

ASSOCIATIVE INTERACTION: JOINT CONTROL OF
KEY PECKING BY STIMULUS-REINFORCER AND
RESPONSE-REINFORCER RELATIONSHIPS

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The joint control of rate of key pecking in pigeons by stimulus-reinforcer and response-reinforcer relationships was studied in the context of a two-component multiple schedule of reinforcement. Food presentation was always associated with one component and extinction with the other. The stimulus-reinforcer relationship was manipulated by varying the relative durations of the two components. In the food-presentation component, a fixed rate of reinforcement, independent of rate of responding, was generated by a schedule referred to as "T*". One aspect of the response-reinforcer relationship, contiguity, was manipulated by varying the percentage of delayed reinforcers. With the multiple T* extinction schedule, stimulus-reinforcer and response-reinforcer relationships could be varied independently of one another. Rate of key pecking was sensitive to manipulations of both relationships. However, significant differential effects due to either the stimulus-reinforcer or response-reinforcer relationship were obtained only when the other relationship was weak: stimulus-reinforcer and response-reinforcer relationships interacted in the joint control of responding.

Key words: stimulus-reinforcer relationship, response-reinforcer relationship, relative component duration, percentage delayed reinforcement, multiple schedule, T* schedule, key peck, pigeon

Substantial bodies of research have demonstrated powerful control of the pigeon's key-peck response by operant (response-reinforcer) (*cf.*, Ferster and Skinner, 1957; Herrnstein, 1970; Honig, 1966) and respondent (stimulus-reinforcer) (*cf.*, Hearst and Jenkins, 1974; Schwartz and Gamzu, 1977) dependencies. Now that the sensitivity of key pecking to both stimulus-reinforcer and response-reinforcer relationships has been established (Hearst and Jenkins, 1974; Schwartz and Gamzu, 1977), the interaction of these two relations becomes a topic of further interest.

The joint influence of operant and respondent factors in the control of key pecking has been examined in at least two types

of situation. In studies addressing the "classical mediation hypothesis" of two-process learning theory (Rescorla and Solomon, 1967; Trapold and Overmeier, 1972), the effects of superimposing conditioned stimuli, paired with response-independent reinforcers, on ongoing operant responding have been documented (Farthing, 1971; LoLordo, 1971; LoLordo, McMillan, and Riley, 1974; Schwartz, 1976). A second line of work, dealing with the phenomenon of positive behavioral contrast, has recently been re-examined as an instance of the combined influence of operant and respondent factors (Boakes, 1973; Gamzu and Schwartz, 1973; Hemmes, 1973; Keller, 1974; Rachlin, 1973; Schwartz, 1974, 1975; Schwartz, Hamilton, and Silberberg, 1975; Spealman, 1976; Staddon, 1972). In general, procedures that produce positive behavioral contrast are also those that typically introduce a stimulus-reinforcer relationship into a situation already maintaining operant responding. The general conclusion from these two areas of research is that an analysis of the interactions between operant and respondent influences can explain a great deal of previously contradictory data (*cf.*, Schwartz and Gamzu, 1977).

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The present study extends previous research on the joint operation of stimulus-reinforcer and response-reinforcer relationships in the control of responding. However, underlying the present procedural details is a conceptual approach that differs from that of other lines of research in this area. Stimulus-reinforcer and response-reinforcer relationships are treated as controlling variables (Skinner, 1953), and as such, call for independent parametric manipulation in order to determine their separate, and combined, effects on behavior.

To accomplish this aim, the basic design of the present experiment involved a multiple-schedule procedure, similar to that used by Gamzu and Williams (1971, 1973), to study autoshaped key pecking, in which one stimulus was correlated with reinforcement, and the other with the absence of reinforcement. However, it was necessary to develop a new schedule of reinforcement, since variable-interval (VI) and variable-time (VT) schedules do not allow independent manipulation of stimulus-reinforcer and response-reinforcer relationships. In a VI schedule, it is not always possible to control the stimulus-reinforcer relationship, because rate of reinforcement can vary with rate of responding. The new schedule maintains a constant rate of reinforcement, independent of rate of responding. This feature of the new schedule resembles a VT schedule. However, in a VT schedule, it is not possible to manipulate the response-reinforcer relationship. The new schedule permits manipulation of response-reinforcer contiguity, without altering rate of reinforcement.

This new schedule, which we call "T*", arranged food presentations according to a variant of the linear interresponse-time (linear IRT) schedule developed by Norman (1966). Within the multiple T* extinction (*mult* T* EXT) procedure employed here, the stimulus-reinforcer relationship selected for study was the relative duration of the two schedule components (*i.e.*, the ratio of the two component durations), which is formally similar to the variation of trial and intertrial interval durations in standard autoshaping (Terrace, Gibbon, Farrell, and Baldock, 1975) and classical conditioning (Gormezano and Moore, 1969) procedures. These studies have shown that strength of excitatory condition-

ing varies inversely with the ratio of trial/intertrial interval durations. The response-reinforcer relationship selected for study was the degree of response-reinforcer contiguity. The percentage of delayed reinforcers was varied, without altering mean rate of reinforcement.

