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The Delay-Reduction Hypothesis of Evocative Effectiveness and Latency

James Bryant Nuzzo
Western Michigan University

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THE DELAY-REDUCTION HYPOTHESIS OF EVOCATIVE EFFECTIVENESS AND LATENCY

by

James Bryant Nuzzo

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THE DELAY-REDUCTION HYPOTHESIS OF EVOCATIVE EFFECTIVENESS AND LATENCY

James Bryant Nuzzo, Phd.

Western Michigan University, 1984

Prior studies found that separations between latencies correlated with differential stimuli in a multiple discrete trial procedure were attenuated with increased intertrial interval durations. In this study six pigeons served as subjects in two groups. The procedure for one group was a multiple DRO-FR chain schedule (Ratio Delay group) while in the other group a multiple DRO - response-initiated delay interval chain schedule (Time Delay group) was used. Results of this study are consistent with the Delay-reduction hypothesis of evocative effectiveness which predicts that with increasing initial link durations relative terminal link evocative effectiveness would decrease. Specifically, relative terminal link latency varied as a function of initial link durations as predicted by the Delay-reduction hypothesis. However, relative terminal link running rates varied as a function of initial link durations, as predicted, for only two subjects, both of the Time Delay group. Failure of the Ratio Delay terminal link running rates to vary as predicted are explained by the possible increased differential reinforcement of short interresponse times afforded by the longer terminal link FR. Implications discussed include the misuse of discrete trial terminology and the application of the Delay-reduction hypothesis to the analysis of behavioral contrast.

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James Bryant Nuzzo

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INTRODUCTION

Reasons and rationales for experimental studies, as Skinner (1956) has noted, are often logical "formalized constructs of statistics" (p. 78), theoretical models, or principles of experimental design. In contrast Skinner (1956, 1979) and, in greater detail, Sidman (1960) have cited and discussed a variety "of more *common* [italics added] reasons ... for the making of experiments" (Sidman, 1960, p. 4).

In the second part of his autobiography, *The Shaping of a Behaviorist*, Skinner (1979) noted, with some dismay, that following his departure from Harvard his research "had turned to other questions .... [to] a kind of technological application .... *using* an experimental analysis" (p. 343), or in other words reacting to the research of others. So too, in a general sense, this study is an attempt to add to the body of literature which counters Skinner's (1961) contention that latency "does not vary continuously or in an orderly manner" (p. 44).

More importantly, this study is an attempt "to explore the conditions under which a phenomenon occurs" (Sidman, 1960, p. 33). The phenomenon of interest was initially noted in latency research by Michael, Burke, Cole, Hesse, LaLonde, Madsen, Nuzzo, Sundberg and Whitley (1981) and Hesse, Michael, Whitely, Nuzzo and Sundberg (1984).

In the research of Michael et al. (1981) a two-component discrete trial multiple schedule was employed, with components differing in some parameter of reinforcement (e.g., ratio required to produce reinforcement, probability of reinforcement or duration of reinforcement). Schedule components were randomly alternated and preceded, initially, by a 5 s intertrial interval (ITI). Response latency was defined as the time from the onset of the differential stimulus, correlated with each component of the multiple schedule, to the first key peck. With such a procedure shorter latencies consistently occurred in the presence of the stimulus correlated with the better parameters of reinforcement, and longer latencies occurred in the presence of the stimulus correlated with the worse parameters of reinforcement; this yielded a separation between latencies. The unanticipated effect noted was that with increased ITI durations (i.e., 10 s, and 20 s) the separation between latencies was attenuated, although the parameters of reinforcement correlated with each stimulus remained unchanged (Michael et al., 1981).

An initial attempt (Nuzzo, 1981) to determine the conditions for and a reasonable analysis of the ITI-generated attenuation of separations between latencies produced only additional questions of uncertain analytical value. Following 2 years and numerous formal exercises intended to generate a profitable course of action, a reasonable approach presented itself by accident. This event was not by experimental accident cited by Skinner (1946) as "serendipity" (p. 88), but by verbal accident of tact and intraverbal relations (Skinner, 1957).

Michael, in a class lecture which this researcher attended, discussed the role of chain schedules in the experimental analysis of conditioned reinforcement. More importantly, Michael, in response to a question, explained the distinction between a homogeneous chain schedule (i.e., a chain schedule in which the response form is the same in all links) and heterogeneous chain schedule (i.e., a chain schedule in which the response form differs in each or some links). The notion that the discrete trial latency procedure of Michael et al. (1981) may also be viewed as a free operant two-link heterogeneous-chain multiple schedule became apparent upon hearing this explanation.

Following Skinner's (1956) suggestion that "when you run onto something interesting, drop everything else and study it" (p. 81), interest in the remainder of the lecture was lost and information relevant to chain and multiple schedules was privately considered. The result of this private verbal interaction was the conclusion that Fantino's (1977) delay-reduction hypothesis might provide a profitable analysis of the ITI-generated attenuation of separations between latencies. The delay-reduction hypothesis has, with varying degrees of success, been applied to the analysis of conditioned reinforcement involving chain schedules (Fantino, 1977; Williams & Fantino, 1978), choice procedures involving chain schedules (Duncan & Fantino, 1972; Hursch & Fantino, 1973), and observing behavior (Fantino, 1977, 1981).

