

REINFORCEMENT DELAY: SOME EFFECTS ON BEHAVIORAL CONTRAST¹

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Thirty five White Carneaux pigeons first received 20 sessions of non-delayed reinforcement according to a multiple variable-interval 1-min variable-interval 1-min schedule. For the remaining 15 sessions, subjects were assigned to one of five groups, with seven subjects per group. Four of these groups involved reinforcement according to the same multiple schedule as before, but reinforcement during one of the components was delayed for either 2.5, 5, 10, or 120 sec. The schedule for the fifth group was changed to multiple variable-interval 1-min extinction schedule of reinforcement. While some subjects in all groups showed behavioral contrast, it occurred more consistently in the groups involving extinction or the longer delays of reinforcement. Groups involving the various durations of delayed reinforcement or even extinction during the altered component did not, however, show a statistically significant difference in the amount of behavioral contrast. It was suggested that neither a reduction in reinforcement frequency nor response rate during the altered component is necessary to the production of behavioral contrast.

A multiple schedule requires successive presentation of two or more independent schedules of reinforcement, each in the presence of a different exteroceptive stimulus. Much of the recent research on multiple schedules (*e.g.*, Herrnstein and Brady, 1958; Reynolds, 1961*a*, 1961*b*, 1961*c*; Reynolds and Limpo, 1968; Terrace, 1968; Weisman, 1969, 1970) has examined the frequent interactions that occur between the component schedules. An interaction occurs when an organism's behavior during one component in which reinforcement contingencies are held constant is in some way affected by a change in the reinforcement contingencies associated with the other component.

Behavioral contrast has been the most widely studied interaction and has been reviewed extensively by Terrace (1966*a*, 1971*a*) and Dunham (1968). Behavioral contrast occurs when the response rate during the un-

altered component increases and moves in a direction away from the response rate during the altered component. For example, the changing of a multiple variable-interval 1-min variable-interval 1-min (*mult* VI 1-min VI 1-min) schedule to a multiple variable-interval 1-min extinction schedule has consistently produced behavioral contrast, *i.e.*, the response rate during the first component is higher when it is alternated with an extinction component than when it is alternated with another variable-interval 1-min component. Behavioral contrast is not, however, limited to the special multiple schedule that has extinction as one of its components, as it has been demonstrated in many other multiple schedules, such as multiple variable-interval 1-min variable-interval 5-min (Guttman, 1959; Terrace, 1968; Weisman, 1969), multiple fixed-interval 1-min fixed-interval 3-min (Staddon, 1969), multiple variable-interval fixed-ratio (Reynolds, 1961*c*; Thompson, 1965; Bloomfield, 1967), multiple variable-interval differential reinforcement of low response rates, or DRL, (Bloomfield, 1967; Terrace, 1968; Weisman, 1969), and multiple variable-interval differential reinforcement of other behavior, or DRO, (Weisman, 1970). It has also been observed when responses during one of the multiple schedule's components are punished with electric shock (Brethower and Reynolds, 1962; Terrace, 1968).

¹This study is based on a dissertation submitted to Michigan State University in partial fulfillment of the requirements for the Ph.D. This research was supported by a National Institute of Health pre-doctoral fellowship to the author and by USPHS Grant MH-18342 to Dr. Mark Rilling. The author wishes to thank Dr. Mark Rilling for his helpful guidance and comments. Reprints may be obtained from the author, Department of Psychology, Colorado State University, Fort Collins, Colorado 80521.

Recent research has required the rejection or modification of several theories of behavioral contrast (*e.g.*, Reynolds, 1961a; Terrace, 1966a, 1966b, 1968). For example, the demonstration that behavioral contrast can occur without a reduction in reinforcement frequency (Brethower and Reynolds, 1962; Reynolds and Limpo, 1968; Terrace, 1968; Weisman, 1969, 1970) has led to the rejection of Reynolds' relative frequency of reinforcement hypothesis. Empirical evidence (Wilkie, Experiment I, 1970) and a theoretical suggestion (*cf.* Premack, 1969) have also forced Terrace (1971a) to modify his earlier position. Wilkie demonstrated that the delivery of the reinforcer independently of the organism's behavior during one component of a multiple schedule did not produce behavioral contrast, although the response rate during this component was reduced. On theoretical grounds, it seems unlikely that satiation during one component would produce behavioral contrast, given that different reinforcers were used in the two components. While Terrace still, apparently, views behavioral contrast as a byproduct of frustration or some other emotional responses, these emotional responses are now seen to be aroused by a reduction in response rate during one component that is produced by an inhibition of responding.

In each of the previous studies, reinforcement occurred immediately upon completion of the schedule's requirements. Following the suggestion of several investigators (Brown and Farber, 1951; Holder, Marx, Holder, and Collier, 1957; Amsel, 1958; Renner, 1964) that delayed reinforcement elicits frustration, the present experiment examined the effects of delaying reinforcement during one component of a *mult VI 1-min VI 1-min* schedule. Specifically, the present experiment attempted to determine if delaying reinforcement during one component would produce behavioral contrast. Also examined was the relationship between the duration of reinforcement delay and the amount of behavioral contrast.

METHOD

Subjects

The 35 experimentally naive, adult, female White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights.

Apparatus

An Industrial Electronics Engineers in-line display cell (model 10-3723-757-L), mounted behind the right key, illuminated each of the two operant conditioning chambers (Lehigh Valley Electronics, model 1519). A minimum force of approximately 15 g (0.15N) was required to operate this key; the other keys were covered with masking tape. No houselight was used, but a white pilot light was attached to the rear wall of both chambers. The key and pilot lights were illuminated by a CM 1829 bulb.

During reinforcement, the keylight was extinguished and a light within the food aperture was illuminated. The reinforcer was 2.75 sec access to mixed grain. The timing of this interval began when the subject placed its head through the food aperture, thus interrupting a light beam focused on a photocell.

Standard scheduling and recording equipment was housed in an adjacent room.

Procedure

Throughout training, the key was illuminated by a green light (S_1) or by a white vertical line superimposed on a green surround (S_2). These stimuli were not adjusted for equal intensity. The duration of each S_1 and S_2 presentation was 30 sec, excluding reinforcement time and reinforcement delay time. The stimuli were presented in random order with the restriction that neither stimulus occur more than three times in succession. A timeout, during which the chamber was dark and responding had no scheduled consequences, separated all stimulus presentations. During Session 1, the timeout duration was 1 sec, while during all subsequent sessions it was 5 sec. Reinforcements arranged but not effected during one component did not carry over to the next.

