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DELAY AND NUMBER OF FOOD REINFORCERS: EFFECTS ON CHOICE AND LATENCIES

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Pigeons were given a choice between two identical-duration situations (terminal links of chain schedules). One terminal link of the choice pair provided two food deliveries, and the other provided five. The exact times of these food deliveries differed between the terminal links and were varied over conditions. A single response during the initial link gave immediate access to the corresponding terminal link. Forced trials, during which only one of the initial-link keys was lighted, were interspersed with choice trials during which both initial-link keys were lighted. Choice tended to favor whichever terminal link was correlated with the higher sum of the immediacies (i.e., the sum of the reciprocals of the delays to each of the reinforcers following the choice, with all delays measured from the choice). Latencies on forced trials and on choice trials also were related (negatively) to the sum of the immediacies. This correlation among response measures (choice and latencies) suggests that both measures are manifestations of the effect of conditioned reinforcement on response tendencies.

Key words: delay of reinforcement, conditioned reinforcement, choice, latency, preresponse pause, number of reinforcers, key peck, pigeons

In the present experiment a pigeon's key peck in the presence of one stimulus (the initial link of a chained schedule) produced access to a second stimulus (the terminal link) during which small bits of food were presented. Access to the terminal link of a chained schedule functioned as conditioned reinforcement for responding in the initial link (Catania, Yohalem, & Silverman, 1980; Dinsmoor, 1983; Kelleher & Gollub, 1962; Royalty, Williams, & Fantino, 1987; Vaughan, 1985). Sometimes the initial links for two different chained schedules were presented concurrently, thus providing a choice between two different terminal links. At other times, only one of the initial links was presented. The temporal distribution of reinforcers differed between the terminal links. The purpose of the study was to find out how two different dimensions of behavior, the percentage of choices of one terminal link over the other and the latency to produce a terminal link given the opportunity, were related to the temporal distribution of food presentations in the terminal link. Both of these behavioral properties can be construed as manifestations of initial-link response probability (e.g., Bush & Mosteller, 1955; Estes, 1959; Herrnstein, 1970) and so might be correlated effects of the conditioned reinforcing potency of access to the terminal link.

The present procedure was similar to that employed by McDiarmid and Rilling (1965). In their procedure a single peck to one of two lighted keys during the initial link (the choice period) changed the key color for a period of time during which a food hopper was briefly presented every 24 s until it had been presented four times. Then, shortly after the fourth food presentation, the key changed back to its original color, allowing the pigeon to make another choice. If the pigeon pecked the other key during the initial link, the color of that key changed for the same period of time, but the hopper was presented only twice: first after 6 s and second after 66 s had elapsed since the choice. Thus, one terminal link provided the greater amount of food per time and the other provided the shorter delay to the first food delivery.

McDiarmid and Rilling (1965) also studied two additional choice pairs where, again, one terminal link provided more food per time and the other provided food more quickly. The three choice pairs are represented in Figure 1.

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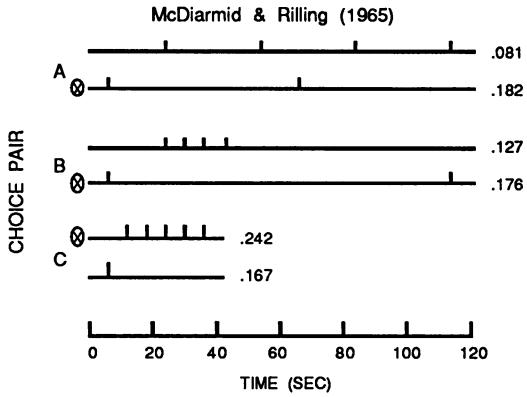

Fig. 1. Schematic of the terminal links comprising the three choice pairs studied by McDiarmid and Rilling (1965). The horizontal lines represent the durations of the terminal links, with time going from left to right. The short vertical lines indicate brief hopper presentations. The encircled Xs at the left indicate which of the two terminal links were chosen most often by the pigeons. The numbers to the right of the terminal-link lines indicate the sums of the immediacies for the corresponding terminal link.

The question was whether choice would consistently favor the alternative providing the higher yield of food or the alternative providing the more immediate food. The former would be consistent with an account based on a common-sense understanding of reinforcement (food-rate) maximizing, such as described (and then rejected) by Mazur and Herrnstein (1988); the latter would be consistent with the view of pigeons' choice as impulsive (Ainslie, 1975; Fantino, 1966; Logue, 1988; Mazur & Herrnstein, 1988; Rachlin & Green, 1972).

As it turned out, choice was consistently related neither to the total yield of food nor to the initial delay to food but was, instead, related to the sum of the immediacies (V), which McDiarmid and Rilling defined as

$$V = \sum \left(\frac{P_i}{D_i}\right), \qquad (1)$$

where D_i indicates the amount of time that elapses from the onset of the terminal link until the ith reinforcer in the series and P_i is the probability that a reinforcer actually will occur at the end of that delay ($P_i = 1.0$ in these studies). It is worth emphasizing that all delay values (D_i) are measured from the same starting point, namely the onset of the terminal link; thus, the D_i values are not interreinforcer times. The summation implies that each reinforcer in the series makes an independent contribution to the conditioned reinforcer value; the reciprocal function ($1/D_i$) implies that the size of the contribution diminishes sharply as a function of the reinforcer's delay from the choice point. The immediacy of a reinforcer is the reciprocal of the delay to the reinforcer.

