EFFECTS OF REINFORCEMENT MAGNITUDE ON CHOICE AND RATE OF RESPONDING¹

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Behavior is sometimes insensitive, and sometimes extremely sensitive, to changes in reinforcement magnitude. The present work attempted to analyze this disparity by comparing, in a single experimental situation, a pigeon's choices with its response rates. Whereas choices varied directly with reinforcement duration, rates of responding were comparatively insensitive to duration changes. These results suggest that the effect of reinforcement magnitude on responding partly depends upon the extent to which responding influences the amount of reinforcement.

Inconclusive and apparently inconsistent results have been obtained from experiments dealing with reinforcement magnitude. Different magnitudes sometimes resulted in little, no, or only transient, differences in behavior (Jenkins and Clayton, 1949; Kling, 1956; Keesey and Kling, 1961; Schrier, 1962; Catania, 1963). Such studies caused one reviewer to conclude that the amount of a reinforcement "... is not usually very consequential. Within narrow limits, at any rate, it has been found that a small reward or a small punishment works just as well as 'larger' reinforcements . . ." (Mowrer, 1960, p. 387). On the other hand, variations in amount of reinforcement sometimes produce large, consistent, and lasting differences in behavior (Festinger, 1943; Denny and King, 1955; Pereboom, 1957; Clayton, 1964; Stadden and Innis, 1966).

Catania (1963), in an attempt to resolve this disagreement, showed that when pigeons were permitted to choose between reinforcement durations, preferences were linearly related to duration. When tested in a single-key apparatus, however, with reinforcement duration arbitrarily controlled by the experimenter, response rates did not vary with changes in reinforcement magnitude. The experimental literature can be advantageously divided according to this distinction, *i.e.*, as to whether magni-

tude was independently varied in a single-operandum situation or whether subjects chose between magnitudes in a multi-operandum situation.

Reinforcement magnitude has also affected responding in some single-operandum situations (Crespi, 1942; Shettleworth and Nevin, 1965; Davenport, Goodrich, and Hagquist, 1966). Such results, together with the negative results often found, might be explained by distinguishing between "shift" (or within-subjects) and "nonshift" (or between-subjects) methods (Schrier, 1958). According to the first, each animal experiences more than one value of the reinforcer: either within sessions, on a day-to-day basis, or after stabilizing at a given value; according to the second, a given animal experiences only one value of the magnitude parameter, and different groups are compared. Schrier (1958) suggested that the effects of reinforcement magnitude are greater in shift situations than in nonshift, and that these effects might increase with frequency of shifts.

The effective difference between single- and multi-operandum situations might be related to the shift-nonshift distinction. All choice situations are necessarily shift situations, subjects experiencing at least two reinforcement values. Furthermore, the frequency of shifts in choice experiments is generally greater than in any single-operandum experiment. If one conceives of a frequency-of-shift continuum, the nonshift situation would lie at one extreme with the choice situation near the opposite end. Placing all magnitude experiments along this continuum might help to order the different results.

On the other hand, the variables controlling

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multi-operandum choices and single-operandum response rates might be fundamentally different, and the obtained results not due to shift. In multi-operandum situations, for example, the animal determines which of two or more reinforcement magnitudes will be presented, whereas in single-operandum situations, the animal's behavior does not usually influence magnitude. Thus, the contingencies relating responding to reinforcement magnitude are different in the two situations.

The present experiment compared the effects of reinforcement magnitude on two-key choices and single-key rates of responding when the shift conditions were the same for both variables. If shift alone determines the differences usually found, choices and response rates should here covary. If, however, the contingencies are important, choices and response rates might vary independently.

METHOD

Subjects

Three male White Carneaux pigeons, numbers 287, 288, and 289, all with previous experience in a variety of experiments, were maintained at approximately 80% of their free-feeding body weights.

Apparatus

Two Plexiglas Gerbrands response keys were mounted on the front wall of an 11.5 by 11-in. experimental chamber. Pecks of at least

10 g were recorded and produced feedback clicks for the pigeon. The left key could be transilluminated with two green Christmas-tree lamps and the right key with two red lamps. The keys, on a horizontal line 9 in. above the floor of the chamber, were 3.5 in. apart (center to center). A grain-hopper opening, 2 by 2.25 in., was 5.25 in. below the keys and centered between them. The chamber was illuminated by diffuse 12-w houselights. During reinforcement, the houselights were extinguished and the grain-hopper was illuminated by 6-w bulbs. White masking noise was continuously present in the chamber. Controlling apparatus, consisting of relays, stepping switches, counters, and timers, was in a separate room.

Procedure

The procedure is represented schematically in Fig. 1. In the presence of two lighted response keys, a pigeon could "choose" one of the keys by emitting a single peck on that key. This "choice response" had two effects: (1) it started a 5-sec timer; and, (2) it caused the opposite key to become inoperative and dark. For a minimum of 5 sec, responses were effective only on the previously chosen key. Each choice response therefore transformed the choice situation into a single-key situation. After the 5-sec interval, the first response to occur on the chosen key produced either food reinforcement or a 1-sec period of blackout, during which the experimental chamber was totally dark.