The pigeons were trained to key peck by the method of successive approximation. The shaping session terminated after 30 consecutive key pecks. Sessions 2 and 3 also terminated after 30 continuous reinforcements. During Sessions 4 and 5, 30 reinforcements occurred according to fixed-ratio 10 and 20 schedules, respectively. All subjects, then, received 20 sessions (60 stimulus presentations per session) of reinforcement according to a *mult VI 1-min VI 1-min* schedule. During all of the above sessions, there was no delay of reinforcement.

Each of the subjects was then assigned to one of five groups, with seven subjects per group. Four of these groups received 15 additional sessions of *mult* VI 1-min VI 1-min reinforcement, but with reinforcement during S_2 delayed for either 2.5, 5, 10, or 120 sec. During the delay period, the keylight was extinguished and the white pilot light on the chamber's back wall was illuminated. At the end of the delay period, the pilot light was extinguished and the food magazine raised. The fifth group received 15 sessions of *mult* VI 1-min extinction training; responding during S_2 extinguished the keylight and illuminated the white pilot light for 120 sec (according to the same VI 1-min schedule), but reinforcement did not occur. The responding of all subjects during S_1 was reinforced as before, VI 1-min with no reinforcement delay. Four of the subjects in each group were trained in one of the conditioning chambers and the remaining subjects were trained in the other chamber.

RESULTS

Figures 1 to 5 show the response rates during S_1 (denoted by the Xs) and S_2 (denoted by the closed circles) during the last 25 sessions of training. Each figure represents one experimental group and contains the data for the seven individual subjects as well as the group mean. To the left of the dashed vertical line are the final 10 sessions under the *mult* VI 1-min VI 1-min schedule with no delay of reinforcement. During the 15 sessions to the right of the dashed vertical line, the contingencies for S_2 responding were altered as indicated by the caption above each figure. That is, the responding of the subjects represented in Figures 1 to 4 continued to be reinforced on the same multiple schedule as before, but with reinforcement during S_2 delayed for either 2.5, 5, 10, or 120 sec. The responding of the subjects in Figure 5 was not reinforced during S_2 during these last 15 sessions.

As shown in Figure 1, delaying reinforcement for 2.5 sec during S_2 produced different effects on the S_2 response rates of the individual subjects. The S_2 response rates were either temporarily increased and then permanently reduced (Bird 38), permanently reduced (Birds 609 and 30), temporarily reduced (Birds 199 and 206), or not affected (Birds 2751 and

404). For four subjects (206, 609, 38 and 404), as well as for the group mean, it is not possible to assess unequivocally whether the delay produced a change in the S_1 response rate because response rates before introduction of the delay were unstable. However, in three subjects (199, 2751, and 30) the delaying of reinforcement for 2.5 sec during S_2 did produce a clear increase in the S_1 response rate.

As with the 2.5-sec delay, Figure 2 shows that the 5-sec delay had no consistent effect on the S_2 response rates. The S_2 response rates either showed no change (Bird 2655), a permanent increase (Bird 622), a temporary decrease (Birds 435 and 389), or a permanent decrease (Birds 32, 2955, and 2549). The mean curve shows a temporary decrease in S_2 response rates. In terms of S_1 responding, four subjects (Birds 435, 2655, 389, and 622) showed a clear increase in response rate. However, by taking Bird 32's very stable response rate during the last six sessions of immediate reinforcement as the baseline, it is clear that this subject also showed an increase in S_1 response rate when the reinforcement during S_2 was delayed for 5 sec. The failure of Birds 2955 and 2549 to respond at a stable rate during the sessions of immediate reinforcement makes it impossible to detect any change in their S_1 response rates during the sessions of delayed reinforcement. Similarly, for the mean curve, the gradual increase in the S_1 response rates during the sessions of immediate reinforcement prevents a clear assessment of changes in the mean S_1 response rate on introduction of the 5-sec delay of reinforcement during S_2 .

Figure 3 shows that the 10-sec delay of reinforcement produced either no change (Birds 1702 and 1794), a temporary (Birds 466, 40, and 2032) or a permanent (Birds 2631 and 990) reduction in S_2 responding. Six subjects (Birds 466, 2631, 2032, 1702, 990, and 1794) showed a clear increase in S_1 response rate; the remaining subject's (40) S_1 response rate curve is only suggestive of an increase in the last three sessions (sessions 38-40). The mean curve shows a temporary decrease in the S_2 response rate and a permanent increase in the S_1 response rate.

From Figures 4 and 5 it is apparent that delaying reinforcement for 120 sec is similar to nonreinforcement in that both procedures reduce S_2 responding to a near-zero level. In terms of S_1 response rates, six subjects (Birds