The sums of the immediacies (V) for McDiarmid and Rilling's (1965) terminal-link pairs are shown in Figure 1 to the right of the corresponding alternative. For each choice pair, the pigeons chose the one associated with the higher value.

Mazur's work (e.g., 1986) has supported a definition of V that differs slightly from McDiarmid and Rilling's (1965). Specifically,

$$V = \sum \left(\frac{P_i}{(D_i + C)}\right), \qquad (2)$$

where C is a constant. The value of C usually has been found to be about 1 s; hence the two definitions will give about the same value except when D is very short. Because D was relatively long in most conditions of the present study, for simplicity Definition 1 will be used in the remainder of this paper.

A variety of different procedures can be conceptualized as involving a choice between situations providing a sequence of reinforcers. When procedures have been conceptualized this way, pigeons' choices have been found consistently to favor the situation correlated with the higher sum of the immediacies even when such choices result in a lower rate of food than would otherwise be possible (Davison, 1988; Kendall, 1986; Mazur, 1984, 1986; Mazur & Vaughan, 1987; Shull & Spear, 1987; Shull, Spear, & Bryson, 1981; Snyderman, 1983). Thus, the property of the temporal distribution of reinforcers described by the sum of the immediacies metric seems to control responding quite generally.

There is another behavioral relation under chain and chain-like schedules that is inconsistent with predictions based on a common-sense understanding of reinforcement maximization. To illustrate, imagine that a pigeon is trained under a chain fixed-ratio 1, fixed-time schedule (i.e., chain FR 1 FT). That is, a single key is lighted, say, white during the initial link. A single peck to the white key (FR 1) changes the key color and starts an interval of time at the end of which food is delivered (FT). Because the timer for food delivery (the FT) does not begin until the initial-link peck,

any pausing during the initial link reduces the rate of food deliveries below the maximum possible. Nonetheless, pigeons pause in the initial link, and the duration of this pause is an increasing function of the delay to food in the terminal link (cf. Shull, 1979).

Although the pausing in the initial link may seem odd if the controlling variable is assumed to be the contingency between pausing and the overall rate of food delivery, the pausing is understandable if access to the terminal link is thought to reinforce the response that produces the terminal link. The more potent access to the terminal link is as a conditioned reinforcer, the higher should be the momentary probability of emitting the initial-link response. (This conclusion follows from the conventional definition of reinforcement as a probability-enhancing process.) The higher the momentary probability of initiating the terminal link of a chain, the less time, on average, will pass until the initiating response occurs. To the extent, then, that the sum of the immediacies describes conditioned reinforcing potency of entering the terminal link due to the temporal distribution of food reinforcers, pause duration as well as choice should vary systematically as a function of the sum of the immediacies. The purpose of the present experiment was to examine this possibility.

Pigeons were given a choice between two terminal links. The initial links required only a single peck to gain access to the corresponding terminal link. One terminal link provided five food deliveries; the other provided two. The time that these food reinforcers were delivered was varied over conditions in order to examine a range of relative and absolute sums of the immediacies. The purpose was to determine whether choice favored whichever terminal link had the higher sum of the immediacies and whether the average pause in the initial link was systematically related to the absolute value of the sum of the immediacies of whichever terminal link was chosen.

METHOD

Subjects

The subjects were 3 adult male pigeons obtained from the Palmetto Pigeon Plant. Each pigeon was reduced to and maintained at about 85% of its free-feeding weight by limiting access to food. Water and grit were available continuously in each bird's home cage. The pigeons had served previously in experiments involving the reinforcement of key pecking by grain, but the particular experiments differed among the birds.

Apparatus

The experimental chamber was a box (34 cm by 38 cm by 50 cm high). The two circular (2.5 cm diameter) translucent response keys were mounted horizontally on the front wall 24 cm above the floor and 8 cm to the left and right of the center of the wall. The keys could be transilluminated white, red, or green by colored lights mounted behind the keys. When lighted white, a sufficiently forceful peck (at least 0.2 N) was recorded as a response. A houselight located on the ceiling near the front wall provided low-level illumination throughout the experimental session. A rectangular opening that gave access to mixed grain when the food hopper was raised was centered below the keys, 10 cm above the floor. At those times, the feeder opening was illuminated and the keylights were darkened. An externally mounted fan provided masking noise and ventilation. Electromechanical control and recording equipment was located in an adjoining room. All hopper presentations were 4 s long.

Procedure

Because of the birds' previous experimental histories, no pretraining was necessary.

