**POSITIVE INTERACTION (INDUCTION) IN MULTIPLE
VARIABLE-INTERVAL, DIFFERENTIAL-
REINFORCEMENT-OF-HIGH-RATE SCHEDULES¹**

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The effect of increases in the rate of responding in one component of a multiple schedule upon the rate of responding in a second component was investigated. Pigeons were exposed to a multiple schedule where both components were initially variable-interval schedules having the same parameter value. After rate of key pecking stabilized, one component was changed to a schedule that differentially reinforced high rates of responding. Rate of reinforcement in this varied component was adjusted to remain equal to rate of reinforcement in the constant (variable-interval) component. Four of five pigeons showed a maintained increase in rate of responding during both the constant and varied components, even though rates of reinforcement did not change.

When the reinforcement schedule in one component (the variable component) of a multiple schedule is changed, rate of responding in the other (constant) component can be affected (*e.g.*, Reynolds, 1961*a*, 1961*b*, 1961*c*, Terrace, 1968). Typically, rate of responding in the constant component changes in a direction opposite that in the variable component, and the interaction is labelled behavioral contrast (*e.g.*, Nevin and Shettleworth, 1966, Terrace, 1966). Attempts to determine the necessary conditions for producing behavioral contrast have stressed the roles of rate of reinforcement and rate of responding. Reynolds (1961*a*) initially proposed that contrast occurred when the *relative* rate of reinforcement in the constant component varied as a result of changes in rate of reinforcement in the variable component. He found that rate of responding in the constant component was directly related to the relative rate of reinforcement in that component. An alternative view was proposed by Terrace (1966), who stated that rate of responding in the constant component varied inversely with rate of responding in the variable component. While most studies of contrast have confounded these two variables by changing both rates of

reinforcement and responding in the variable component, some studies have isolated the response rate manipulation and found it to be a determinant of contrast. Terrace (1966, 1968), for example, found that when rate of responding was decreased in one component by a differential-reinforcement-of-low-rate (DRL) schedule, punishment, or a decreased rate of reinforcement, rate of responding in the other component increased even when rate of reinforcement was unaltered in that component. The present study represents the converse of Terrace's (1966, 1968) studies. Rate of responding was increased in one component by a differential-reinforcement-of-high-rate (DRH) schedule that was adjusted to keep rate of reinforcement the same in both components.

METHOD

Subjects

Five male White Carneaux pigeons were maintained at 75% of free-feeding weights. One bird (B1) had a history of pecking under various reinforcement schedules and on red-green discrimination and reversal procedures. A second bird (B55) had previous training in a two-key Grason-Stadler test chamber on fixed-interval (FI) and variable-interval (VI) reinforcement schedules and on a red-green discrimination procedure. Three other birds (B175, B234, and B235) were experimentally naive.

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Apparatus

Birds B1, B55, and B175 were studied in a Grason-Stadler single-key pigeon chamber, Model number E3125A-300. The response key was located 3.75 in. (9.4 cm) above the feeder and 8 in. (21.8 cm) above the floor. A house-light, located above and to the right of the key, was continuously illuminated during sessions. Birds B234 and B235 were studied in a Grason-Stadler two-key pigeon chamber of the same type. The keys were 3.25 in. (8 cm) apart and centered 3.8 in. (9.7 cm) above the feeder and 8 in. (21.2 cm) above the floor. No houselight was used. In both chambers the response keys could be transilluminated by red or green lights of approximately equal intensity, and each required a force of approximately 10 g (0.10N) for operation. A ventilating fan and white noise provided sound masking. Associated scheduling equipment was housed in a separate room.

Procedure

After key-peck responding had been established in the experimental chamber, all birds were exposed to a multiple variable-interval variable-interval schedule (*mult VI VI*) where the parameter value was the same in both components. Presentation of grain was arranged for both components by a single tape puller which ran continuously. The distribution of interreinforcement intervals on the tape assured that the momentary probabilities of reinforcement were approximately equal (Catania and Reynolds, 1968). The reinforcer consisted of 3-sec access to mixed grain, during which the keylight was turned off. Sessions lasted 1 hr and components, signalled by red and green keylights, alternated. Component

duration and value of the VI schedule in effect for each bird are listed in Table 1. When the multiple schedule was studied in the two-key box (B234 and B235), only one key at a time was lighted and operative. The key made operative varied randomly during sessions. As with the single-key procedure, components (signalled by red and green keylights) alternated. A 4-sec blackout separated components for Birds B234 and B235. During blackout, the chamber was completely darkened and key pecks were not reinforced.