These two notions now require a more detailed and formal review. First consider the notion that the discrete trial procedure of Michael et al. (1981) may be viewed as a free operant schedule. In this procedure, upon termination of reinforcement, a new trial began with an ITI: a period of time in which the response key was dark and any pecks to the key reset the ITI timer, followed by the transillumination of the response key. If a response class may be defined by exclusion, as with a "differential reinforcement of behavior other than key pecking [DRO] ... schedule" (Reynolds, 1961, p. 59), then the ITI may be viewed as a schedule in which the response class of non-key pecking (i.e., engaging in other behavior) is reinforced by the onset of a stimulus transilluminating the response key. Indeed, the transillumination of the response key is contingent upon not pecking the response key during the ITI. Specifically, the ITI may be considered an initial link DRO, of a heterogeneous chain, followed by a terminal link consisting of an interval with a stimulus transilluminating the response key and its associated schedule of reinforcement (e.g., fixed ratio). Since the procedure of Michael et al. involved two differential stimuli (i.e., terminal links) correlated with differing schedules of reinforcement the procedure is best described as a two-link heterogeneous-chain multiple schedule and not a "three component multiple schedule involving two FR components separated by one extinction component (called the ITI)" (Hesse, et al., 1984).

A potentially profitable analysis of the DRO-generated attenuation of separations between latencies is suggested by the delay-reduction hypothesis of conditioned reinforcement. Fantino's (1977) delay-reduction hypothesis stipulates that the conditioned reinforcing effectiveness of a stimulus (e.g., terminal link stimulus) "is a function of the reduction in time to reinforcement correlated with the onset of that stimulus" (p. 313). Similarly, consider the possibility that the evocative effectiveness of the terminal link stimulus is determined in the same way as the conditioned reinforcing effectiveness of that stimulus is determined. Specifically, the evocative effectiveness of a stimulus is a function of the reduction in the time to reinforcement correlated with the onset of that stimulus.

Such a notion finds some support in Keller and Schoenfeld's (1950) discriminative stimulus hypothesis of conditioned reinforcement initially suggested by Skinner's speculation that "in order to act as a conditioned reinforcer for any response, a stimulus must have status as a discriminative stimulus for some response" (1938, p. 236). Though more recent analysis suggests that the discriminative function is not necessary for a stimulus to function as conditioned reinforcement (Fantino, 1965), the discriminative function may be sufficient; thereby a basis is provided for the speculation that the same variables which determine the conditioned reinforcing effectiveness of a stimulus also may determine the evocative effectiveness of that stimulus.

Recently Fantino (1981) has addressed the notion of the evocative effectiveness of a stimulus in terms of the delay-reduction hypothesis with the query:

> A stimulus following a long intertrial interval is correlated with a greater reduction in time to reinforcement than a stimulus following a shorter intertrial interval. Will such a stimulus also maintain a higher rate of responding in its presence? Some data from autoshaping procedures suggest an affirmative answer. (p. 194)

Although, Fantino's (1981) suggestion was made with respect to the dependent measure of response rate in the terminal link stimulus, logically the notion of evocative effectiveness can be extended to the dependent measure of response latency in the terminal link stimulus. Specifically, the response latency to a stimulus following a long DRO should be shorter than one following a short DRO.

The delay-reduction hypothesis, in its unmodified version, is formally expressed as:

$$\frac{R_L}{R_L+R_R} = \frac{T-t_{2L}}{(T-t_{2L})+(T-t_{2R})} \qquad (1)$$

where R_L and R_R are initial link response rates in a concurrent chain choice procedure. The average time or delay to terminal link reinforcement from the onset of the initial links is T. Lastly, t_{2L} and t_{2R} are the average time to reinforcement in the corresponding terminal links. The reduction in delay to reinforcement correlated with the onset of the left terminal link is indicated by $(T-t_{2L})$.

When applied to concurrent chain performance the formula predicts that with increasing initial link durations there would be decreasing choice of the prefered key. That is, the relative difference in response rate in the initial links would decrease. Likewise, when applied to the heterogeneous-chain schedule of Michael et al. (1981), the delay-reduction hypothesis would predict with increasing initial link durations that there would be decreasing differences in terminal link latencies initially established by differing terminal link fixed ratios (FRs). Consistent with this prediction is the implicit speculation that the relative difference of response rate in the terminal links would also decrease with increasing initial link durations. Evaluation of these predictions is the primary concern of this study as well as replicating and extending the DRO-generated attenuation phenomenon initially noted by Michael et al. (1981).