Under all conditions pigeons chose between two terminal links, one providing two and the other providing five identical food reinforcers. Both terminal links were the same duration and both ended with a food delivery. In addition, during the two-food terminal link, a single reinforcer was delivered, independently of responding, after a delay of x s. During the five-food terminal link, four food reinforcers were delivered in sequence, with the first delivered t s after the choice, the second delivered $2t$ s after the choice, the third delivered $3t$ s after the choice, and the fourth delivered $4t$ s after the choice.

Choice trials and forced trials were intermixed during a session. During forced trials, only one of the keys was illuminated and operative during the initial link. Forced trials were presented in order to guarantee exposure to both terminal links and to permit measure-

Table 1

Summary of experimental conditions. Shown are the durations of the terminal links, the delays to food (s) timed from the choice for each of the terminal links comprising a choice pair, the key position for the two-food terminal link, the order of the conditon within the experiment, the corresponding sum of the immediacies (including the food delivery at the end of every terminal-link period), and the relative sums of the immediacies—$V_5/(V_5 + V_2)$, where V refers to the sum of the immediacies value and the subscripts identify the terminal link (two-food or five-food).

Condition set	Two-food on left or right	Order	Sum of the immediacies	$\frac{V_5}{(V_5 + V_2)}$
t = 20 s; Terminal link = 120 s				
Food deliveries at 20, 40, 60, 80, 120 s			.11	
versus				
Food deliveries at: 4, 120 s	L, L, L	3, 11, 12	.26	.30
8, 120 s	L, L, L, L	2, 4, 8, 10	.13	.46
12, 120 s	L	5	.092	.54
16, 120 s	L, L	6, 9	.071	.61
20, 120 s	L, L	1, 7	.058	.65
t = 40 s; Terminal link = 240 s				
Food deliveries at 40, 80, 120, 160, 240 s			.056	
versus				
Food deliveries at: 8, 240 s	R	13	.13	.30
32, 240 s	R, R	14, 16	.035	.62
t = 8 s; Terminal link = 480 s				
Food deliveries at 80, 160, 240, 320, 480 s			.028	
versus				
Food deliveries at: 16, 480 s	R, L, L	17, 23, 41	.065	.30
32, 480 s	R, L, L, R	21, 22, 26, 27	.033	.46
48, 480 s	L, R	24, 28	.023	.55
64, 480 s	R, R, L	18, 20, 25	.018	.61
t = 160 s; Terminal link = 960 s				
Food deliveries at 160, 320, 480, 620, 960 s			.014	
versus				
Food deliveries at: 32, 960 s	R	42	.032	.30
64, 960 s	R	46	.017	.45
128, 960 s	R, R	43, 45	.0087	.62

ment of initial-link latencies for each of the two terminal links.

For a block of daily sessions (i.e., for a condition), x and t were held constant. Within a set of conditions, the duration of t was held constant while x was varied in order to alter the relative values of the sum of the immediacies between the two terminal links. The duration of t was varied between sets of conditions in order to alter the absolute values of the sums of the immediacies comprising a choice.

A number of conditions were repeated in order to assess replicability. Also, the correlation among key position, terminal-link color, and the terminal-link schedule was varied between conditions. Table 1 summarizes the conditions studied and indicates the order in which they occurred. Also shown are the sums of the immediacies for the food-delivery schedules in each terminal link. Most conditions remained in effect for at least 20 consecutive sessions. Conditions 15, 19, 29 through 41, and 44 arranged the same general sorts of choices, but those arrangements were designed to answer questions other than those raised here, and so data from these conditions are not presented. Pigeon 3498 died after completing Condition 30; Pigeon 3758 died after completing Condition 44.

The following paragraphs describe the first condition in detail. The other conditions were similar except for the time values.

Choice trials. The two keys, left and right, were lighted white. A single peck on the left key changed its color to green for 120 s and darkened the right key. (Pecks to a darkened key had no programmed effect.) Four seconds after the transition to green, food was pre-

sented independently of responding. After that hopper presentation, the key color remained green, with no more food being delivered, until the 120-s terminal-link interval elapsed. At that time the key was again darkened and the hopper presented, following which the next initial-link period began. A similar sequence of events occurred if the pigeon instead pecked the right key during the choice (initial-link) period. That is, a single peck on the right key changed its color to red for 120 s and darkened the left key. Twenty seconds later the hopper was presented independently of responding; the hopper was then presented again 40, 60, and 80 s after the transition to red. After the fourth hopper presentation, food was not available again until the end of the 120-s red-key period, at which time the hopper was presented once more and then the next initial-link period began.

Thus, the initial-link schedules required one response (FR 1). Both terminal links (red and green) were the same duration (120 s), and both ended with the delivery of food. The latter ensured that the initial-link period always began following the same event, namely food delivery. In addition to the food delivery at the end, one terminal link (green/left) provided a short (4-s) delayed reinforcer, whereas the other terminal link (red/right) provided a sequence of four reinforcers delivered after consecutive intervals of $t = 20$ s timed from the transition to red. The reason for extending the terminal link for a period of time well beyond the delivery of the last of the sequence of four was to make sure that there would be a relatively long delay between the initial-link response on one trial and food deliveries obtained during later trials. In that way, choice should be little affected by the relation between initial-link responding on one trial and food deliveries during later trials (cf. Shull & Spear, 1987).