METHOD

Subjects

Eighteen experimentally-naive adult Silver King pigeons were maintained at 80% of their free-feeding body weights throughout the experiment.

Apparatus

Three automated³ pigeon chambers, measuring 32 by 35 by 37 cm, were used. The rear wall, ceiling, and one side wall were made of plywood and painted white. The other side wall consisted of two sheets of clear Plexiglas, and allowed observation of birds during sessions. The floor of each chamber consisted of 1.75-cm hardware cloth. The control panels were polished aluminum, and contained three houselights, a response key, and a standard Lehigh Valley grain hopper with hopper light. The houselights were two 7-W Westinghouse Christmas Bulbs (D18-1/2) mounted behind a deflector, which directed their light toward the ceiling of the chamber, and a #1820 24-V dc bulb, which projected 1 cm out of the control panel and was surrounded by a deflector, which also directed its light toward the ceiling. One response key was centered on each control-panel wall 24 cm above the floor of the chamber. Each key was a piece of frosted Plexiglas mounted behind a circular hole, 2.5 cm in diameter, cut into the control-panel surface. The response key could move through an excursion of approximately 3 mm, at which point it was stopped by a bolt mounted on the back of the panel. Movement of the key through a small fraction of this distance resulted in the operation of a photocell, also mounted on the back of the panel. The key required a minimum of 0.12 N to operate the photocell. The key could be transilluminated by either a red or a green 7-W Westing-

³Details of the procedure and apparatus used to automate the pigeon chambers are available from D. R. Williams.

house Christmas Bulb. A grain-hopper aperture, which measured 6 by 5 cm, was centered 10 cm below the response key.

All programming and data recording were accomplished by means of a PDP-8/I computer.

Procedure

The 18 pigeons were first given two sessions of hopper training, during which all were trained to approach rapidly and eat from the hopper whenever presented. In the experimental sessions, reinforcement was always 4-sec access to mixed grain, during which the hopper light was illuminated and the house-lights and keylights were extinguished. Daily sessions terminated with the thirtieth grain presentation.

During each session, the key was alternately transilluminated by red or green light. In the presence of the red keylight, reinforcers were presented at a mean rate of two per minute; in the presence of the green keylight, no reinforcers were presented. The reinforcement schedule in effect during the red key (hereafter referred to as the T^* schedule) was a version of a linear interresponse-time (linear IRT) schedule (Norman, 1966), designed to (1) make the mean rate of reinforcement independent of the rate of responding, and (2) allow explicit manipulation of one aspect of the response-reinforcer relationship—the degree of contiguity between responses and delivery of grain. The first aim was attained in the following way: the probability that a key peck would deliver a reinforcer was made to vary as a direct linear function of the IRT preceding the response. Thus, a key peck that occurred 2 sec after the previous key peck was twice as likely to produce reinforcement as was a key peck preceded by a 1-sec IRT. Since two 1-sec IRTs could occur for every 2-sec IRT, the pigeon (in this example) could produce reinforcement at precisely the same mean rate by pecking at either of the two rates (*i.e.*, with IRTs of 1 sec or of 2 sec). Thus, for moderate to high rates of responding, the rate of reinforcement was decorrelated from the rate of responding. However, if the pigeon never pecks under the schedule described thus far, reinforcement never occurs. To remove this correlation, the computer was programmed to insert an event, hereafter referred to as a "pseudopeck", whenever an IRT

reached a certain duration. This interval is here referred to as T^* , and gives the schedule its name. These "pseudopecks" could deliver reinforcers in the same way that actual key pecks could, and they defined the starting point for the next IRT. "Pseudopecks" were not counted in calculations of response rate, however. With this modification, the T^* reinforcement schedule removed any correlation between the mean rates of responding and reinforcement. In the present experiment, the T^* interval was set at 4-sec. It should be noted that the specification of this variable determines the similarity between T^* and a VI or a VT schedule. As $T^* \rightarrow 0$, the schedule approximates a VT schedule: most or all reinforcers are delivered independent of responding. On the other hand, as $T^* \rightarrow \infty$, the schedule approximates a VI schedule: most or all reinforcers are delivered dependent upon responding.

The second aim of the T^* schedule, to allow manipulation of the degree of response-reinforcer contiguity, was attained in the following way: whenever an actual key peck produced a reinforcer, that reinforcer could be delivered either immediately, or after a delay. The contiguity between individual reinforcers and key pecks that produced them was manipulated by changing the percentage of reinforcers delivered after a delay. The delay periods averaged 4 sec, and their durations were randomly and uniformly distributed over the range from 0.1 to 8.0 sec. Key pecks that occurred during a delay interval did not affect the length of the delay, and could produce reinforcers just as all other key pecks could. Delayed reinforcers not delivered by the end of a component were saved and delivered at the appropriate time during the next T^* component. For one group of pigeons, all reinforcers were delivered immediately after occurrence of the response that produced them (Group A). For a second group, 50% of all reinforcers were delivered after a delay and 50% were delivered immediately (Group B). For a third group, all reinforcers were delivered after a delay (Group C).