The general experimental procedure involved a multiple two-link heterogeneous-chain schedule, or in more traditional terms a two-component discrete trial multiple schedule (e.g., Michael et al., 1981; Hesse et al., 1984). A pseudo-yoke procedure was employed to evaluate the proposition that the time or delay to reinforcement was the critical variable determining the evocative effectiveness of the terminal link stimulus and not some feature of FR schedules. Therefore, two experimental groups were used differing only in the schedule of reinforcement in the terminal links of the chain schedules. For one group the terminal links consisted of FRs while for the other group response-initiated delay intervals were programed. The latter group functioned as the pseudo-yoke procedure with delay intervals approximating those generated by the specific FR values used in the former group.

Other issues addressed in the discussion of the experimental results include the view of discrete trial procedures as operant schedules. An additional speculation, more theoretical in nature, concerns the analysis of behavioral contrast (Reynolds, 1961) in terms of the delay-reduction hypothesis of evocative effectiveness. Behavioral contrast is either the increase (i.e., positive) or decrease (i.e., negative) in response rate to one stimulus caused by changing the schedule of reinforcement associated with a different stimulus. Basically, it would be expected that by increasing or decreasing the delay to reinforcement in one stimulus the relative evocative effectiveness of the other stimulus would correspondingly increase or decrease generating a corresponding increase or decrease in response rate. Similarly there would be a corresponding decrease or increase in latency.

METHOD

Subjects

Six 5-to-8-year-old female White Carneaux pigeons served as subjects. All had extensive variable interval and discrete trial schedule histories. Each was maintained at 80 % ± 10 grams of their free-feeding weight. Access to mixed grain served as reinforcement in the experimental sessions, with additional provisions provided in the home cage as needed to maintain their 80% weight. Water and grit were continuously available in the home cage.

Apparatus

Three Lehigh Valley Electronics test chambers (Model 002), with three response keys were utilized. For this experiment only the center key was operational. The translucent key was mounted behind a 2.5 cm circular aperture 26 cm above the chamber floor and 17.5 cm from either side of the intelligence panel. A force of 0.2 N ± 0.02 N was required to operate the key's microswitch. An IEE single-plane projector transilluminated the response key with stimuli. Stimuli consisted of the hues red and green (Kodak Wratten filters: #72B and #74, respectively).

Access to mixed grain occurred with the illumination of the 6 cm high by 5 cm wide hopper opening centered 13.5 cm below the response key. General chamber illumination was provided by a 7.5 watt shielded lamp located 7 cm above the response key. Externally mounted exhaust fans and white noise masked sounds extraneous to the experimental chamber.

Experimental control and data acquisition procedures were provided by a State Systems Inc., SUPERSKED system (Snapper, Kadden & Inglis, 1981) located in a separate room.

Procedure

Chambers were illuminated throughout experimental sessions, which terminated at the end of the 61st initial link DRO. The basic experimental procedure consisted of a two-link heterogeneous-chain multiple schedule. Two experimental groups were employed differing only in the terminal link response contingency resulting in reinforcement.

For one group, terminal link reinforcement was contingent upon completion of FRs. Consequently, this group's delay to reinforcement was generated by the time to complete the FRs and is therefore called the Ratio Delay group. As indicated by the State Diagram (Snapper, et al., 1981) in Figure 1, a session began with the illumination of the house light and a initial link DRO (i.e., 5 s). Any key pecks during the interval reset the DRO timer. With the completion of the DRO, green transilluminated the response key in the terminal link of the chain. The chains with their differential terminal link hues, green and red, alternated from trial to trial. This simple alternation was used instead of the procedures of Michael et al. (1981) and Hesse et al. (1984) where chains were alternated on a pseudo-random basis, since pilot data

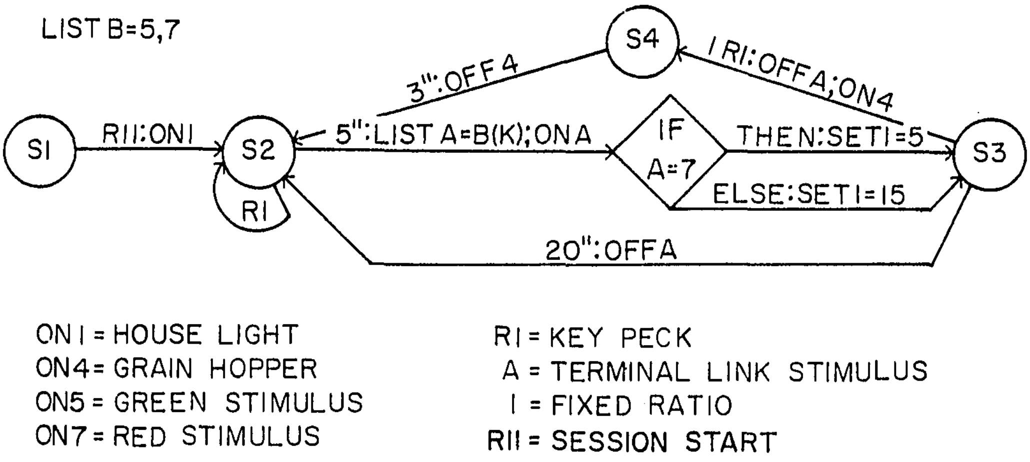

Figure 1. Basic State Diagram of the Ratio Delay procedure.

indicated a slight decrease in session-to-session variability of median latency. Reinforcement was contingent upon completing a specific FR correlated with each hue (e.g., FR 5 in red, FR 15 in green) within a 20 s limited hold period. Termination of the 3 s of reinforcement or the 20 s limited hold initiated a new chain.