2.5-SEC DELAY

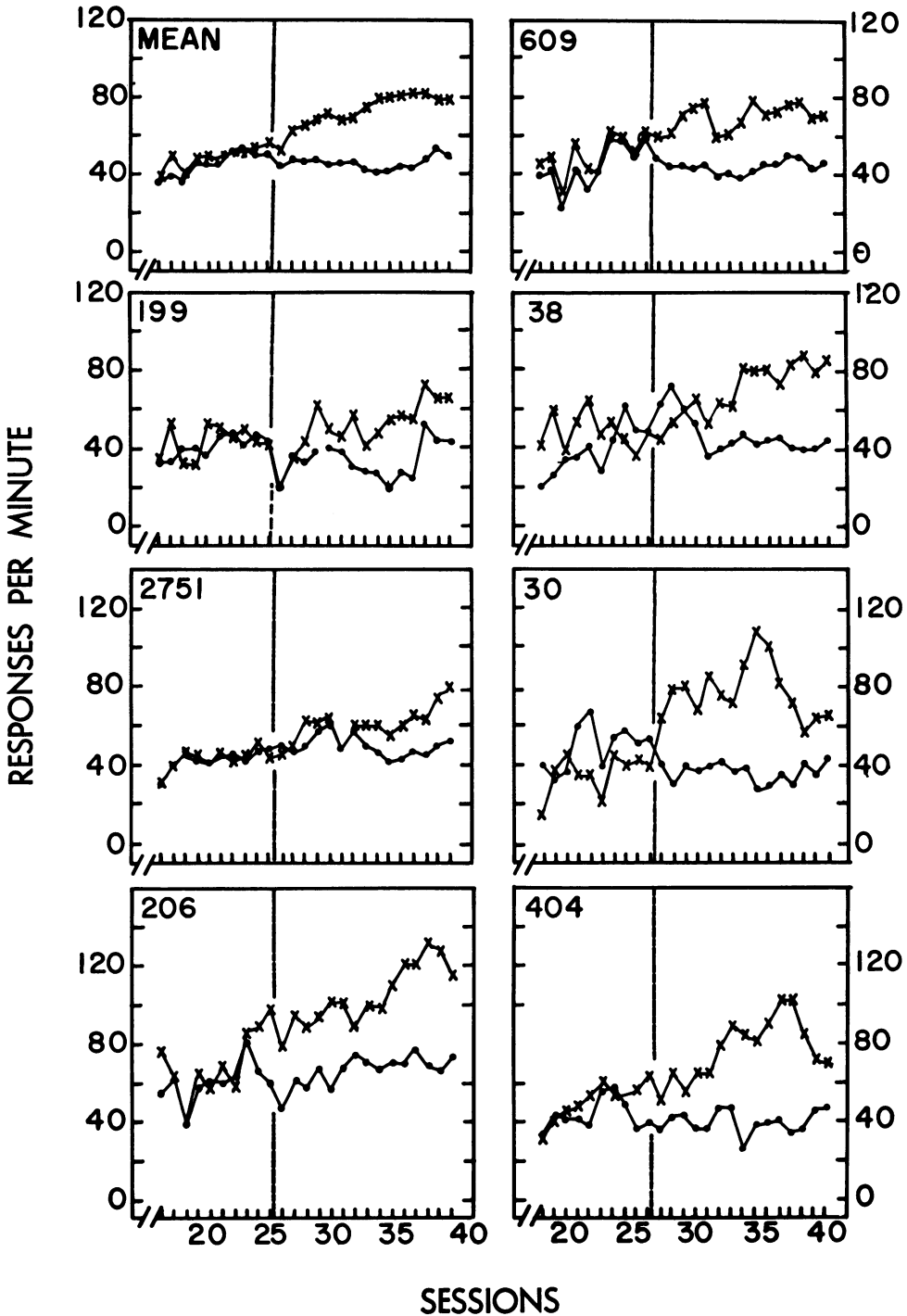


Fig. 1. Response rates to S_1 (Xs) and S_2 (circles) over sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult* VI 1-min VI 1-min with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line, responding continued to be reinforced on the same *mult* VI 1-min VI 1-min schedule, but with reinforcement during S_2 delayed for 2.5 sec.

5-SEC DELAY

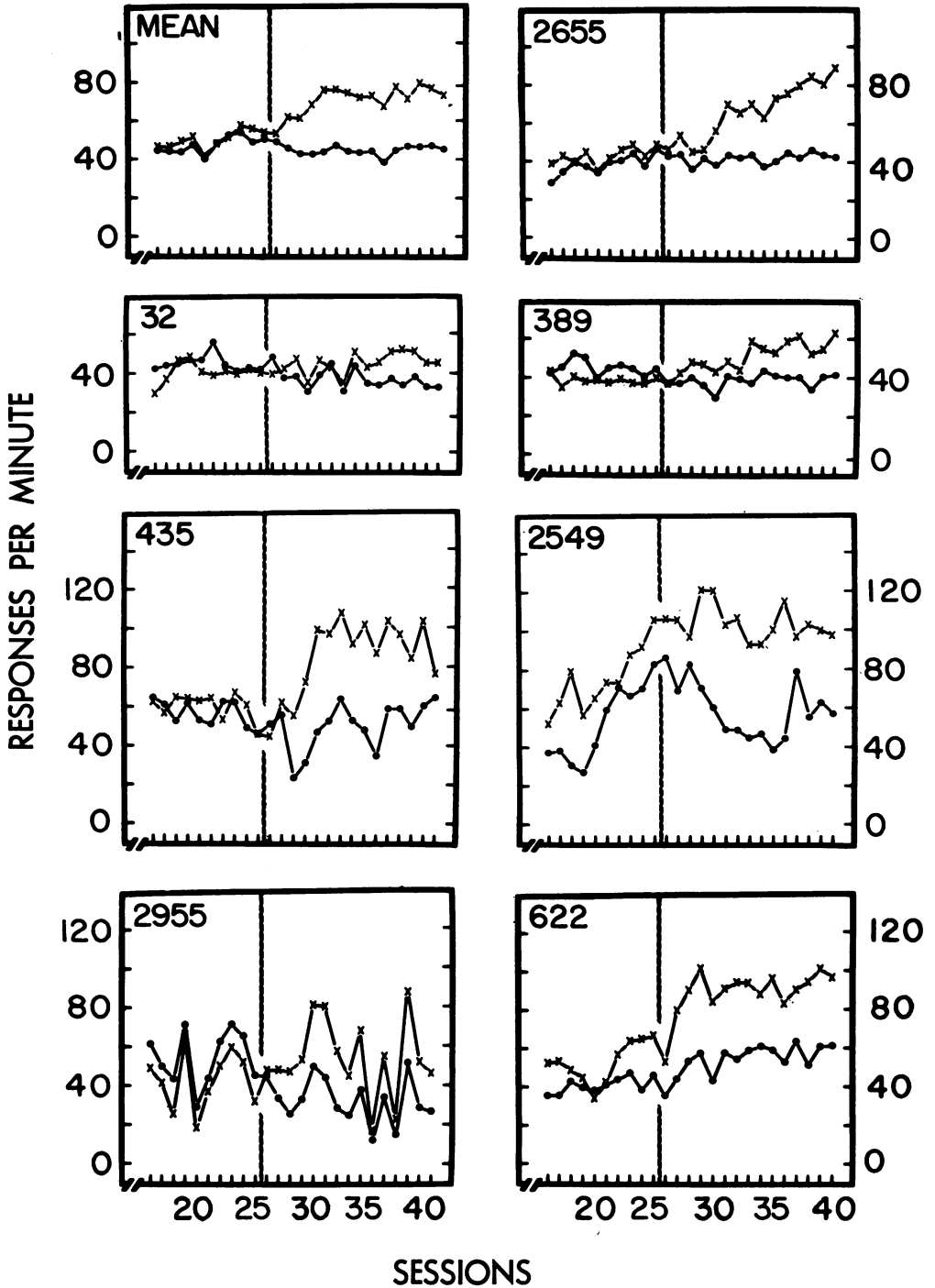


Fig. 2. Response rates to S_1 (Xs) and S_2 (circles) over sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult* VI 1-min VI 1-min with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line, responding continued to be reinforced on the same *mult* VI 1-min VI 1-min schedule, but with reinforcement during S_2 delayed for 5 sec.