Food reinforcements were programmed on the two keys by two independent and concurrently activated variable-interval (VI) programmers. Each programmer was activated at all times throughout the session except when the individual programmer had programmed a reinforcement and during periods of blackout and reinforcement. The average interreinforcement interval on each of the VI schedules was 1 min. When a reinforcement had not been programmed, responding resulted in blackout. Following either reinforcement or blackout, the two keys were again lighted and operative, and the pigeon was again permitted to choose one key. Sessions ended after 55 reinforcements.

The independent variable was the duration of reinforcement, *i.e.*, the time that the pigeon was permitted access to grain. For Subjects 288 and 289, the duration of reinforcement on the

Fig. 1. Diagram of one cycle of the experimental procedure. Each box represents one possible stimulus condition. At the start of a cycle (left box) both keys were lighted and operative. One peck on either key, a "choice," led to one of the conditions represented by the middle boxes, during which only the previously pecked key was lighted and operative. The first peck to occur on the lighted key after 5 sec produced either reinforcement or blackout, as determined by the schedule of reinforcement.

right, or standard, key was always 2 sec, while reinforcement durations on the variable left key were, in the order presented, 6, 10, 4, 3, 2.5, 2, and 2.25 sec. Each of these comparisons was maintained for approximately 30 sessions. Subject 287 entered the experiment with a strong position preference and therefore each of the above comparisons was presented twice: first the left key was the 2-sec standard key for approximately 15 sessions and then the right key was the 2-sec standard key for an equal number of sessions. For Subjects 288 and 289, the data to be discussed were arithmetic averages from the last five sessions at each comparison point. Since Subject 287 was exposed to each reinforcement duration twice, the last three sessions during each exposure, for a total of six sessions, were averaged.

The behavioral variables to be compared were choice and rate of responding following a choice. A choice is defined as a single peck on one of the two keys when both keys were lighted and operative. Rate of responding is defined as the number of responses to a lighted and operative key divided by the time that only that key was lighted and operative. In calculating response rate, the choice responses and the times spent "choosing" were excluded. Thus, choice and rate of responding were independently measured.

RESULTS

Figure 2 shows the number of choices emitted by each subject. As reinforcement duration increased on the variable key, choices of that key increased while choices of the standard 2-sec key decreased.

Rates of responding following choices are shown in Fig. 3. As the variable-key reinforcement duration increased, response rates on that key *decreased* for Subjects 287 and 289; the rates on the standard 2-sec key increased for Subjects 288 and 289.

The relationship between choices of the standard and variable keys is shown in Fig. 4. A relative measure of preference was obtained by dividing variable-key choices by the total choices emitted during each session. According to this measure, 0.50 indicates that the two keys were chosen equally often, 0.67 indicates that the variable key was chosen twice for each choice of the standard key, 0.75, three to one, and so on. An arithmetic average of the sub-

Fig. 2. Number of choices of standard and variable keys as functions of reinforcement duration on the variable key. The reinforcement duration on the standard key was always 2 sec.

Fig. 3. Rates of responding following choices of the standard and variable keys as functions of reinforcement duration on the variable key.

jects' performances is used in this and the following figures. The rising function indicates that preference for the variable key increased with reinforcement magnitude. Figure 4 also shows the rates of responding on the variable key relative to the sum of the rates on both keys. The falling function indicates that the response rates on the variable, or greater magnitude, key were generally less than the rates on the standard key; the difference between these rates increased with reinforcement magnitude. As reinforcement duration increased, choices varied over a greater range than did rates of responding and the two changed in opposite directions.

Since they did not covary, the two behavioral variables might have been controlled by different dimensions of the reinforcing stimu-

Fig. 4. Relative choices and relative rates of responding as functions of reinforcement duration on the variable key. Relative values were calculated by dividing variable-key choices (or rates) by the sum of the choices (or rates) on variable plus standard keys. Data were averaged across subjects.

lus. Catania (1963) showed that, in a similar situation, choices were linearly related to reinforcement duration. In his experiment, the number of reinforcements was presumably equal on the two keys; however, Fig. 5 shows this not to be the case in the present work. While the VI programs on the two keys were the same, the choice distributions caused the obtained numbers of reinforcements to differ. To take this difference into account, choices were related to total access to reinforcement, calculated by multiplying the number of reinforcements obtained on a key by the duration of each reinforcement. Relative choices are plotted in Fig. 6 as a function of relative total access to reinforcement. The data points are roughly approximated by the diagonal line, suggesting a proportionality between the two variables. Relative choices equaled relative access to reinforcement.