The experiment proper consisted of four phases, the latter two phases being replications of the first two, with one exception noted below. During Phase I, the duration of the T^* component of the *mult* T^* EXT schedule was

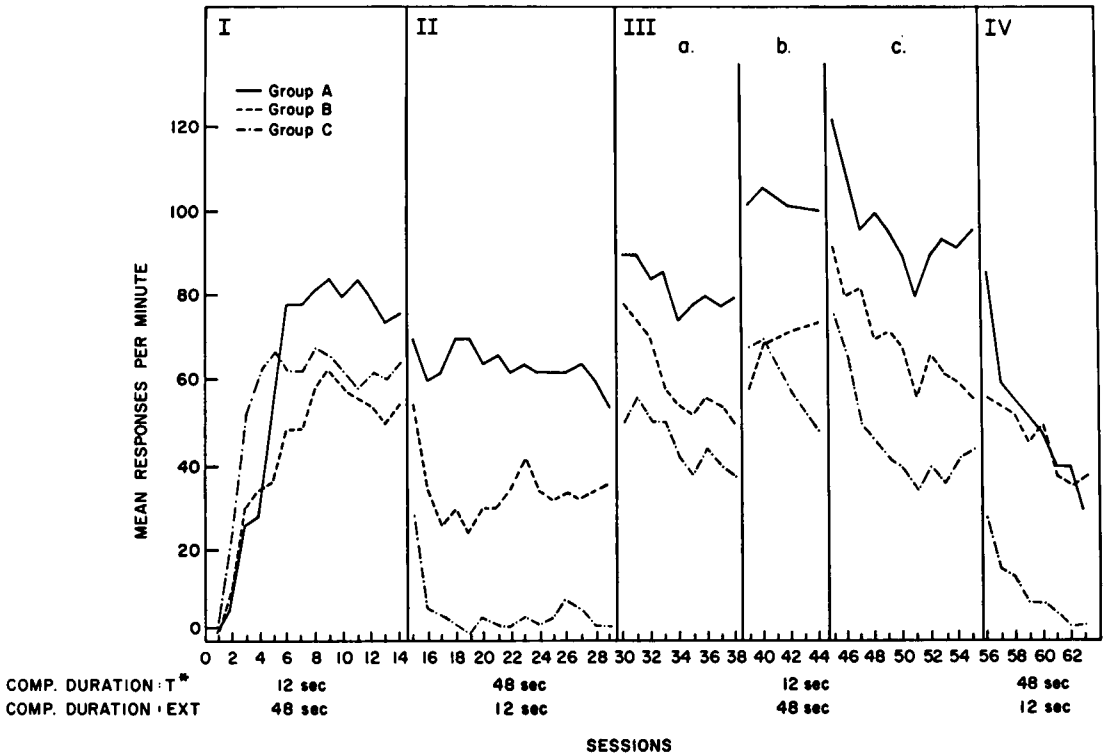


Fig. 1. Mean response rate in the T* component for each of the three groups of birds, across all sessions of the experiment.

always 12 sec; duration of the EXT component averaged 48 sec, with individual component durations ranging from 16 to 192 sec (geometrically distributed). Phase I conditions remained in effect for 14 daily sessions.

During Phase II, duration of the T* component was always 48 sec, and the EXT component averaged 12 sec, with individual component durations ranging from 4 to 48 sec. This change in the relative component durations was presumed to be a decrease in the strength of the stimulus-reinforcer relationship, or "informativeness" of the stimulus associated with food presentation (*cf.*, Hearst and Jenkins, 1974), similar to changing the relative durations of "trials" and "intertrial-intervals" in autoshaping (Terrace, Gibbon, Farrell, and Baldock, 1975) and traditional respondent (Gormezano and Moore, 1969) paradigms. Phase II conditions remained in effect for 15 daily sessions.

During Phase III, the original conditions of Phase I were reinstated. After a number of sessions in this phase, two interruptions occurred in the daily schedule, lasting 20 and 50 days, respectively. During these periods,

the pigeons remained at 80% free-feeding body weights. There were thus three sub-phases in Phase III: before any interruptions (Phase IIIa), after the first interruption (Phase IIIb), and after the second interruption (Phase IIIc). Phases III a, b, and c remained in effect for 9, 6, and 11 daily sessions, respectively. The conditions in all three phases were identical to those of Phase I.

During Phase IV, the durations of the T* and EXT components were again reversed, so that stimulus conditions were identical to those of Phase II. In addition, the T* schedule for Group A was changed so that it was the same as that for Group C (*i.e.*, 100% delayed reinforcers). Thus, across Phases III and IV, both the stimulus-reinforcer and the response-reinforcer relationships were manipulated for Group A. Phase IV conditions remained in effect for eight daily sessions.