Forced trials. A forced trial consisted of lighting only one of the two keys white during the initial link. The other key was dark, and pecks to it had no effect. In all other respects the schedules were identical to those on choice trials.

Each daily session consisted of a mixture of eight forced (four to L and four to R) and 12 choice (C) trials presented in the following sequence: LRCCRLCCLCCRCCLCCRCC. This first condition was in effect for 26 daily sessions, a number of sessions well beyond that needed for performance to stabilize (i.e., no systematic trend over days in any of the performance measures).

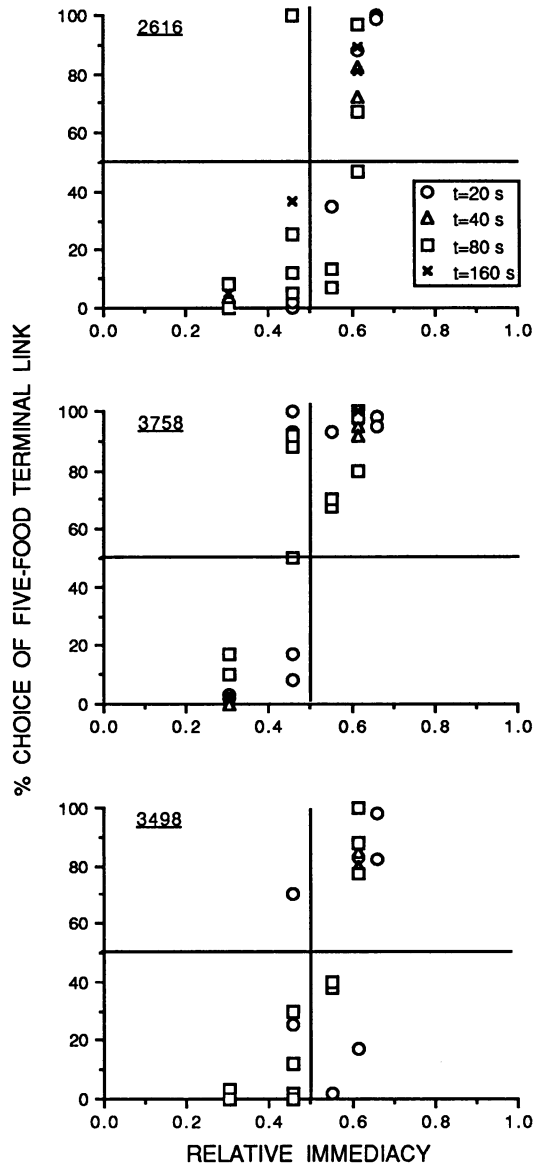

Fig. 2. Percentage of choices for the terminal link that provided five food deliveries plotted as a function of the sum of the immediacies for that terminal link relative to the sum of the sums of the immediacies for the two terminal links. Each point shows the choice percentage from a particular determination of a condition (last five sessions). Each panel shows data from a different bird. The horizontal line shows the 50% choice value; the vertical line shows the .5 relative immediacies value (i.e., the value where the sum of the immediacies is equal).

The performance measures on choice trials

included the number of initial-link pecks to each key, from which choice percentages could be calculated, and the cumulative time from the start of an initial-link period until a response, from which mean response latencies on choice trials could be computed. The performance measure on forced trials consisted of the cumulative time from the start of the initial-link period until the initial-link response. These times were recorded separately for forced-left and forced-right trials, so mean latencies to respond could be calculated for both alternatives.

RESULTS

Choice percentages for each condition were calculated from totals summed over the last five sessions of the condition. Latency (pause) durations for each condition were the medians of the means from each of the last five sessions of the condition.

Figure 2 shows for each bird how the percentage of choices of the five-food terminal link varied as a function of the relative sum of the immediacies for the five-food terminal link. The relative sum of the immediacies equaled $V_5/(V_5 + V_2)$, where V_5 is the sum of the immediacies for the five-food terminal link and V_2 is the sum of the immediacies for the two-food terminal link (see Table 1). This index (i.e., the relative sum of the immediacies) has a value of .5 when the sum of the immediacies for the two terminal links are equal. Relative sum of the immediacies values less than .5 indicates that the two-food terminal link had the higher sum of the immediacies; values greater than .5 indicate that the five-food terminal link had the higher sum of immediacies.

There are several effects to note in Figure 2. First, note that the experimental conditions cover only a small range of x-axis values on either side of the point at which the sum of the immediacies was equal (i.e., relative sum of the immediacies was .5). This restriction in range was by design: The most extreme values studied produced unambiguous choice data, so there seemed little point to examining even more extreme relative sum of the immediacies values. Instead, the most informative data seemed likely to come from values that closely bracketed the equality point because the function was expected to change most sharply within that range. At the same time, it should be understood that choice data are likely to be variable when the sums of the immediacies are close to equality because the terminal links should exert only a small differential effect.