The choice distributions also affected the ratios of obtained reinforcements to obtained blackouts—or the probabilities of reinforcement. Reinforcement probability is defined as the number of reinforcements obtained on a key divided by the number of reinforcements plus blackouts on the key. Since reinforcements were programmed by VI timing devices, the probability of reinforcement was largely determined by the frequency at which a key

was chosen. When the standard key was rarely chosen, choices of that key were likely to be reinforced. Conversely, when choices of the variable key were frequent, the probability of such a choice leading to reinforcement was relatively low. Figure 7 shows the reinforcement probabilities at each comparison. Due to the variations in choices, reinforcement probability decreased on the variable key and increased on the 2-sec key. These relationships might account for the decrease in relative rates of responding with increasing reinforcement magnitude. Figure 8 shows a roughly linear relationship between relative response rate and relative probability of reinforcement. If, as suggested by this figure, the rates of responding in the present experiment varied with probability, rather than duration of reinforcement, choices and response rates were controlled by different dimensions of the reinforcing stimulus.

DISCUSSION

In choice experiments, subjects can "compare" different reward magnitudes, a condition

Fig. 5. Relative number of obtained reinforcements, defined as the obtained reinforcements on the variable key divided by the sum of obtained reinforcements on variable plus standard keys, as a function of reinforcement duration on the variable key. Data were averaged across subjects.

Fig. 6. Relative choices (variable key/variable plus standard keys) as a function of relative total access to reinforcement. Total access to reinforcement is defined as the number of obtained reinforcements on a key multiplied by the duration of each reinforcement. Total access on the variable key is divided by the sum on the variable plus standard keys. The diagonal line shows the function that would be obtained if choices exactly matched access to reinforcement. Data were averaged across subjects.

Fig. 7. Probabilities of reinforcement on standard and variable keys as a function of reinforcement duration on the variable key. Probability of reinforcement is defined as the number of reinforcements obtained on a key divided by the total choices of that key. Data were averaged across subjects.

referred to as "shift," whereas comparisons often are not permitted in single-operandum situations ("nonshift"). The disparate results obtained in these situations might therefore be a function of shift. In the present experiment, however, with shift conditions identical, two-key choices and single-key rates of responding varied in opposite directions.

The obtained proportionality between choices and access to reinforcement confirms and extends Catania's (1963) results. The present study extended the range over which pigeons' choices match relative access to reinforcement and demonstrated this relationship with a novel experimental paradigm. Similar proportional relationships have been obtained by Herrnstein (1961) for frequency of reinforcement and Chung and Herrnstein (1967) for delay of reinforcement.

The inverse relationship between post-choice response rates and reinforcement magnitude must be viewed in light of the present

Fig. 8. Relative rates of responding (variable divided by variable plus standard) as a function of relative probabilities of reinforcement (variable divided by variable plus standard). Data were averaged across subjects.

paradigm. First, note that the response-rate calculations were in terms of the separate times spent responding on each key and therefore excluded both the choice responses and the pauses before these choices. This definition of response rate is similar to that used by Findley (1958) for a concurrent schedule and by Shettleworth and Nevin (1965) for a multiple schedule; it should not be confused with the overall response rate measures—responses divided by total session time—employed in most concurrent situations (*e.g.*, Herrnstein, 1961; Catania, 1963). Second, since choices preceded all rate of responding components, the rates might have been affected by the prior choices. Whether similar response rates would be obtained in the absence of choices, or whether the rates would be equal if the reinforcement probabilities were equal, cannot be determined from the present experiment. The results show, however, that choices and response rates in a single experiment do not covary. Thus, the presence or absence of comparisons, or the shift condition, does not alone determine the disparate effects of reinforcement magnitude.

Single- and multi-operandum results might depend upon two other obvious situational differences. First, the contingencies between responding and reinforcement magnitude are often different. Magnitude is a contingent dimension of reinforcement in many multi-operandum choice experiments; *e.g.*, one magnitude is obtained for a left choice and a different magnitude for a right choice. In most

single-operandum experiments, magnitude is a non-contingent dimension, different magnitudes presented independently of the subject's behavior. Second, there are at least two effective responses in choice experiments while only one in single-operandum experiments. The experimental literature suggests that the response-magnitude contingency, and not the number of responses, is critical. For example, Hendry (1962) and Hendry and Van-Toller (1964) reported striking effects when the magnitude of a reward is controlled by rate of responding in a single-operandum situation. Thus, when the contingencies in single-operandum experiments are similar to those in choice experiments, the effects of reinforcement magnitude are similar. Likewise, when magnitude is varied independently of responding in multi-operandum situations, little or no effects are found (Furchtgott and Rubin, 1953; McKelvey, 1956). These, together with the present findings, suggest that the effects of reinforcement magnitude depend upon the contingencies relating magnitude to behavior. The disparities between choice and response rate results might often be due to the different contingencies relating each of these behavioral variables to the magnitude dimension.

The effects obtained when reinforcement magnitude is a non-contingent dimension might well be related to shift (Schrier, 1958; Shettleworth and Nevin, 1965). The present analysis suggests, however, that the contingency between response and magnitude is an independent, and significant, factor. When responding influences reinforcement magnitude, the magnitude dimension exerts considerable control over responding. Furthermore, these effects are generally greater and more reliable than those obtained when magnitude is non-contingently varied. Similar results have been reported with respect to other stimulus dimensions, e.g., frequency of reinforcement (Herrnstein, 1964; Neuringer, 1967), intensity of punishment (Azrin and Holz, 1966), and frequency of punishment (Rachlin, 1967).

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