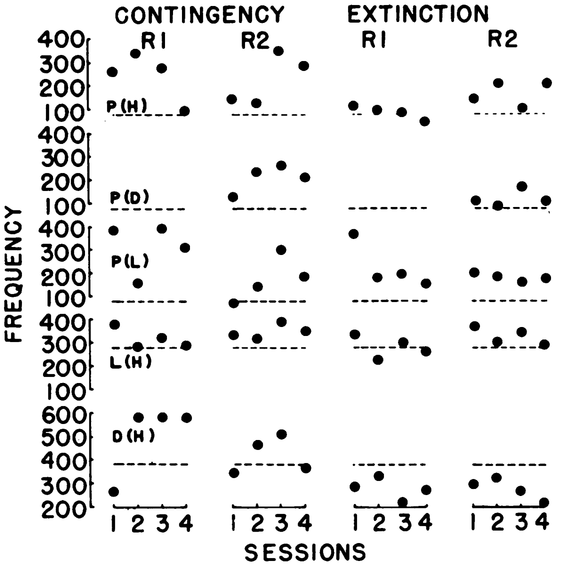

Fig. 4. Frequency per session on all five predicted-positive cases, with separate displays for contingency and extinction, and for replications 1 and 2 (R1, R2). Open letter, *e.g.*, P, indicates free response, and bracketed letter, *e.g.*, (H), contingent response; dotted lines give independent rates or operant-levels of free responses. Data for Chicko.

Frequency per session for all of Chicko's contingency and extinction sessions for the five incremental cases on both replications is shown in Fig. 4 (omission of the P [L] case on the first replication was an experimenter oversight). The general trends of these data are shown in Fig. 5, which gives frequency per session averaged over all five cases, with separate curves for replications. As shown in Fig. 5, the averaged contingency and extinction gradients differed in the expected manner. In eight of the nine possible contingency cases, frequency was greatest on either the second or third session; the relative decrement on the fourth session probably reflects the 24-hr ISI which, by itself, typically produces a decrement in this kind of responding. Although total number of contingency responses was less on the second replication than on the first (5621 *vs.* 4756), none of the individual cases in Fig. 4 show any more-probable response to have lost its power to reinforce a less-probable one.

An extinction level above that of the operant-level is shown clearly in Fig. 4 for all P and L cases, but was not found in any case of D (H). Extinction, even more than contingency training, occurred under an adverse ISI. Whereas base frequencies are for a 96-hr ISI, even the first of the four extinction sessions represents the fifth consecutive exposure to an item at only a 24-hr ISI.

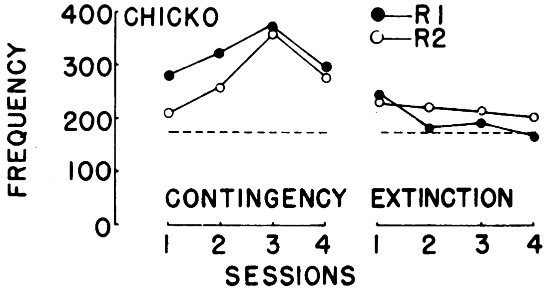

Fig. 5. Averaged contingency and extinction gradients for all five predicted-positive cases; dotted line gives operant-level averaged over all free responses. Data for Chicko.

Within-session contingency and extinction results for Chicko are shown in Fig. 6, where each of the nine sections treats the pair of items joined by the horseshoe or material conditional sign. In the bottom row, for example, P was consistently the free item, while, in separate series of tests, operation of D, H and L, respectively, were contingent upon operation of P. The x and y axes show, respectively, time and rate per 10 min interval averaged over the four and in some cases eight sessions given per pair.

The independent rate protocol for Chicko permitted three kinds of contingencies: contingent response higher than, less than and, in the one inconsistent case, about equal to the free response. First, contingent higher than free response produced in all five cases an increment in the free response, shown in $P \supset D$, $P \supset H$, $P \supset L$, $L \supset H$, $D \supset H$. Second, contingent less than free response produced a decrement in the free response, shown in $H \supset D$, $H \supset P$, and less clearly in $D \supset P$. Third, contingent and free responses about equal tended to produce little or no change, shown in $L \supset D$.