Training continued until performance stabilized (*i.e.*, daily rates of responding did not vary more than 15% of the mean value over five consecutive days, and there were no increasing or decreasing trends). Then, the variable-interval schedule in one component was changed to a schedule that differentially reinforced high rates of responding (DRH). Thus, the multiple schedule changed from *mult VI VI* to *mult VI DRH*. The green keylight was associated with DRH for B1, B55, and B175; the red keylight signalled DRH for B234 and B235. After 10 sessions on *mult VI DRH*, B234 and B235 received 10 additional sessions on this schedule with the discriminative stimuli reversed. Table 1 indicates the number of sessions devoted to the different procedures.

Scheduling the DRH. Differential reinforcement for high rate was scheduled in a manner similar to that described by Ferster and Skinner (1957, p. 33). Food was presented when key pecks advanced a counter to value C. As key pecks advanced this counter, a clock moved the counter back toward zero by one step every T sec. For all birds except B175, the value of T was varied within sessions throughout the experiment to maintain rate of reinforcement nearly equivalent in the VI

Table 1
Multiple schedules and the number of sessions each as studied in five pigeons.

Pigeons	Component Duration	Baseline Training	DHR Training	Cue Reversal
1	3 min	VI 3-min VI 3-min 8 sessions	VI 3-min DRH 8 sessions	
55	3 min	VI 1-min VI 1-min 13 sessions	VI 1-min DRH 21 sessions	
175	3 min	VI 1-min VI 1-min 40 sessions	VI 1-min & VI 1-min DRH 21 sessions	
234	1 min	VI 1-min VI 1-min 39 sessions	VI 1-min DRH 10 sessions	VI 1-min DRH 10 sessions
235	1 min	VI 1-min VI 1-min 48 sessions	VI 1-min DRH 10 sessions	VI 1-min DRH 10 sessions

and DRH components. For B1, rate of reinforcement during DRH was held to an average of one every 3 min, since VI 3-min was scheduled in the VI component. For all other birds, rate of reinforcement was held to an average of one every minute during DRH, since VI 1-min was scheduled in the VI component. The decision to change the value of T during a particular DRH component was based upon the number of food presentations during the previous DRH component. If there were none, T was increased one step. If there were more than one food presentation, the value of T was decreased one step. T could assume the following values: 0.075, 0.10, 0.15, 0.20, 0.30, or 0.50 sec. The value of C remained constant at five, except for B235. This bird had such a high local rate of responding during DRH that it was necessary to adjust the value of C as well as the value of T in order to hold rate of reinforcement during DRH within the range of that prevailing during VI. The value of C ranged between five and 12 for this bird, but was constant during any one session.

For B175, DRH was scheduled in tandem with a VI 1-min requirement (*tand* VI 1-min DRH). The VI timer operated during both the VI and the DRH components of the multiple schedule, and food was presented during the DRH component only if both the VI 1-min and the DRH requirements had been met. The value of C was held constant at five, and the value of T was held constant at 0.5 sec. This procedure also insured that rates of reinforcement in the VI and DRH components were equated.

RESULTS

Data from the last eight sessions of *mult* VI VI baseline training and all *mult* VI DRH sessions are presented in Figure 1. The vertical line separates *mult* VI VI sessions from *mult* VI DRH sessions. After the DRH schedule was introduced in the variable component, all birds increased their rate of responding in the VI (constant) component as well as in the DRH component. The pattern of rate increase differed somewhat among the five subjects. For four of five pigeons, rate of responding in both components remained above the *mult* VI VI baseline rate. However, B235's rate of responding returned to baseline in the constant component after an initial increase. For B1 and

Fig. 1. Rates of responding in each component during the last eight sessions of *mult* VI VI baseline training and during all sessions of *mult* VI DRH. The vertical line separates *mult* VI VI sessions from *mult* VI DRH sessions. The horizontal lines represent the median response rate for the constant component during the last eight sessions of baseline training. Note that the ordinates have been broken.