For the second group terminal link reinforcement was contingent upon a response-initiated fixed-time interval. That is, this group's delay to reinforcement was generated by a programed timer initiated by the first response to the transilluminated key in the terminal link and is therefore called the Time Delay group. As indicated by the State Diagram (Snapper, et al., 1981), in Figure 2, a session began with the illumination of the house light and a DRO (i.e., 5 s). Following the DRO the response key was transilluminated green. The chains with their differential terminal link hues, green and red, alternated from trial to trial. The first

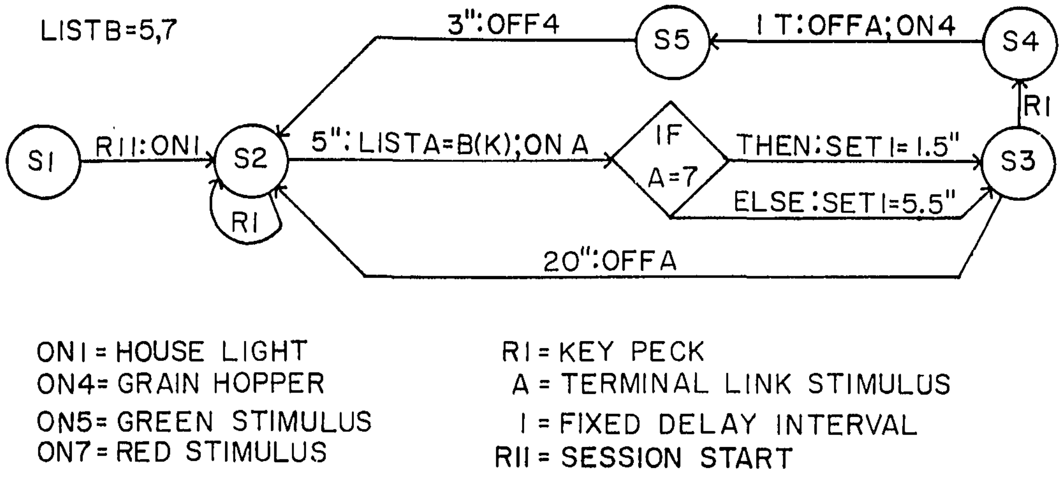

Figure 2. Basic State Diagram of the Time Delay procedure.

response to the transilluminated key, within the 20 s limited hold period, initiated a timer correlated with each hue (e.g., 1.5 s in red, 5.5 s in green). When the timer reached zero, 3 s of reinforcement was delivered. Responses during the delay interval had no scheduled consequence and were merely recorded. Termination of 3 s reinforcement or the 20 s limited hold initiated a new chain.

The reader should note that for the Time Delay group the 20 s limited hold defined when the reinforcement contingency had to begin to be effective (i.e., response-initiated delay interval), while in the Ratio Delay group the limited hold defined when the reinforcement contingency had to be meet to be effective (i.e., completion of an FR).

All experimental conditions lasted eight sessions. This phase change criterion was used because of past failures to establish a stability criterion, other than by visual inspection (Michael et al., 1981, Hesse et al., 1984). Longer latencies were particularly difficult to judge as stable, even when experimental conditions were held unchanged for more than 60 sessions.

Subjects in all groups were initially trained with 5 s DRO initial links and equal terminal link components. That is, FR 5s for the Ratio Delay subjects and 1.5 s intervals for the Time Delay group. This training permitted the assessment of bias for one of the two terminal link stimuli.

Following the eighth session of initial training, one terminal link schedule, appropriate to each group, was increased in ratio size or interval duration. For the Ratio Delay group the terminal link schedules were FR 5 and FR 15. For the Time Delay group the terminal link schedules were 1.5 s and 5.5 s delay intervals. For subjects, 1145, 3115, and 9913, with a bias for one of the two terminal link stimuli, as determined in initial training performance, the prefered terminal link scheduled was changed. These terminal link schedules and 5 s DRO initial links constituted baseline conditions.

The experimental or independent variable manipulated in the course of this experiment was initial link DRO duration. Various DRO durations, (i.e., 2 s, 10 s, 20 s and 30 s), were alternated with the 5 s DRO baseline condition. The order of these manipulations, for each subject, is listed in Table 1. As noted previously, each condition or phase lasted eight sessions.

Table 1

Order of DRO Presentation

	ORDER of DRO's				
Subject	1	2	3	4	5
Ratio Delay					
1145	5 s	2 s	30 s	20 s	10 s
9860	5 s	2 s	20 s	10 s	30 s
5172	5 s	30 s	10 s	20 s	2 s
Time Delay					
10780	5 s	30 s	2 s	20 s	10 s
3115	5 s	20 s	10 s	2 s	30 s
9913	5 s	20 s	2 s	30 s	10 s

Median response latency in each terminal link stimulus constituted the primary dependent variable. Median latency was computed by Minitab (release 81.1) which averages the two middle data values "each of which has a depth of ($\underline{n}$+1)/(2-1/2)" (Velleman & Hoaglin, 1981, p. 42). This formula was selected instead of the semi-logarithmic method, described by Hesse et al. (1984), for ease of computation and to avoid the possible artificial introduction of variability in long latencies. The possible artificial variability is a function of extrapolating the median for long latencies from large unit frequency bins instead of between actual latencies.