RESULTS

Phase I

Figure 1 (Panel I) shows mean rates of responding in the T* component for each

group, across the 14 sessions of Phase I. All birds initiated key pecking within the first four sessions of exposure to the *mult* T*EXT schedule. Key pecking was initiated by 11 birds in the first session, five in the second session, one in the third session, and one in the fourth session. Stable rates of responding were reached by all three groups within 10 sessions. Response rates for each bird from Sessions 10 to 14 were used to compute mean asymptotes for each group. The mean asymptotic rates of responding in the T* component were 86, 60, and 68 responses per minute for Groups A, B, and C, respectively. Mean asymptotic rates of responding in the EXT component were 0.9, 0.9, and 0.6 responses per minute for Groups A, B, and C, respectively. Mean response rates for each group of birds during the EXT component never exceeded 1.0 responses per minute in any phase, and thus are not discussed further.

Although the degree of response-reinforcer contiguity differed between groups, and rates of responding in the T* component were slightly higher for Group A relative to the other groups, an analysis of variance revealed that the differences between groups in rate of response were not significant ($F < 1$, $df = 2, 15$, $p > 0.05$).

Phase II

Durations of the T* and EXT components were reversed in Phase II. This manipulation produced a decrease in response rate for five of six birds in Group A, four of six birds in Group B, and all six birds in Group C. Figure 1 (Panel II) shows mean rates of responding in the T* component for each group of birds across the 15 sessions of Phase II. Response rates declined quite rapidly, reaching a new asymptote within two or three sessions for each group. In order to show clearly the course of the change in rates during initial exposure to the conditions of Phase II, daily response rates were computed as a proportion of the Phase I asymptotic rate. Figure 2 (Panel A) shows these proportions for each group during the first eight sessions of Phase II.

This figure allows direct comparison of the magnitude of changes in rate of responding observed for each group. All three groups approached a new asymptote at approximately

the same rate, with changes in responding essentially complete by the third session.

Although rate of approach to new asymptotes was the same for all three groups, the new asymptotes themselves were different between groups, expressed either as proportions of previous asymptote (Figure 2) or as absolute response rate (Figure 1). The mean asymptotic rates of responding in the T* component, calculated over the last five sessions of Phase II, were 65, 37, and 7 for Groups A, B, and C, respectively. An analysis of variance revealed that these differences were significant ($F = 23$, $df = 2, 15$; $p < 0.01$). *Post hoc* analyses also showed that each group differed reliably from the other two ($p < 0.01$).

The temporal pattern of responding during the T* component was examined to determine whether the overall rate differences between groups depicted in Figures 1 and 2 during Phases I and II were also characteristic of local rate differences throughout individual component presentations. Figure 3 shows asymptotic mean rate of response for each group during each second of the T* component, calculated over the last five sessions of Phase I (Panel A) and Phase II (Panel B). Panel A shows that the slightly higher overall rate for Group A in Phase I was produced by a higher rate of responding during the entire component. The slight difference between Groups B and C in overall rate was produced by a more gradual acceleration of responding at the beginning of each component presentation for Group B. Panel B shows that the significant difference in overall rates between groups in Phase II was a characteristic of local rates throughout each component. Each group showed the same temporal pattern, however, consisting of an initial burst of responding followed by a steady rate for the duration of the component. Thus, the overall rate differences between groups in Phase II were not an artifact of the increased component length. Local rates differed between groups in the first 12 sec, and throughout the rest of the component.

Phase IIIa

When the durations of the T* and EXT components were changed back to the initial values employed in Phase I, response rate increased for four of six birds in Group A, four of six birds in Group B, and five of six birds