Second, the consistencies in the choice functions illustrated in Figure 2 are notable. The pigeons' choices consistently favored the two-food terminal link when the delay (x) to the first of two food deliveries was 20% of the delay (t) to the first of the five deliveries in the other terminal link (see the points above .30 in each panel). In contrast, the pigeons' choices favored, with two exceptions, the five-food terminal link when x was 80% of t (see the points above .61 in each panel). As expected, the patterns of choice were inconsistent over replications and between pigeons when x was either 40% or 60% of t (see the points above .45 and .54 in each panel). (When more than one point had the same coordinate values, the point from the series with the larger value of t covered the other point or points. Thus, e.g., for Bird 3498 the square at the lower left covers two circles and a triangle, see Table 1, so there was even greater consistency than the number of visible points might suggest.)

The final point to note is that the absolute value of t did not appear to have a systematic effect on choice patterns. A full set of points was obtained from each bird with $t = 20$ s and $t = 80$ s, a four-fold difference. There does not appear to be any consistent difference between these two sets of points.

Another way to assess the conditioned reinforcing potency of the terminal link is to examine the time spent in the initial links until the single initial-link response occurred (i.e., the initial-link latency). As described above, longer latencies can be interpreted as implying lower tendencies to respond and thus lower conditioned reinforcing effectiveness of access to the terminal link. What is needed, then, is a graph showing how initial-link latency varies as a function of the terminal-link sum of the immediacies. If conditioned reinforcement potency is an increasing function of the sum of the immediacies, latency should be a decreasing function of the sum of the immediacies. Latencies on choice trials should be especially instructive because under some conditions the five-food terminal link had been favored and under other conditions the two-food terminal link had been favored. Thus, it should be possible to determine whether initial-link latency

was a similar function of the sum of the immediacies regardless of which terminal link had been favored.

Figure 3 shows the median latency on choice trials plotted as a function of the sum of the immediacies of whichever terminal link of the choice pair had been chosen most often for that condition. Circles show choice latencies from conditions in which the two-food alternative had been favored; triangles show latencies from conditions in which the five-food alternative had been favored. Because the pattern of choice differed somewhat among pigeons, the number of circles and triangles differed. Sums of the immediacies toward the left (i.e., low values) came from conditions with relatively long delays in the terminal links (i.e., large t or large x values). Although there is considerable variability (especially for Bird 3758), there are two consistent trends. First, and most important, the points scatter around a decreasing function, left to right. Note that the axes are scaled logarithmically. Latency durations varied over several orders of magnitude as a function of the sum of the immediacies. The length of the initial-link latencies at low sums of the immediacies—as long as 43 *min* for Bird 3758—seems especially remarkable given that the pigeons had only to make a single peck to enter the terminal link. Second, the latencies tended to be longer for a given sum of the immediacies when the five-food terminal link was chosen than when the two-food terminal link was the chosen alternative.

Initial-link latencies also were obtained on forced trials. For each condition, the median latency was determined separately when the pigeon was forced toward the two-food terminal link and when it was forced to the five-food terminal link. Figure 4 shows these forced-trial initial-link latencies plotted over the sum of the immediacies for the corresponding terminal link. Each plot contains four different symbols, indicating whether the latency was followed by the two-food terminal link or the five-food terminal link and whether the forcing was to a terminal link that was favored on choice trials or to one that was unfavored.

Because there were only four forced trials to each terminal link per day, it is not surprising that the plots in Figure 4 reveal considerable variability (especially for Bird 3758). Nevertheless, a negative trend is apparent, similar to that observed for the choice-trial