10-SEC DELAY

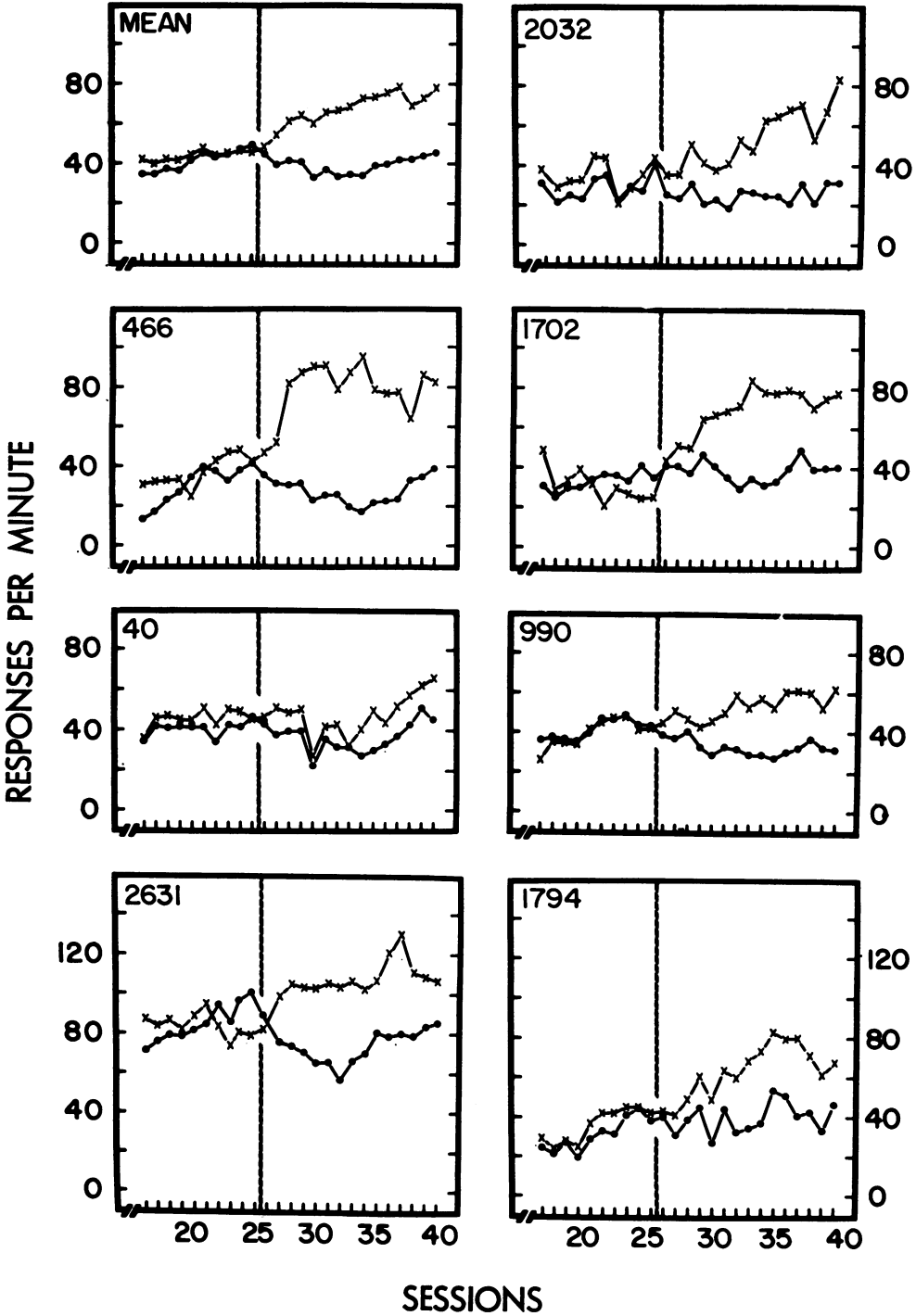


Fig. 3. Response rates to S₁ (Xs) and S₂ (circles) over sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult* VI 1-min VI 1-min with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line, responding continued to be reinforced on the same *mult* VI 1-min VI 1-min schedule, but with reinforcement during S₂ delayed for 10 sec.