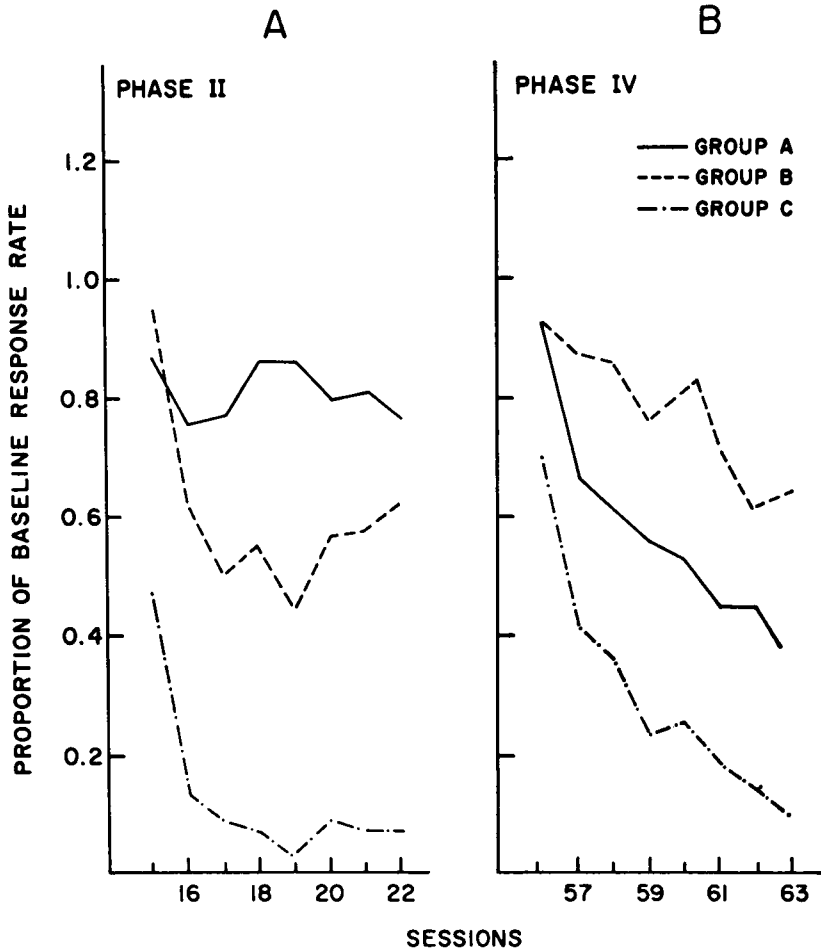


Fig. 2. Mean response rate in the T* component, computed as a proportion of the immediately preceding asymptotic response rate, for each group of birds. Proportions are shown for the first eight sessions of Phases II and IV in Panels A and B, respectively.

in Group C. In all cases, rate increases occurred within the first session of Phase IIIa. Figure 1 (Panel IIIa) shows mean response rates for each group across the nine sessions of this phase. Mean rates showed an initial "overshoot", surpassing the asymptotes observed in Phase I, followed by a decline to new asymptotes. Mean rates of responding at asymptote, calculated over the last five sessions of Phase IIIa, were 86, 60, and 47 responses per minute for Groups A, B, and C, respectively. Although rates differed between groups in the same direction as those in Phase II, and the rate for Group C was slightly lower than that observed in Phase I, an analysis of variance revealed that these differences were not significant ($F = 1.5$, $df = 2, 15$; $p > 0.05$).

Most birds in the experiment showed

changes in rate similar to those shown in the averaged group curves of Figure 1. Asymptotic mean response rates for individual birds in each group during the first three phases of the experiment are shown in Figure 4. One bird in Group A, two birds in Group B, and two birds in Group C showed rate changes in a direction opposite to those observed in the majority of birds. The upper bound on the range of rates was approximately equal across groups in Phases I and IIIa. The lower bounds, however, were not equal: there was a notable absence of "low"-rate (*i.e.*, rates below 60 responses per minute) birds in Group A. In Phase II, there was a marked difference in the range of rates observed between groups. With one exception (in Group B), there was no overlap in rates between birds in Groups