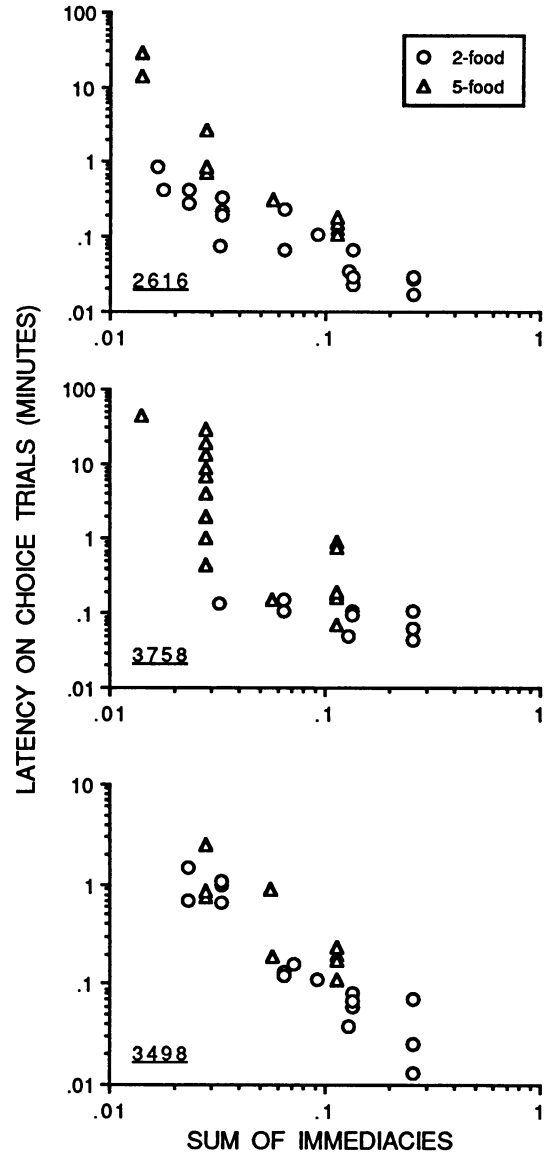

Fig. 3. The median initial-link latency (min) on choice trials plotted as a function of the sum of the immediacies for the terminal link (two-food or five-food) that the pigeon's choice favored during a particular condition. Each panel shows data from a different pigeon. Each determination of each condition is represented by a point. Note that both axes are scaled logarithmically.

latency plots. The relation between latency and sum of the immediacies appears to be about the same regardless of whether the terminal link provided two or five food deliveries. However, latencies to initiate the two-food terminal link tended to be somewhat longer, for a particular sum of the immediacies, when the ter-

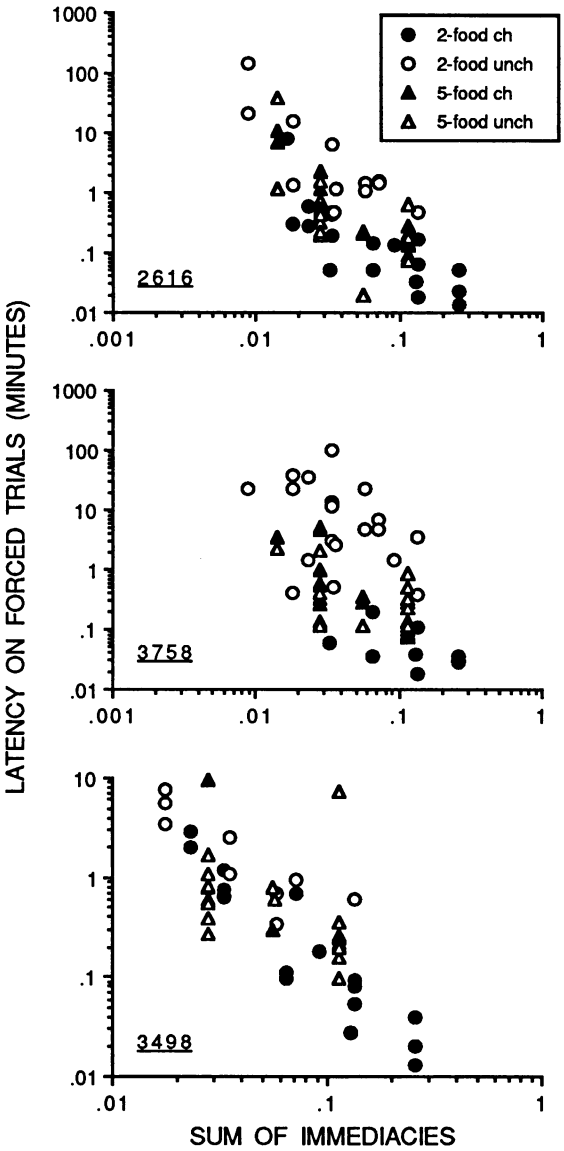

Fig. 4. The median initial-link latency (min) on forced trials plotted as a function of the sum of the immediacies for the terminal link (two-food or five-food) that followed the latency. Closed points indicate that the terminal link that followed the latency was the one favored on choice trials; open points indicate that the terminal link was unfavored. Each panel shows data from a different pigeon. Each determination of each condition is represented by a point. Note that both axes are scaled logarithmically.

minal link was the less favored member of the choice pair than when it was the favored member (i.e., the trend for the open circles in Figure 4 tended to be above that for the closed circles).

We consider now the ratio of latencies on forced trials. If latency indicates the conditioned reinforcing potency of a terminal link, the terminal link that produces the shorter latency would be regarded as the more effective reinforcer. The ratios of the average latencies on forced trials from a condition, then, would show which of the latencies is the shorter and by how much.

Figure 5 is a scatter plot intended to assess the correspondence between choice and latency-ratio measures. Each point represents the data from a condition, and the location of the point shows the percentage of choice on choice trials plotted over the latency ratio on forced trials. To determine which one of a terminal-link pair is the more effective conditioned reinforcer, the choice dimension can be dichotomized at 50 and the pause-ratio dimension can be dichotomized at 1.0. To the extent that latency-ratio and choice measures correspond, the points should fall in the lower left and upper right quadrants. Most of the points do, indeed, fall in those quadrants. The exceptions occurred mainly when the latency ratios were close to unity.

It appears that conclusions about the conditioned reinforcing value of the terminal links are about the same regardless of whether percentage of choice on choice trials or ratios of initial-link pausing on forced trials are used to define the reinforcing potency of entering the terminal links.