120-SEC DELAY

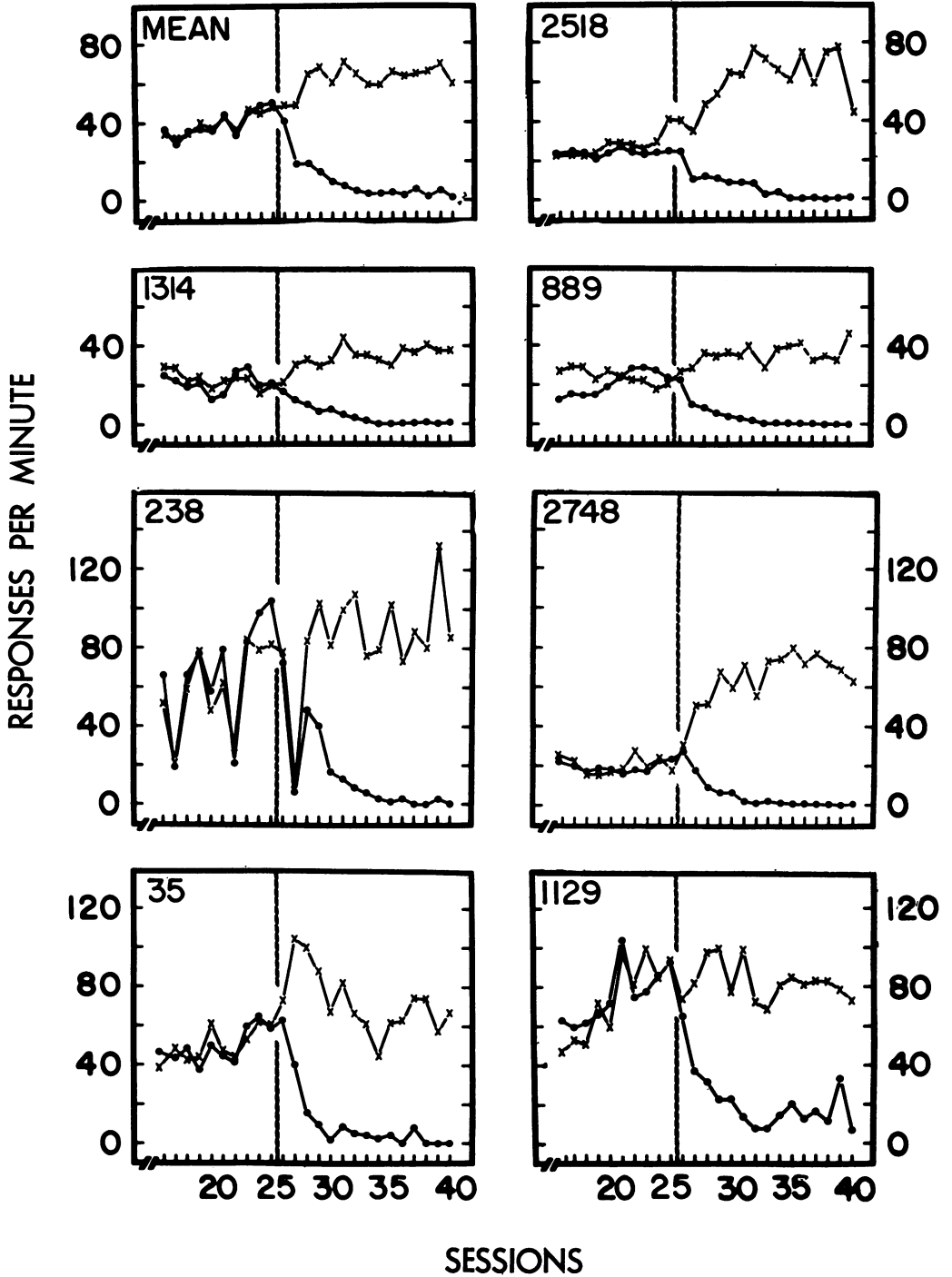


Fig. 4. Response rates to S₁ (Xs) and S₂ (circles) over sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult* VI 1-min VI 1-min with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line, responding continued to be reinforced on the same *mult* VI 1-min VI 1-min schedule, but with reinforcement during S₂ delayed for 120 sec.

EXTINCTION

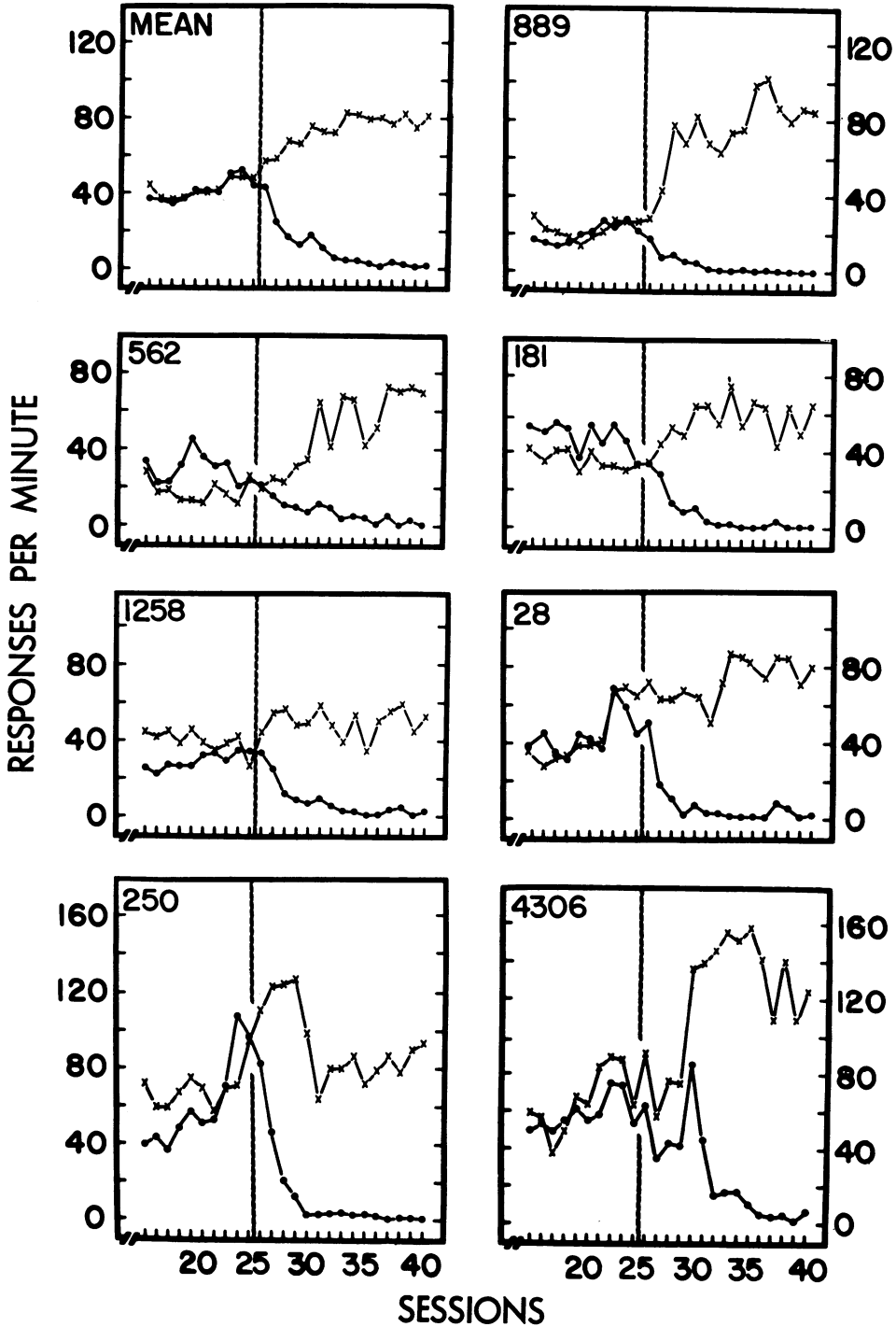


Fig. 5. Response rates to S_1 (Xs) and S_2 (circles) over sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult* VI 1-min VI 1-min with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line responding was reinforced on a *mult* VI 1-min extinction schedule.

1314, 238, 35, 2518, 889, and 2748) in the 120-sec delay group showed an increase, and all subjects in the extinction group showed an increase. Mean curves show a reduction in S_2 response rate to near zero and an increase in S_1 rate.

In order to determine if the five groups differed in the amount of increase in S_1 response rates, the final 18 sessions were collapsed into six, three-day blocks. Thus, the first block was the mean S_1 response rate during the last three sessions of the *mult VI VI* without reinforcement delay. The remaining five blocks represented mean S_1 rates during the sessions where reinforcement during S_2 was either delayed or discontinued. The results of this two-way (trials by groups) analysis of variance with repeated measures on one of the factors (trials) showed that the only significant effect

was the increase in S_1 response rate over sessions ($F = 27.641$, $df = 5/150$, $P < 0.001$) due to the changes in the S_2 contingencies. The groups did not differ significantly in the magnitude of the S_1 response rate increase ($F < 1$, $df = 4/30$).