Terminal links in which the subject failed to key peck, at least once, within the 20 s limited hold were eliminated from the computation of median latency but were counted as abort trials. Terminal link data recorded also included the "running rate" (Doughery & Peckins, 1973, p. 112) that is the response rate following the first response, sequential response latencies, and for the Ratio Delay subjects, the mean delay interval generated by the FR's. Initial link data included the mean initial link intervals, and number of key pecks.

The delay-reduction hypothesis as expressed in Formula 1 is applicable to initial link response rates for concurrent chain procedures. Since this study involved multiple chain schedules and the dependent variable was latency, slight modifications of Formula 1 are in order.

The dependent measure of response rate is composed of response units (e.g., number) divided by time units (e.g., minutes). Similarly, the dependent measure latency is composed of time units (e.g., seconds) divided by response units (i.e., one response); that is, the reciprocal of response rate. The first modification is to simply replace response rate, in Formula 1, with reciprocal latencies.

Secondly, Formula 1 describes concurrent chain procedures and must be modified to describe this study's multiple chain procedure. Instead of identifying the average terminal link delay as left and right (i.e., t_{2L} and t_{2R}) these values are described as the longer and shorter terminal link delay as illustrated in Formula 2.

$$\frac{1/L_S}{1/L_S+1/L_L} = \frac{T-t_{2S}}{(T-t_{2S})+(T-t_{2L})} \tag{2}$$

Where $1/L_L$ and $1/L_S$ are reciprocal latencies to the terminal link stimulus with the longer delay (e.g., 5.5 s or FR 15) and the shorter delay (e.g., 1.5 s or FR 5), respectively. As in Formula 1 T represents the averaged delay to terminal link reinforcement from the onset of the initial links. The average time to terminal link reinforcement from the first response in the terminal links (i.e., latency) are t_{2L} and t_{2S}. That is, the average terminal link time was the time from onset of the terminal link stimulus minus latency, since latency was the dependent measure varying as a function of the reduction in delay to reinforcement. The reduction in delay to reinforcement correlated with the onset of the longer delay terminal link stimulus is represented by $(T-t_{2L})$.

Formula 2 may be re-expressed simplifying mathematical computions as in Formula 3.

$$\frac{L_L}{L_L+L_S} = \frac{T-t_{2S}}{(T-t_{2S})+(T-t_{2L})} \tag{3}$$

Where the resulting value to the left of the equality sign is the obtained proportional or relative latency in the terminal links (i.e., dependent variable). The resulting value to the right of the equality sign is the value predicted by proportional reduction in delay to reinforcement correlated with the onset of the terminal link stimuli (i.e., independent variable).

The data from the eighth session of each experimental phase were used to compute, by Formula 3, the relative separation between terminal link latencies or relative latency as a function of each initial link DRO durations. For the 5 s DRO initial links condition, the eighth session of the first occurrence of this phase was utilized (i.e., session 16).

Formula 2 may also be modified to permit the analysis of relative terminal link running rates. The modification simply entails replacing the reciprocal latencies with running rate as illustrated in Formula 4.

$$\frac{R_S}{R_S+R_L} = \frac{T-t_{2S}}{(T-t_{2S})+(T-t_{2L})} \qquad (4)$$

Where R_S and R_L represent the running rates for the shorter and longer delay terminal links, respectively.

A linear function, using a least squares fit, was computed to compare the fit between the obtained relative terminal link latency or relative terminal link running rate and the values predicted by the proportional reduction in delay to reinforcement. In addition the percentage of variance accounted for by each linear regression function, or coefficient of determination, was calculated. A slope of 1.0 with 100% of the variance accounted for would indicate perfect correspondence or matching between the obtained measure and that predicted.

RESULTS

Changes in DRO duration

Median response latencies to differential terminal link stimuli, for the Ratio and Time Delay groups, became increasingly similar with increasing DRO durations and increasingly dissimilar with decreasing DRO durations. That is, the separation between median latencies was attenuated with increasing DRO durations as reported by Michael et al. (1981) and Hesse et al. (1984).