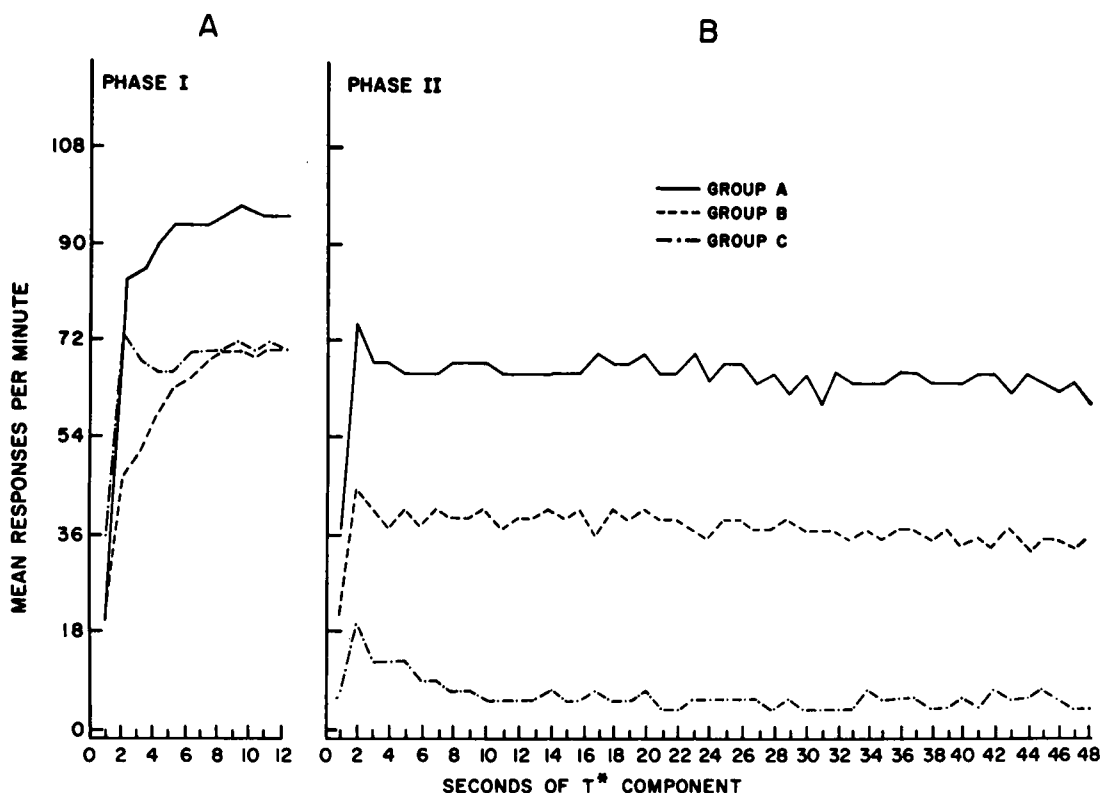


Fig. 3. The local rate of responding during each successive second of the T* component. Panel A depicts the local rate of responding through the 12-sec T* component for each of the three groups, averaged over the last five sessions of Phase I. Panel B depicts local response rate through the 48-sec T* component of Phase II, again averaged over the last five sessions.

A and B, and between birds in Groups B and C.

Phases IIIb and c

Immediately after the 20-day interruption that preceded Phase IIIb, 13 of 18 birds showed rate increases. Figure 1 (Panel IIIb) shows mean rates for each group in the six sessions of this phase, and indicates that rates increased to levels higher than those observed in previous phases of the experiment. Immediately after the second, 50-day interruption, 10 of 18 birds again increased rate. These rate increases were generally transient: they initially surpassed the asymptotic rates observed in previous phases, and then decreased over the next few sessions. Figure 1 (Panel IIIc) shows mean rates of responding for the 11 sessions of Phase IIIc. Asymptotic rates of responding for each group, calculated over the last five sessions of this phase, were 98, 66, and 44 responses per minute for Groups

A, B, and C, respectively. Although rates of response for each group showed a larger divergence than they did in Phases I, IIIa, and IIIb, an analysis of variance revealed that these differences were still not significant ($F = 1.8$, $df = 2, 15$; $p > 0.05$).

The high rates of response observed in Phases IIIb and c, especially for Group A, do however show that the lack of significant differences between groups in Phases I and III was not attributable to a "ceiling effect" on response rate.

Phase IV

Figure 2 (Panel B) shows that by the eighth session of Phase IV, rates for Groups B and C declined to the levels observed in Phase II. Rates for Group A showed a substantially greater decrease in Phase IV (by 60%) than in Phase II (by 20%). Thus, comparison of levels of responding for Group A across Phases II and IV revealed a within-group sen-

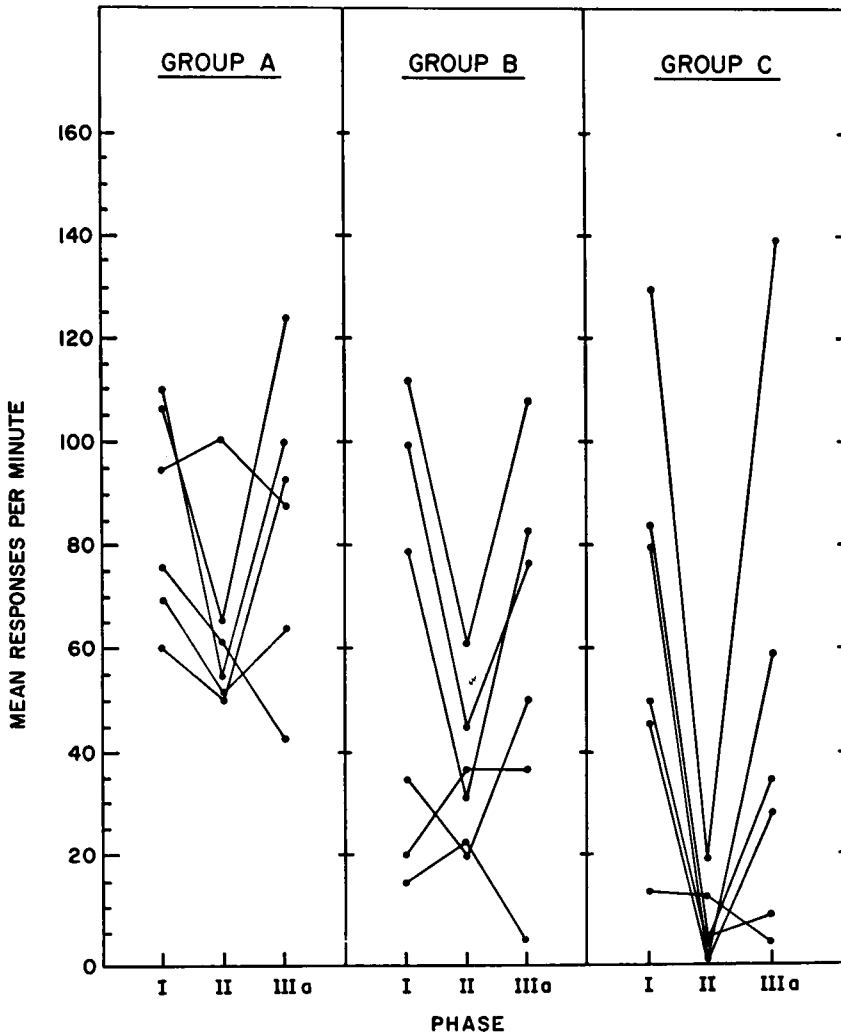


Fig. 4. The asymptotic response rate for each bird, averaged over the last five sessions of an experimental phase. Panels A, B, and C contain data points for each bird in Groups A, B, and C, respectively. In each panel, solid lines connect data points for individual birds, across Phases I, II, and IIIa.