Figures 6 to 9 show the mean rates of reinforcement during S_1 (denoted by the Xs) and S_2 (denoted by the closed circles) for the subjects in each group. The rate of reinforcement was computed by dividing the number of reinforcements during S_1 (or S_2) by the total time that the key was illuminated by S_1 (or S_2). For clarity, the S_2 reinforcement rates have been displaced to the right of the S_1 rates in these figures. The brackets around the mean reinforcement rates show the range of values within these sessions. As can be seen in these figures, there was no large change in the S_1 or

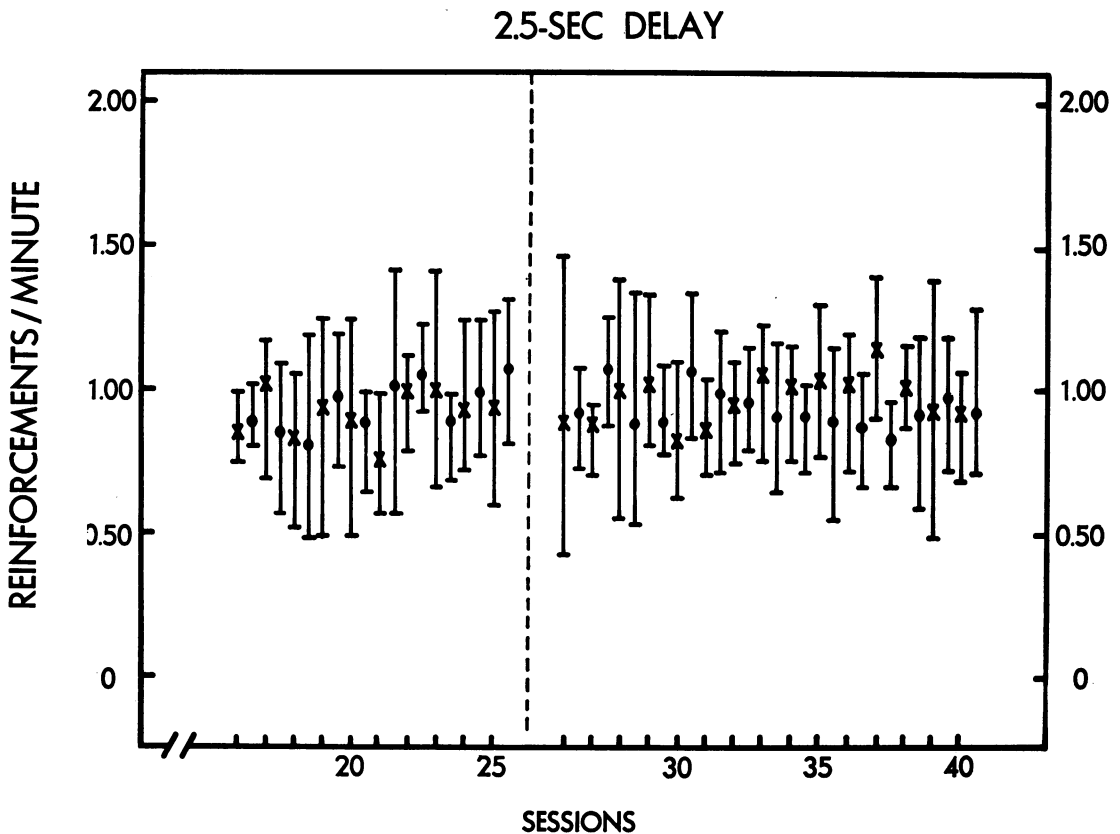


Fig. 6. The mean reinforcement rates during S_1 (Xs) and S_2 (circles) over sessions. For clarity, the S_2 reinforcement rates have been displaced to the right of the S_1 rates. The brackets around the mean reinforcement rates show the range of values within these sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult VI 1-min VI 1-min* with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line, responding continued to be reinforced on the same *mult VI 1-min VI 1-min* schedule, but with reinforcement during S_2 delayed for 2.5 sec.

5-SEC DELAY

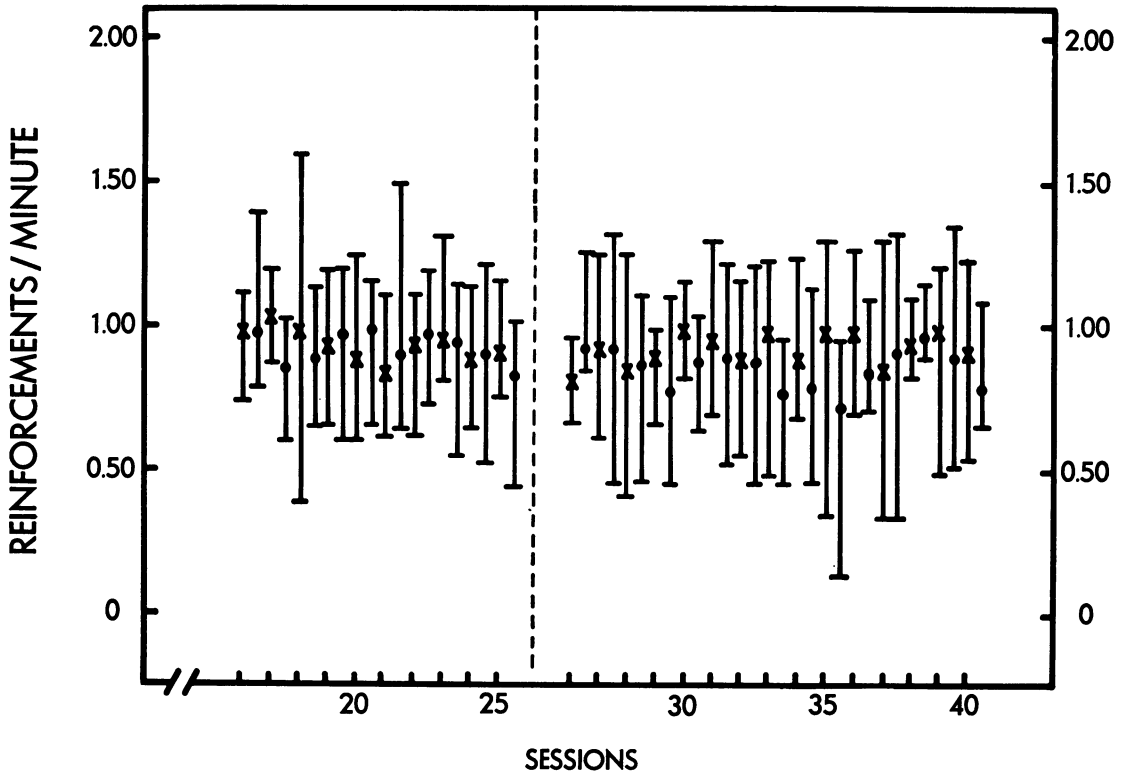


Fig. 7. The mean reinforcement rates during S_1 (Xs) and S_2 (circles) over sessions. For clarity, the S_2 reinforcement rates have been displaced to the right of the S_1 rates. The brackets around the mean reinforcement rates show the range of values within these sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult* VI 1-min VI 1-min with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line, responding continued to be reinforced on the same *mult* VI 1-min VI 1-min schedule, but with reinforcement during S_2 delayed for 5 sec.