Figure 3, presents terminal link median latencies for subject 1145 of the Ratio Delay group. During initial training in sessions

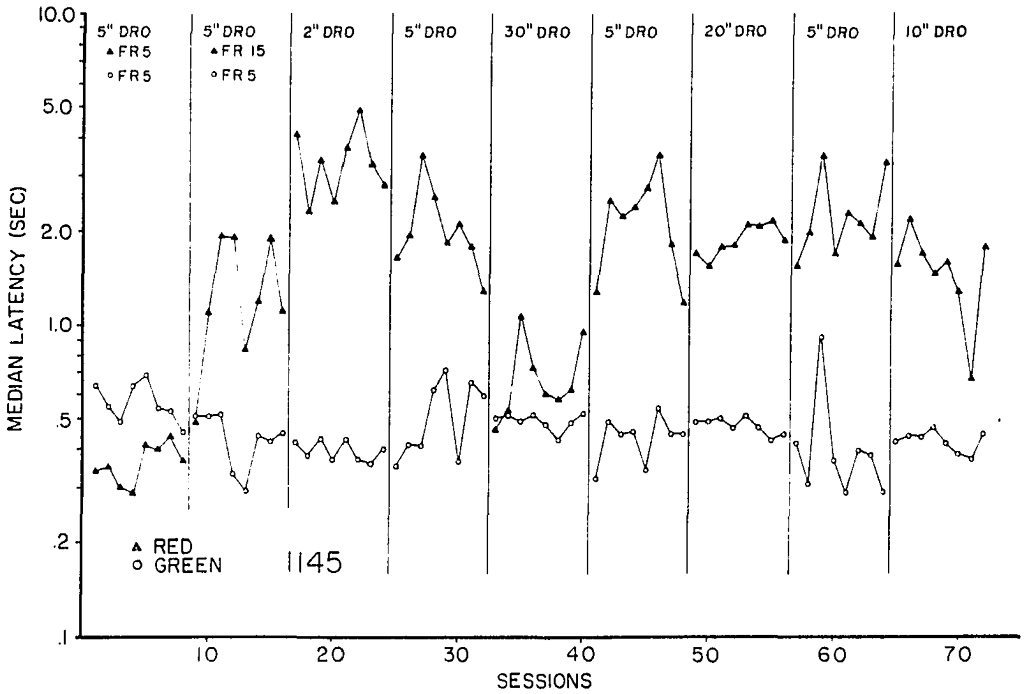

Figure 3. Median session latencies during all experimental conditions for subject 1145 of the Ratio Delay group.

1 through 8, with equal terminal link FR 5s and 5 s DRO initial links, shorter latencies consistently occurred in the presence of the red terminal link stimulus, indicating a bias for that stimulus. In sessions 9 through 16, with the increase to FR 15 in the red terminal link stimulus resulted in a decrease in latencies correlated with that stimulus. Correspondingly, latencies in the presence of the unchanged green terminal link stimulus decreased, indicative of behavioral contrast. Increasing DRO durations beyond the 5 s DRO baseline increasingly attenuated the separation between latencies. In contrast the 2 s DRO initial links resulted in an increase in the separation between the terminal link latencies.

Figure 4 presents terminal link median latencies for subject 9860, also of the Ratio Delay group. Equivalence training during sessions 1 through 8 resulted in equally short latencies to both terminal link stimuli. Interestingly in sessions 9 through 16, with the increase to FR 15 in the green terminal link stimulus, there was a corresponding increase in latency in the unchanged red terminal link stimulus, indicative not of behavioral contrast but "negative induction" (Schwartz & Gamzu, 1977, p. 73). The effects of varying DRO duration on the separation between terminal link latencies were consistent with those noted for subject 1145.

Terminal link median latencies for subject 5172 of the Ratio Delay group are presented in Figure 5. As with subject 9860, in session 1 through 8 during equivalence training, there was no indication of a bias for one of the two stimuli. In sessions 9 through 16, the increase to FR 15 in the red terminal link stimulus