DISCUSSION

If total yield of food per terminal-link time had determined choice, the pigeons should have chosen the five-food terminal link at all values of x and t. If, instead, the delay to only the first food in a terminal link had determined choice, the pigeons should have chosen the two-food terminal link for all values of x less than t. In fact, choice favored the two-food terminal link when x was relatively short but favored the five-food terminal link when x was relatively long but still shorter than t. Because choice favored the five-food terminal link even when x was shorter than t, food deliveries after the first must have had some effect. Furthermore, such later food deliveries influenced choice even when t was as long as 160 s (cf. Poniewaz, 1984; Timberlake, 1984).

Overall, the pattern of choice is consistent with the proposal that each food delivery in a series contributes to the conditioned reinforc-

ing value of entering the terminal link, with the size of each reinforcer's contribution being a decreasing function of the reinforcer's delay from the point of entry into the terminal link. The sum of the immediacies is one example of a metric representing this property of the temporal distribution of reinforcers.

If this property determined choice, choice should have favored whichever of the two terminal links had been correlated with the higher sum of the immediacies. The data were consistent with that implication (see Figure 2). It is worth noting that the relation between choice and relative sum of the immediacies did not appear to differ systematically as a function of the absolute delay durations (compare the points from different t durations in Figure 2).

Initial-link latency also varied systematically as a function of the sum of the immediacies. Recall that choice-trial and forced-trial latencies decreased over several orders of magnitude as a function of increasing sum of the immediacies (Figures 3 and 4). Moreover, for a particular choice pair, the terminal link that produced the shorter latency on forced trials was usually the terminal link that was more often chosen on choice trials (Figure 5). The sum of the immediacies metric thus summarizes a property of the temporal distribution of reinforcers that appears to determine both initial-link latency and choice.

The latency data are interesting in part because they show clearly that food-rate maximizing is not a general principle in these procedures. Any pausing in the initial link postpones the start of the terminal link and so reduces the rate of food below the maximum possible. Nonetheless, the pigeons paused in the initial links—for average durations longer than 30 min in some cases. Such pausing is understandable, however, as an effect of control by the sum of the immediacies. The tendency to initiate the terminal links presumably was determined by the conditioned reinforcing potency of access to the terminal link, as described by the sum of the immediacies metric. When access to the terminal link was a weak conditioned reinforcer, the response probability presumably was low, thus resulting in long latencies on average. The fact that such long pausing reduced the overall rate of food delivery below the maximum possible may have been irrelevant to controlling the pigeon's performance (cf. Shull, 1979).

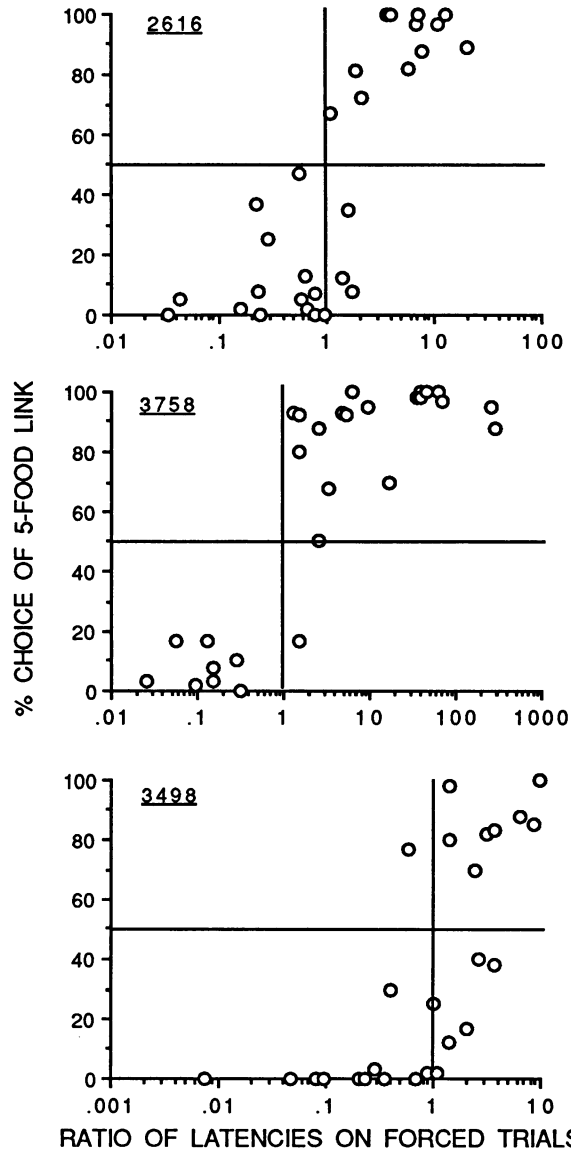

Fig. 5. The percentage of choice of the five-food terminal link on choice trials plotted over the ratio of latencies on forced trials (latency for two-food/latency for five-food terminal link). Each determination of each condition is represented by a point. Each panel shows data from a different bird. The y axis is arithmetic; the x axis is logarithmic. The horizontal and vertical lines indicate the points on the two dimensions at which response tendencies are equivalent.