S_2 reinforcement rates as a result of either the 2.5-, 5-, or 10-sec delay contingency. The 120-sec delay, however, sharply reduced the S_2 rate of reinforcement. In fact, during these delay sessions only Bird 1129 consistently obtained reinforcers during S_2 , and it is the reinforcement rates of this bird that produced the large range in S_2 reinforcement rates during Sessions 33 to 40.

DISCUSSION

Behavioral contrast is said to occur if, following a change in the S_2 reinforcement contingencies, the increased S_1 response rate changes in a direction away from that maintained by S_2 . The present experiment was conducted to determine whether the delaying of reinforcement during one component of a

mult VI 1-min VI 1-min schedule would produce behavioral contrast. The relationship between the duration of reinforcement delay and the amount of behavioral contrast produced, if any, was also examined.

From Figures 1 to 4 it is clear that delay of reinforcement during one component of a multiple schedule produces behavioral contrast. Of the 28 subjects with delayed reinforcement during S_2 , 20 clearly showed behavioral contrast. With a procedure similar to that of the present experiment, Wilkie (1970, Experiments III, IV and V) also reported behavioral contrast following the delay of reinforcement during one component of a multiple schedule. Using a modified discrete-trial paradigm, where both S_1 and S_2 were associated with different durations of reinforcement delay and where the delay was not associated

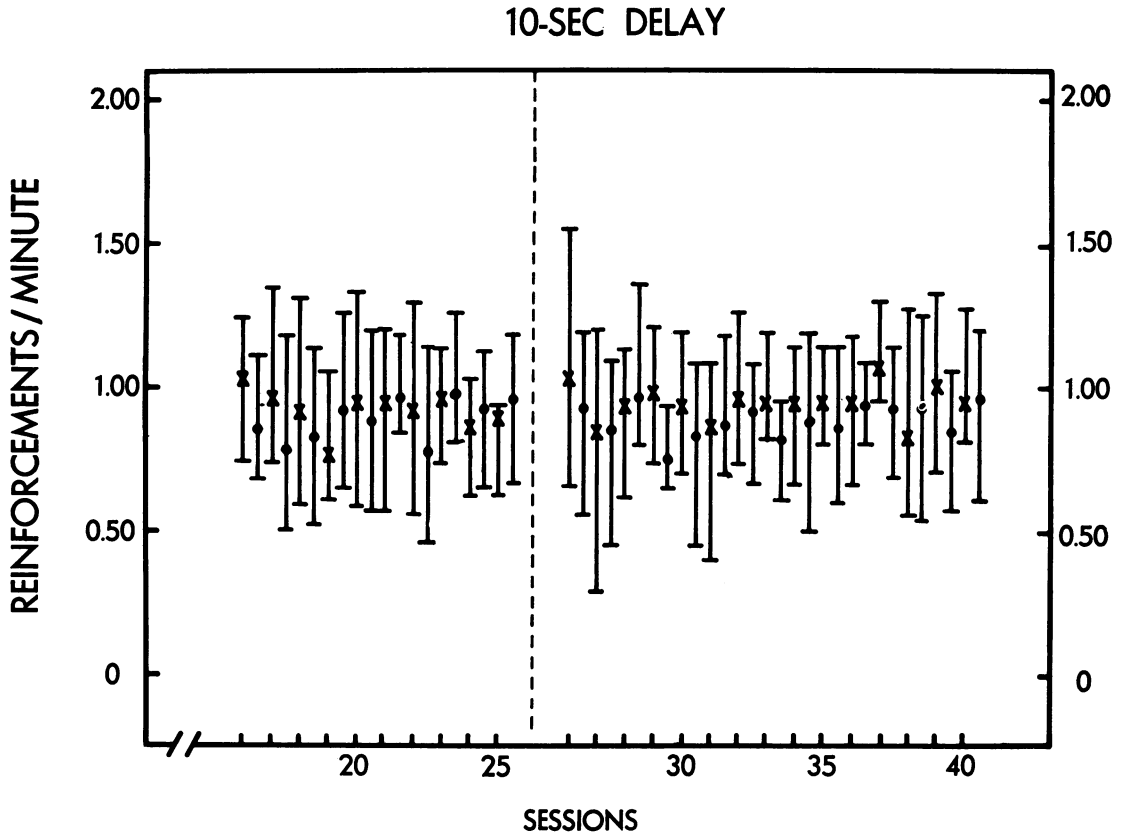


Fig. 8. The mean reinforcement rates during S_1 (Xs) and S_2 (circles) over sessions. For clarity, the S_2 reinforcement rates have been displaced to the right of the S_1 rates. The brackets around the mean reinforcement rates show the range of values within these sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult* VI 1-min VI 1-min with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line, responding continued to be reinforced on the same *mult* VI 1-min VI 1-min schedule, but with reinforcement during S_2 delayed for 10 sec.

with a stimulus change, Keller (1970) also demonstrated behavioral contrast. The conclusion that delayed reinforcement produces behavioral contrast, thus, seems to hold across large variations in procedure.

Groups that received reinforcement delays of 2.5, 5, 10, or 120 sec or even extinction during S_2 did not show a statistically significant difference in the magnitude of behavioral contrast. Several possible reasons for the failure to find a relationship between the duration of reinforcement delay and the amount of behavioral contrast should be noted. In terms of detecting differences in the magnitude of behavioral contrast, neither the between-subjects design nor the 1-min VI baseline (Reynolds, 1963) of the present study may have been the most sensitive. A third possibility is that the function relating delay duration to the amount

of behavioral contrast reaches asymptote at or before the minimum delay duration of the present study (2.5 sec). Indeed, a relationship between the duration of reinforcement delay and the magnitude of behavioral contrast might have been found, if some shorter delays had been included. Of course, it may be that the duration of reinforcement delay, like the number of errors emitted during the acquisition of a discrimination (Terrace, 1966a), is not related to the magnitude of behavioral contrast by a simple function.