B234, rate of responding was consistently higher in the presence of the DRH stimulus than in the presence of the VI stimulus. Birds B55 and B175, on the other hand, initially responded faster during the VI stimulus, and

only after several sessions did rate of responding during the DRH component consistently exceed rate during the VI component. For only one bird (B235) did rate of responding appear to reach an asymptotic value in both components. Cumulative records for all subjects showed relatively constant rates of responding within sessions during each component of *mult* VI VI and *mult* VI DRH schedules of reinforcement. No appreciable pauses were seen (either post-reinforcement or at other times) in either the VI or DRH components.

Figure 2 shows rate of responding for B234 and B235 following reversal of the discriminative stimuli. Rate in both components declined at first, then the new DRH stimulus began to control a higher rate of responding than that maintained by the new VI stimulus. Bird B234 reversed response rates after three sessions, and B235 reversed after two sessions.

Figure 3 presents relative rates of reinforcement in the constant component for four birds: B55, B175, B234, and B235. Relative rate of reinforcement was computed by dividing the number of reinforcements in the constant component by the total number of reinforcements for each of the last eight sessions of *mult* VI VI and for all sessions of *mult* VI DRH. As can be seen from the figure, the experimental procedure was successful in holding constant the relative rates of reinforcement before and after introduction of *mult* VI DRH in three of four birds. Relative rate of reinforcement in the constant component increased slightly after *mult* VI DRH was introduced for B55.

To assess the possibility that changes in relative rate of reinforcement in the constant component contributed to the increased rate of responding in that component, correlations were computed between relative rate of reinforcement and rate of responding in the constant component before and after introduction of *mult* VI DRH. Correlations computed over the last eight sessions of *mult* VI VI and over the first 10 sessions of *mult* VI DRH are presented in Table 2. The correlations obtained during *mult* VI VI ranged from -0.72 to $+0.88$, showing little consistent relation between these two variables. After DRH was introduced, correlations were negative for three of four birds, and approximately zero for the fourth bird. Hence, for *mult* VI DRH

Fig. 2. Rates of responding during each component before and after cue reversal. The vertical line separates prereversal from postreversal sessions. Open squares represent response rates for the constant (VI) component stimulus during the original *mult* VI DRH training. This stimulus was associated with DRH after cue reversal. Filled circles represent response rates for the variable (DRH) component stimulus that was associated with VI following cue reversal. Note that the ordinates have been broken.

Fig. 3. Relative rate of reinforcement in the constant component during the last eight sessions of *mult VI VI* and during all sessions of *mult VI DRH*. The vertical line separates *mult VI VI* sessions from *mult VI DRH* sessions. Note that the ordinates have been broken.

there was an overall negative correlation between these variables.

DISCUSSION

The procedural variations in the treatments for subjects of this experiment emphasize the generality of the overall effect. Four birds out of five showed a sustained increase in VI rate of responding after a DRH schedule was introduced in the varied component of the multiple schedule. This effect occurred regardless of

whether VI 1-min or VI 3-min was used, or whether DRH was or was not arranged in tandem with VI. Typically, the descriptive terms adopted by Reynolds (1961a) have been used to label changes in rate of responding during the constant component. If the rate change is in a direction opposite that which occurred during the variable component, the interaction is called "contrast". If the change is in the same direction, the interaction is labelled "induction". Thus the terms "contrast" and "induction" describe changes in rate of responding in the constant component in terms of *rate changes* in the variable component. This nomenclature, in effect, implies that response rate in the variable component is the determinant of multiple schedule interaction. Since other factors may produce multiple schedule interactions, it would seem that changes in rate of responding in the constant component should be named *independently* of rate changes in the variable component. We therefore suggest that the term "interaction" be used to label all such changes; the term "positive interaction" will describe constant component rate increases, and "negative interaction" will describe constant component rate decreases. This new nomenclature excludes information regarding variable-component rate change, information that is more justifiably provided in the description of independent variables rather than in the description of the dependent variable. Thus, the result of the present experiment will be called positive interaction.