sitivity to the response-reinforcer contiguity variable (percentage delayed reinforcement), when the stimulus-reinforcer relationship was relatively weak. A second result shown in Panel B was that rates of response declined more gradually for each group during Phase IV than during Phase II, under the same stimulus conditions. This aspect of the results suggests that some historical factor, such as "exercise" of responding (Catania, 1973), may have influenced key pecking in this phase.

Reinforcement Rates

Although the T^* schedule is designed to maintain a constant rate of reinforcement,

this feature of the schedule is achieved probabilistically. Nevertheless, over the entire experiment, variability in obtained rates of reinforcement was quite low. The rate of reinforcement was computed for each bird over the last five sessions of each phase (For Phase IIIc one session's data were not available and only the last four sessions were used.): the mean obtained rate of reinforcement was 2.13 reinforcers per minute ($S.E.M = 0.02$). In addition, mean rate of reinforcement and mean rate of responding were computed and ranked for each group, again over the last five sessions of each phase. The Spearman rank correlation coefficient between ob-

Table 1

Mean key-peck duration (msec) for birds in each group during the last five sessions of Phases I, II, and IIIa.

Group	Bird	Phase		
		I	II	IIIa
A	P5054	48	44	48
	P5662	31	35	28
	P5575	39	32	36
	P5099	22	23	24
	P0913	33	22	27
	P5515	24	24	25
	Group Mean	33	30	31
B	P0649	27	25	26
	P0541	41	33	35
	P0923	24	22	21
	P5501	29	19	26
	P0042	42	31	33
	P5653	65	50	73
	Group Mean	38	30	36
C	P5379	20	17	19
	P0038	30	30	27
	P0313	20	22	20
	P5717	21	33	16
	P5646	30	23	26
	P5247	49	29	42
	Group Mean	28	26	25

tained rate of reinforcement and rate of responding was -0.22 . Thus, the low variability of rates of reinforcement, and the lack of a significant correlation between mean rates of responding and reinforcement, indicate that the T* schedule indeed maintained a constant rate of reinforcement independent of rate of responding. The reported results are not dependent on artifacts of obtained rates of reinforcement.

Key-Peck Durations

Previous research (Schwartz and Williams, 1972; Schwartz, Hamilton, and Silberberg, 1975) has indicated that key pecks with short duration may be primarily influenced by stimulus-reinforcer relationships, while key pecks with longer durations may be primarily influenced by response-reinforcer relationships. Since the present study also involved manipulations of these relationships, key-peck durations were examined. Table 1 shows mean peck durations computed over the last five sessions of exposure to Phases I, II, and IIIa for each bird. There were no systematic differences between groups in key-peck durations, as a function of the degree of response-

reinforcer contiguity, and there were no systematic differences across phases for individual birds, as a function of the relative component durations. Inspection of duration frequency distributions showed some birds with either one, two, or three modal durations. There were no systematic changes in the frequency or the duration of these modes between groups or across phases.

DISCUSSION

The major finding of the present experiment was that the stimulus-reinforcer (relative component durations) and response-reinforcer (percentage delayed reinforcement) relationships interacted in determining rate of key pecking. Specifically, the magnitude of the observed differential effects of either relationship on rate of responding was determined by the concurrent strength of the other relationship.

In Phases I and III, when the stimulus-reinforcer relationship was relatively strong (*i.e.*, the ratio of T*/EXT component durations was small), response rates were not significantly different between groups. Thus, differential effects of response-reinforcer contiguity were minimal. In Phases II and IV, however, when the stimulus-reinforcer relationship was relatively weak (*i.e.*, the ratio of T*/EXT component durations was large), response-rate differences between groups (Phase II) and within Group A (Phase II *versus* Phase IV) were substantial. Rate of key pecking varied inversely with the percentage of delayed reinforcers.

Just as the observed differential effects of the response-reinforcer relationship were influenced by the strength of the stimulus-reinforcer relationship, the reverse was also true. When the stimulus-reinforcer relationship was weakened at the outset of Phase II, response rate decreased slightly (20%) for Group A, somewhat more (40%) for Group B, and quite substantially (90%) for Group C. Thus, when the response-reinforcer relationship was relatively strong (*i.e.*, no delayed reinforcement in Group A), manipulation of the relative component durations had little effect. When the response-reinforcer relationship was relatively weak (*i.e.*, 50% or 100% delayed reinforcement in Groups B and C, respectively), manipulation of the component

durations had large effects on responding. Rate of key pecking varied inversely with the relative duration of the T* component.