The durations of reinforcement delay did, however, differ in their reliability of producing behavioral contrast in the individual subjects. While the 2.5-sec. delay produced behavioral contrast in only three of the seven subjects, the 5-sec delay produced it in five of the seven subjects. Both the 10-sec and 120-sec delays

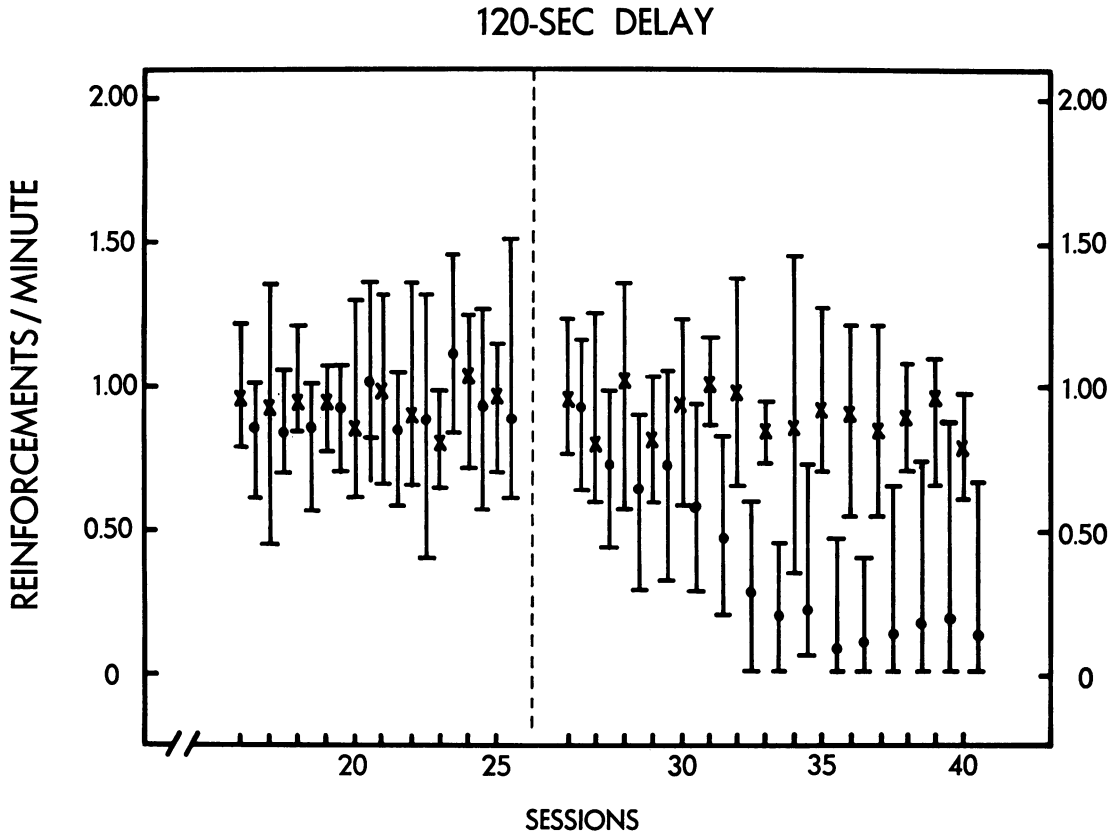


Fig. 9. The mean reinforcement rates during S_1 (Xs) and S_2 (circles) over sessions. For clarity, the S_2 reinforcement rates have been displaced to the right of the S_1 rates. The brackets around the mean reinforcement rates show the range of values within these sessions. During the 10 sessions to the left of the dashed vertical line, the schedule of reinforcement was a *mult* VI 1-min VI 1-min with no reinforcement delay. During the 15 sessions to the right of the dashed vertical line, responding continued to be reinforced on the same *mult* VI 1-min VI 1-min schedule, but with reinforcement during S_2 delayed for 120 sec.

produced contrast in six of the seven subjects. Only the extinction procedure produced contrast in all seven subjects.

Results of the present study also have important implications for conditions necessary to the production of behavioral contrast. From Figures 6 to 8 it is clear that behavioral contrast can be produced without reducing the reinforcement rate during the altered component. This finding is in agreement with several studies that were specifically designed to hold reinforcement rate constant during the altered component (*e.g.*, Terrace, 1968; Weisman, 1969, 1970).

Terrace (1971a) maintained that behavioral contrast is a byproduct of some emotional responses produced by the subject's reduced and inhibited responding during the altered component. Of the 21 subjects in the 2.5-, 5-, and

10-sec delay groups, five showed no change in S_2 response rate; however, four of these showed behavioral contrast. Seven subjects showed only a temporary reduction in S_2 responding and five of these showed behavioral contrast. Of the eight that did permanently reduce S_2 responding, four showed behavioral contrast. Clearly, a permanent reduction in responding during the altered component is not necessary to the production or maintenance of behavioral contrast. The present data further show that behavioral contrast can occur regardless of any reduction in responding during the altered component (*cf.* Wilkie, 1970). Independent investigation of the possible inhibitory properties of reinforcement delay (see Hearst, Besley, and Farthing, 1970) will, however, be necessary for a complete assessment of Terrace's position on behavioral contrast.

Although only four subjects showed behavioral contrast without a reduction in responding during the altered component, it does seem that Terrace's position needs some modification. Keeping within the rubric of his emotionality theory, it may be that the reduction in response rate, like behavioral contrast, was just a frequent byproduct of some emotional responses elicited by the delay of reinforcement. In support of this interpretation, it should be noted that in many cases the response rate reduction, like behavioral contrast (Terrace, 1966*b*), disappeared with further training. Extended training (Terrace's subjects received 60 sessions) might have shown the response rate reduction to be temporary in all subjects.

If one accepts the emotionality interpretation of behavioral contrast, there still remains the problem of specifying the necessary and sufficient conditions that produce the frustration or other emotional responses. Guttman's suggestion that the weaker of two reinforcement schedules can become "functionally negative," while intrinsically appealing, is not very useful. There are no specified or readily apparent criteria for classifying one of two schedules of equal reinforcement frequency as the weaker. For example, it is unclear why a DRO should be considered weaker than a VI of equal reinforcement frequency, and yet, it is quite clear that changing a *mult* VI VI to a *mult* VI DRO does produce behavioral contrast (Weisman, 1970). The use of Premack's (1969) suggestion that "Contrast results if and only if there is a change in the aversiveness associated with one of the components in the schedule [p. 136]" as an hypothesis specifying the conditions that produce these emotional responses may be the most workable position at present. This hypothesis is, of course, quite similar to Bloomfield's (1969) contention that behavioral contrast is produced by "a worsening of conditions" during one of the components. If behavioral contrast occurs, the stimulus associated with the altered component should possess all the properties of other aversive stimuli—subjects should learn a new response to escape from the stimulus and the stimulus should serve as an elicitor of aggression and as a punisher of ongoing behavior. Likewise, if no contrast is observed, these properties should not be present. Although a beginning has been made in studying multiple

schedules within these different paradigms (e.g., Rilling, Askew, Ahskog, and Kramer, 1969; Rilling, Kramer, and Richards, 1971; Terrace, 1971*b*; Weisman and Premack, 1966), more research will be required before a definitive conclusion can be reached.

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Received 14 May 1971.

(Final acceptance 13 December 1971.)