The present account of latencies and choice is contrary to one possible everyday interpretation of impulsiveness. One might suppose that choosing a smaller, more immediate reinforcer over a larger, more delayed reinforcer is a byproduct of a hasty choice. In everyday

language, impulsive responding sometimes seems synonymous with rapid, unreflective responding. If such an account were applied to the present data, we might expect impulsive choice (i.e, choice of the two-food over the five-food terminal link) to be most apparent for the conditions arranging short t durations. Under those conditions, the absolute delay durations (both t and x) were shortest. Consequently, the sums of the immediacies were relatively high, and the choice latencies tended to be short. Conversely, under the conditions arranging the longest durations of t, the absolute delay durations (t and x) were longest. Thus the sums of the immediacies were relatively low, so the latencies tended to be long. As shown in Figure 2, however, the tendency to choose the two-food alternative was independent of the duration of t and hence of the choice latency over a range of several orders of magnitude. Thus, time taken to choose per se does not seem to matter; at least it did not in the present study.

Although the sum of the immediacies predicted the major trends in the latency and choice data, there was one systematic effect not represented by the sum of the immediacies metric. The choice latencies tended to be longer for a given sum of the immediacies when the favored terminal link contained five food deliveries than when it contained two (i.e., the triangles tended to lie above the circles in Figure 3). There are at least two possible interpretations of this difference. One possibility is that earlier deliveries in a sequence partially block or interfere with the effects of subsequent deliveries (cf. Catania, Sagvolden, & Keller, 1988). If so, the effectiveness of a food delivery would decline not only as a function of its delay but also as a function of its ordinal position in a sequence. The sum of the immediacies metric, then, would have to be modified to take ordinal position into account. Arguing against this possibility, however, is the fact that relative sum of the immediacies predicted choice rather well. If there were an additional decremental effect of ordinal position, the choice functions should have been biased in favor of the two-food alternative. Another possibility recognizes that when the pigeons chose the five-food terminal link, they received more food than when they chose the two-food terminal link, and hence might have been less food deprived after the five-food than after the two-food terminal link. The longer latencies, then, may have resulted from this reduced deprivation. Although the pigeons' body weights were controlled by supplementary feeding as needed to maintain a roughly constant level, short-term changes in deprivation could have been influential. If so, the ordinal position of a reinforcer in a series might not have mattered. In principle, the latencies from forced trials should have been able to shed light on the satiation possibility. The satiation argument implies that forced-trial latencies should have been longer when the five-food terminal link had been the favored alternative on choice trials because the five-food terminal link provided more food. The relevant data are in Figure 4: From satiation the open circles should have fallen above the closed circles and the open triangles should have fallen below the closed triangles. Although there is a hint of such a difference between the closed and open circles, no such difference is apparent between the closed and open triangles. Thus, the data provide, at best, ambiguous support for the satiation account. Consequently, the latency-function difference (triangles vs. circles in Figure 3) remains an unresolved problem. For the present, given the relatively small size of the latency differences, it seems fair to say that the unmodified sum of the immediacies metric provides a good first-approximation account of the choice and latency data.

Throughout this paper, the sum of the immediacies has been interpreted as describing how the delays of reinforcement after the start of the terminal link influence the conditioned reinforcing potency of stimuli correlated with entering the terminal link. One might argue, however, that conditioned reinforcement is a superfluous concept. Perhaps the delayed food reinforcers can be thought to strengthen directly the initial-link response instead of affecting the potency of a conditioned reinforcer that, in turn, strengthens the initial-link response.

Although the present procedures were not designed to distinguish between these two interpretations, there is good reason to stress the conditioned reinforcement function of stimulus changes in chained schedules. First, when the appropriate comparisons have been made, the data have supported the view that the stimulus changes in chained schedules do, indeed, function as conditioned reinforcers (e.g., Catania et al., 1980; Dinsmoor, 1983; Royalty et al.,

1987). Second, a consideration of the stimulus events in chained schedules suggests that control by the sum of the immediacies is entirely consistent with a conditioned reinforcement interpretation. To appreciate this consistency, it is necessary to consider precisely what aspect of the terminal-link stimulus is likely to be functioning as a conditioned reinforcer for initial-link responses. Although it is common to think of the stimulus present during the terminal link as the conditioned reinforcer, it might be more appropriate to think of the stimulus *transition* from initial to terminal links as the conditioned reinforcer. The transition per se is likely to be a salient event, and the transition is the environmental event that follows most immediately upon an effective initial-link response (cf. Baum, 1974; Fantino, 1987; Smith, 1974; Vaughan, 1985). Also, there is a specifiable relationship between the transition and the time intervals until primary reinforcers. Because these intervals are analogous to trace intervals in Pavlovian procedures, the longer they are, the weaker should be the conditioning effect of the primary reinforcers (e.g., Balsam, 1984). The sum of the immediacies integrates the effects of all such delayed primary reinforcers and thus seems a good prospect for summarizing the temporal variables that determine the conditioned reinforcing potency of the stimulus transition from the initial to the terminal link.

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