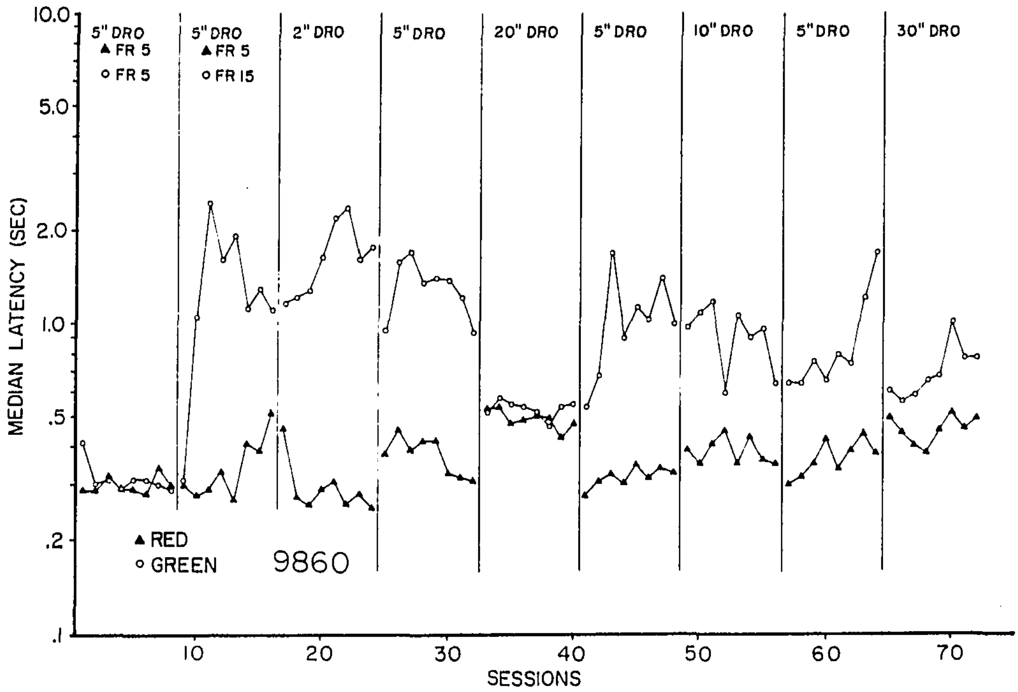

Figure 4. Median session latencies during all experimental conditions for subject 9860 of the Ratio Delay group.

generated a corresponding decrease in latencies to the unchanged green terminal link, indicative of contrast. Unlike subjects 1145 and 9860 baseline separations in latencies were not always recovered, as in the transition from the 20 s DRO initial links phase to the baseline condition in sessions 24 through 32.

Also, for subject 5172, the degree of separation between terminal link latencies was less than that observed for subjects 1145 and 9860 in Figures 3 and 4, respectively. Despite the failure to recover baseline separations following the 20 s DRO initial links phase and smaller separations across all conditions, relative to those obtained with the other Ratio Delay subjects, increasing

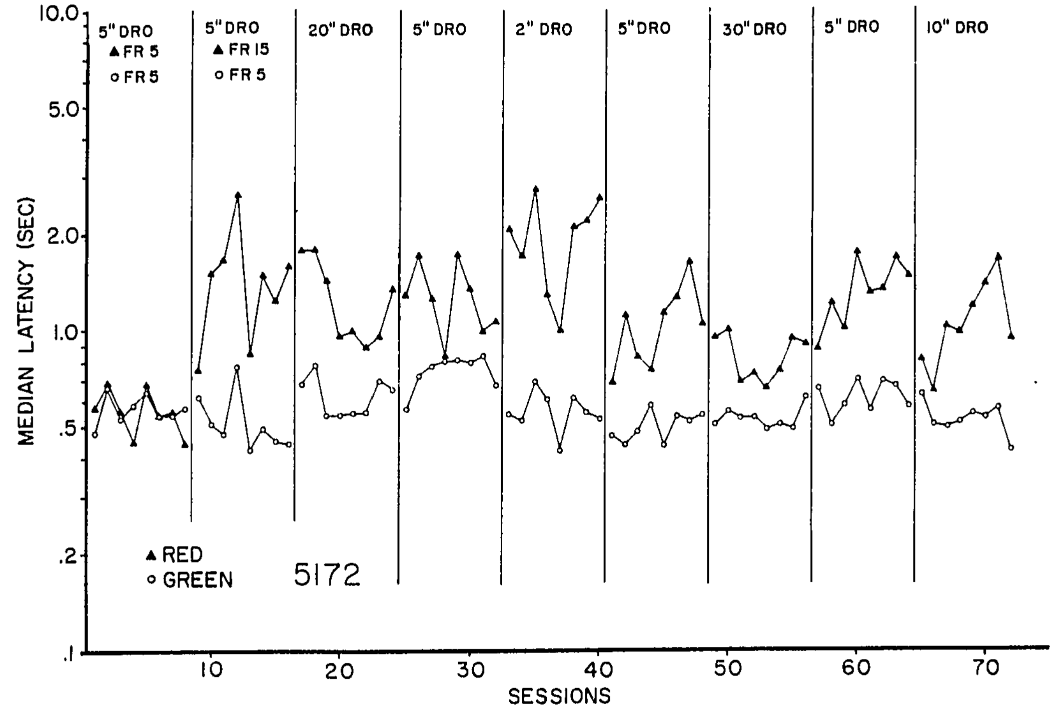

Figure 5. Median session latencies during all experimental conditions for subject 5172 of the Ratio Delay group.

DRO durations attenuated the separation between latencies. Conversely, the separation between latencies increased with a DRO duration shorter (i.e., 2 s DRO) than the baseline condition.

Figure 6, presents terminal link median latencies for subject 10780 of the Time Delay group. During equivalence training in sessions 1 through 8, with equal terminal link 1.5 s response-initiated delay intervals, short latencies consistently occurred in the presence of both terminal link stimuli. The increase to a 5.5 s delay interval in the green terminal link generated steadily increasing latencies in the presence of this stimulus as seen in sessions 9 through 16 and latencies in the