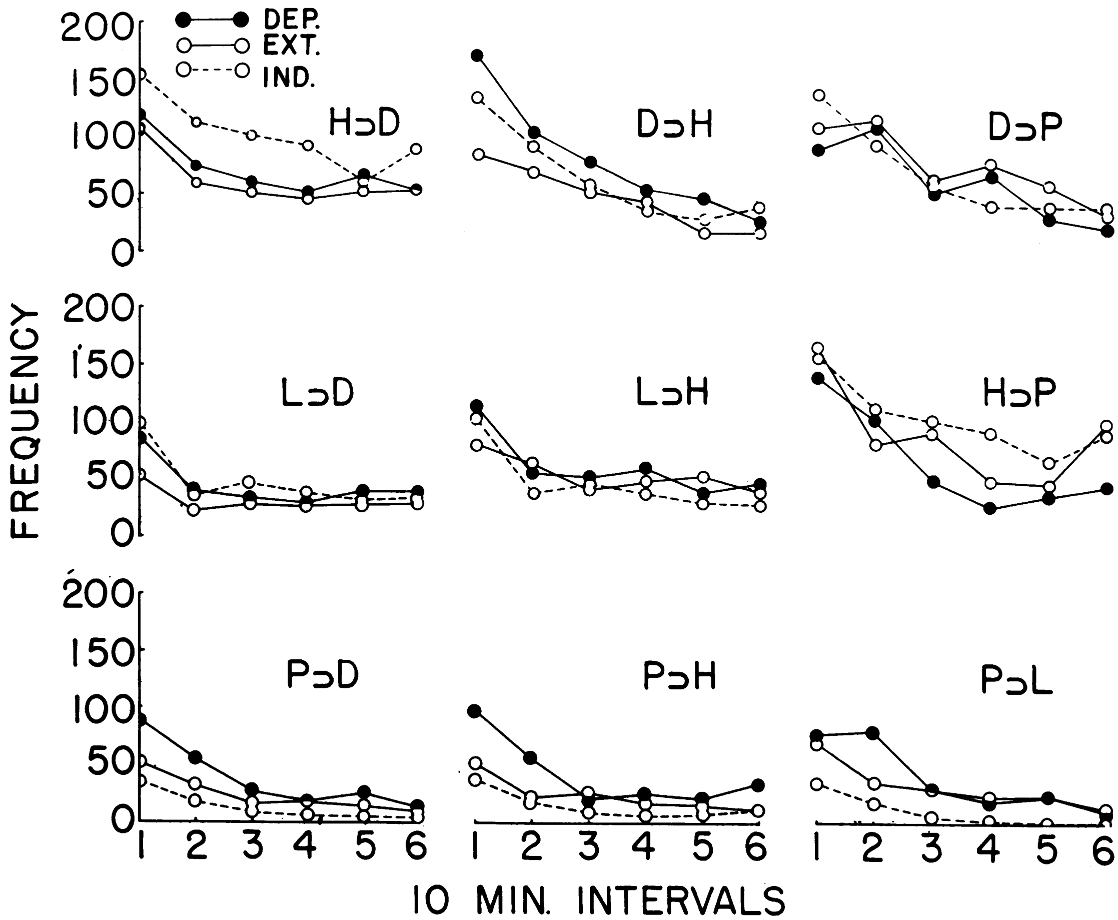

Fig. 6. Within-session responding on contingently-paired items. Frequency per 10 min interval averaged over all replications, with separate curves showing independent rate, dependent rate (reinforced), and extinction; data for Chicko.

Two further comparisons shown in Fig. 6 deal with the effect of (a) different contingent responses upon the same referent response, and (b) the same contingent response upon different referent responses. The first case, where H, D and L all served to reinforce P, is pertinent to the assumption that the increment to the referent response is proportional to the independent probability of the contingent response. This assumption was only weakly supported. Differences in H, D and L were reflected in the initial rates of P (mean initial 10 min) but not in total P responses per session. The second case, where H served to reinforce P, L and D, showed that the same reinforcer applied to three different referent responses did not produce the same reinforced rate, but rather a rate that was proportional to the operant-levels of the referent responses. Further, since the increments to D, L and P (reinforced minus operant-level) were 85, 62 and 185 responses per hr, respectively, there is the suggestion that independent rates of contingent and free responses may interact in determining reinforced rate. However, on this point, the present data cannot do more than raise the question of whether there is an interaction or whether operant-level enters simply as an additive constant in determining reinforced rate.