While a number of studies have shown positive interaction in multiple schedules, in most cases this effect was associated with a decrease in rate of responding during the variable component (*e.g.*, Reynolds, 1961a, 1961b, 1961c, and Nevin and Shettleworth, 1966). Positive interaction associated with a rate *increase* in the variable component has been shown by Reynolds (1963, 1964) and in the present report. In Reynolds' studies, positive interaction seemed to occur when rates of responding and reinforcement in the variable component were increased from very low values. When rates of responding and reinforcement have been increased from intermediate values (Reynolds, 1961c, 1963, and Terrace, 1968), either a negative interaction or no interaction has resulted. In the present study, however, positive interaction did occur when rate of

Table 2

Correlation coefficients between relative rate of reinforcement and rate of responding in the constant component.

Pigeons	<i>mult VI VI</i>	<i>mult VI DRH</i>
55	-0.41	0.04
175	-0.72	-0.58
234	0.88	-0.47
235	0.07	-0.59

responding was increased from an intermediate value in the variable component. It will be recalled that, unlike Reynolds (1961c, 1963, 1964) and Terrace (1968), the present study held constant the rate of reinforcement in the variable component. Thus, the positive interaction in the constant component is an effect of the increased rate of responding in the variable component, uncontaminated by change in rate of reinforcement.

The present results cannot be accounted for by most explanations of multiple schedule interaction that have been proposed in the literature. Reynolds' (1961a) notion that rate of responding in the constant component is a positive function of relative rate of reinforcement in that component is not predictive for the present results for two reasons: relative rate of reinforcement changed only slightly, and rate of responding was found to be negatively related to relative rate of reinforcement. Terrace's (1966) suggestion that response suppression in the variable component produces multiple schedule interaction is not applicable to the present experiment, because rate of responding increased rather than decreased. Only one interpretation of multiple schedule interaction seems helpful in accounting for the present data. Terrace (1963a, 1963b, 1966) suggested that an increased rate of responding in the constant component may result from increased "aversiveness" in the variable component. It is possible that introduction of a high rate requirement in the variable component of the present study produced an aversive situation in that component. Such an assertion is supported by evidence (Fantino, 1968) that birds prefer FI to DRH schedules with equal reinforcement rates. However, the explanatory value of the aversiveness hypothesis is tempered by the fact that "aversiveness" is not operationally defined.

There remain two additional possible interpretations of the present data. One concerns the role of the temporal distribution of reinforcements in the variable component. It is likely that some change in the distribution of interreinforcement intervals occurred in the variable component after the DRH schedule was introduced. It is certain, for example, that unlike the VI schedule, the first key peck after reinforcement was never reinforced on the DRH schedule, since the birds were required to make a minimum of five key pecks

for each reinforcement. To assess the importance of changes in temporal distribution of reinforcement in the variable component on rate of responding in the constant component, it would be informative to study multiple schedule interaction in a yoked situation. In such a procedure, one bird would be exposed to *mult* VI DRH with equal reinforcement densities in both components, while the second bird would be exposed to a *mult* VI VI schedule where the distribution of reinforcements in the variable component matched that prevailing in the DRH component for the first bird.

Another possible interpretation of the present experiment is that the increased rate of responding in the constant component merely represents stimulus generalization from the DRH component. This stimulus generalization interpretation is available when rate of responding in both components changes in the same direction, but not when the rates diverge. It would be puzzling, however, if the color stimuli of the present experiment were substantially less discriminable than those used by Terrace (1968) in demonstrating positive interaction in a *mult* VI DRL schedule. Although the differences between introduction of DRL and DRH may allow interpretation of one effect in terms of schedule interaction and the other in terms of stimulus generalization, a more parsimonious account would interpret both effects as schedule interactions. Further, the appropriate changes in behavior produced by cue reversal (Figure 2) show that the stimuli did control behavior. For these reasons, it seems more reasonable to interpret the present results within the context of schedule interaction.

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