Considered separately, the effects of the T*/EXT duration ratio and the percentage of delayed reinforcement on rate of responding are in line with Gibbon's (1976) "scalar expectancy", and Gibbon, Berryman, and Thompson's (1974) "contingency space" models of conditioning. The "scalar expectancy" model predicts that the smaller the trial/inter-trial interval ratio, the stronger the excitatory conditioning. We found that rate of responding varied inversely with the ratio of the T*/EXT components, in keeping with this model. The "contingency space" model for instrumental conditioning predicts that the larger the ratio between $P(US|R)/P(US|no R)$ (*i.e.*, the ratio of the probabilities of reinforcement given a response, and given no response in some unit period of time), the stronger the excitatory conditioning. In the present T* schedule, increasing the percentage of delayed reinforcers decreased this ratio. We found that rate of responding varied inversely with percentage delayed reinforcement, in keeping with this model.

The T* schedule, in the context of multiple-schedule procedures, should be quite attractive for further research on the fundamental properties of stimulus-reinforcer and response-reinforcer relationships. The T* schedule lends itself to independent parametric manipulation of a variety of stimulus-reinforcer factors (*e.g.*, relative component durations, differential probabilities of reinforcement in the two components), and response-reinforcer factors (*e.g.*, contiguity, correlation, rate of reinforcement). Future research with variants of the T* schedule may contribute to the development of conditioning models that bring together the effects of a wide variety of associative factors under one theoretical framework (*cf.*, Gibbon, 1976).

Several other aspects of the present results bear discussion. First, key-peck durations revealed no systematic changes as a function of variations in the relative component durations or the percentage delayed reinforcement. Since Schwartz and Williams (1972) and Schwartz, Hamilton, and Silberberg (1975) have found systematic differences in peck durations with manipulations of other stimulus-

reinforcer and response-reinforcer relationships, this raises the interesting possibility that key-peck durations may not be similarly influenced by all operant or respondent factors. However, it should be emphasized that Schwartz and Williams (1972) functionally separated the two sources of control, and Schwartz *et al.* (1975) used a spatial separation. In the present experiment, both sources of control were presumed to be acting jointly at all times. In addition, previous studies employed a contact microswitch, whereas we used a photocell to record durations of key contact. Thus, it is difficult to ascertain whether the difference between the present results and those of earlier studies should be regarded as a genuine discrepancy, or merely the result of procedural differences.

A second finding, response-rate increase after 20- and 50-day interruptions in the daily running of the experiment, was quite unexpected. These rate increases were generally transient, but were replicable, occurring after both interruptions in all three groups of birds. This aspect of the results finds no obvious explanation in terms of the associative factors manipulated in the present study.

A third aspect of the results points to an "exercise" factor (Catania, 1973) at work here. Rates of responding declined more gradually in Phase IV, after extended exposure to the *mult* T* EXT schedule, than they did in Phase II. This result is the opposite of what might be expected, given that considerations of "overtraining", or repeated exposures to extinction (*cf.* MacKintosh, 1974), would predict a more rapid decline in responding in Phase IV relative to Phase II.

The important contribution of the present study to an understanding of associative learning is the demonstration of an interaction between operant and respondent factors, at the behavioral level. Although the present study focussed on positive relationships, situations involving negative relationships may also be subject to similar analysis in terms of interactions. In the presence of a strong stimulus-reinforcer contingency, as for example in discrete-trial procedures, a negative response-reinforcer dependency may exert minimal control over responding (*cf.*, the negative automaintenance phenomenon demonstrated by Williams and Williams, 1969). In the presence of a weaker stimulus-reinforcer

contingency, as for example in a free-responding situation with no differential reinforcer-correlated stimuli, a negative response-reinforcer dependency may have large effects on responding (e.g., differential-reinforcement-of-other-behavior (DRO) schedules).

More broadly, associative interaction is an important consideration (1) for assessment of the efficacy of associative procedures in the control and modification of behavior (Honig, 1966), and (2) for assessment of the learning capacities of different organisms. Much care should be afforded the interpretation of data that show weak or negligible behavioral effects of an associative variable in a particular situation, especially when the strengths of other associative variables are left uncontrolled. As an illustration, it might have been concluded from the results of Phase I alone that the pigeon's key peck is insensitive to the response-reinforcer contiguity variable that we manipulated. However, substantial sensitivity was revealed in Phase II, by reducing the strength of the stimulus-reinforcer relationship. The present experiment calls attention to an important question for future conditioning research: do evolutionary or neurophysiological "constraints on learning" (Hinde and Stevenson-Hinde, 1973; Shettleworth, 1972), or "prepared" and "contraprepared" instances of learning (Seligman and Hager, 1972), require a divestment of accepted laws of learning, or an investment in further research on the manner in which operant and respondent factors interact in the control of behavior? The present analysis of factors controlling the pigeon's key peck (a topic of much recent interest in this regard) affirms the latter alternative.

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