A last point of major interest is the evidence contained in Fig. 6 concerning the relativity of reinforcement. As shown in Chicko's data in both Fig. 1 and 3, H was the most probable response of the set, P the least, and D intermediate. Figure 6 shows that H reinforced all members of the set while P reinforced none and, instead, was itself reinforced by all other members. Considered jointly, the results for H and P appear to ubstantiate the traditional absolute view: H, which is a reinforcer, reinforces all responses, while P, which is not a reinforcer, reinforces no response. But the results for D controvert this view, for D, which was of intermediate probability, reinforced P but failed to reinforce H. Thus, depending upon the relative probability of the referent response, D both was and was not a reinforcer. These results do not accord with the trans-situationality assumption which Meehl (1950) has shown to characterize the classical account of reinforcement. Since the present case appears to represent the first direct test of the assumption, the previous success of the assumption may rest largely upon a failure to have tested it.

DISCUSSION

Operant-level manipulation was used both as the contingent and instrumental events, underscoring the assumption that any more-probable response will reinforce any less-probable one. Although manipulation proved to be unstable and of low frequency, its main detriment for the present procedure is the lack of that kind of information which would permit an advance ordering of a set of manipulation responses. Thus, the present four items were chosen essentially at random, and on this set of items, of four *S*s, only one showed sizable and consistent differences; another showed no reliable differences; and two others, generally small and inconsistent differences.

Results for the *S* that differed consistently among the items substantially confirmed the main predictions. When items were presented in contingent pairs, no more-probable contingent event failed to reinforce any less-prob able free event; further, no more-probable free event was reinforced by any less-probable contingent event.

The *S* that showed no differences among the items showed no reinforcement effects, as was predicted, but this kind of outcome is necessarily less instructive than when both positive and negative effects are obtained. Least informative were the two inconsistent *S*s; their contingency results were as indeterminate as their original differences among the items. In general, agreement between *S*s' individual response probabilities and the number of contingent pairs that subsequently produced reinforcement confirmed a practical implication of the model—*S*s that differ little in probability of responding to the components of their environment will be proportionately limited in their reinforcement possibilities for the environment.

Contrary to what may be suggested by the response units used in these experiments, the present assumptions place a unique burden upon definitions of response and response probability. At the time of the experiment, the response problem had not been seriously considered, but a formal response treatment can now be provided that both satisfies the logical requirements of the present assumptions and suggests why the response units used were generally successful.

Only two pieces of information are required by the treatment: (a) operational definition of the behavior in question, and (b) determination of the minimum duration for which the behavior occurs. Divide experiment time into successive time intervals equal to the minimum duration of the behavior; then make a digital, or yes-no, decision for each interval. That is, simply decide for each interval whether or not the operational definition was fulfilled in the interval. Let $P_r \cong \frac{F_{0i}}{F_{pi}}$ (1), where P_r is probability of the response, and F_{oi} and F_{pi} are, respectively, observed frequency of occupied or "yes" intervals, and total possible intervals, the latter being the ratio of experiment time to minimum duration of the behavior. If the response is defined as the minimum duration for which the operationally-defined behavior is observed to occur, then (1) becomes $P_r \cong \frac{F_r}{F_{pi}}$, where F_r is observed frequency of the response. A further exact alternative is to operate a clock whenever the operational definition is fulfilled; then P_r is simply the ratio of observed response time to possible response time.

Response duration, defined as the period for which the micro-switch was activated, was measured for Chicko from Esterline Angus records taken in the original sessions for independent rate. Mean response durations for H, D, L and P were: 1.48, 1.37, 1.40, and 2.00 sec, respectively. Although response durations differed for the several items, the differences were not so great as to offset the differences in frequency. Thus, estimated mean response probabilities for H, D, L and P were: .22, .15, .11, and .04, respectively. This is the same rank order as that given by consideration of frequency alone.

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