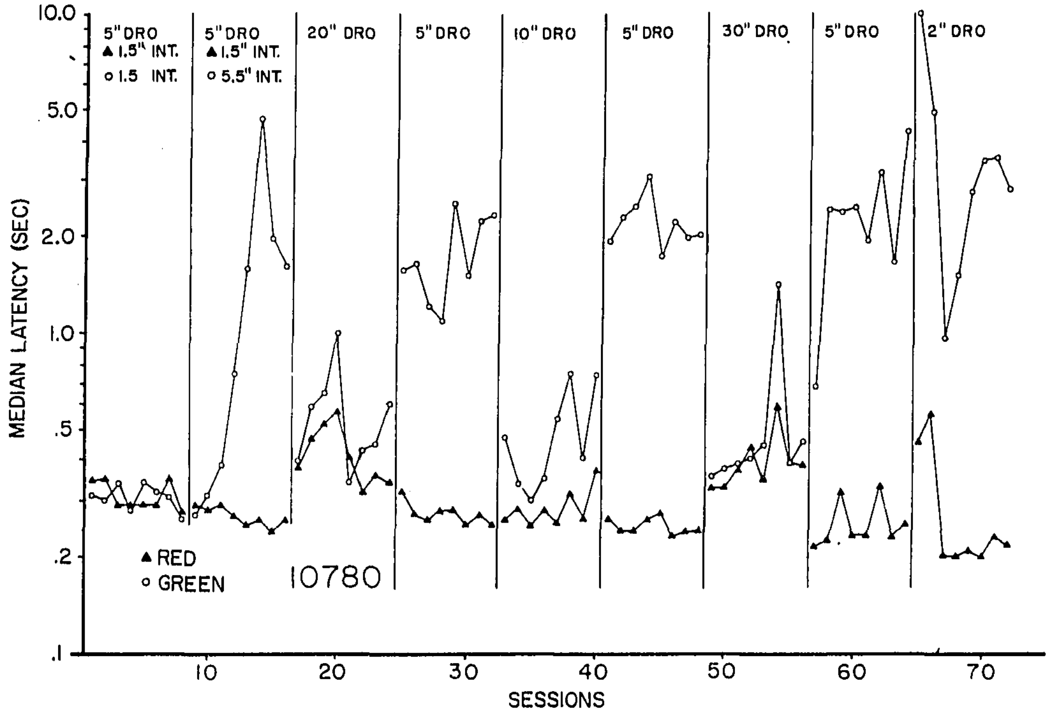

Figure 6. Median session latencies during all experimental conditions for subject 10780 of the Time Delay group.

unchanged red 1.5 s terminal link decreased, indicative of behavioral contrast. Consistent with the previously described results, increasing initial link DRO durations attenuated the separations between terminal link latencies. The introduction of the 2 s DRO initial links condition generated separations larger than those obtained in baseline conditions.

Terminal link median latencies for subject 3115, of the Time Delay group, are presented in Figure 7. Slightly shorter latencies occurred in the presence of the red terminal link stimulus during equivalence training, in sessions 1 through 8, indicating a bias for that stimulus. The increase to a 5.5 s delay interval in the

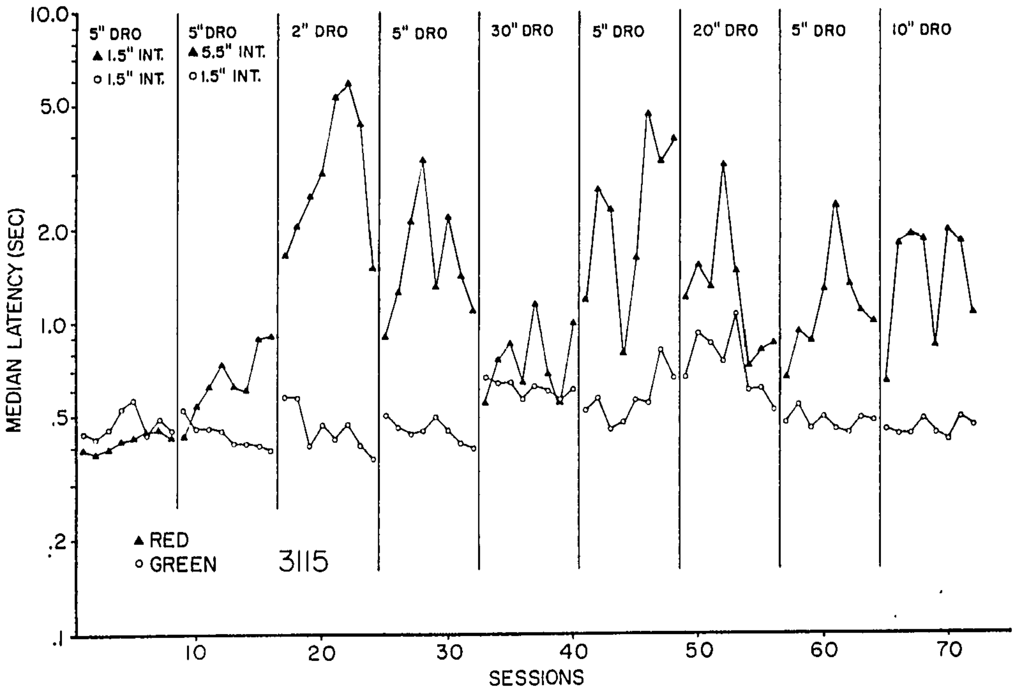

Figure 7. Median session latencies during all experimental conditions for subject 3115 of the Time Delay group.

preferred red terminal link stimulus generated an increase in latencies correlated with red and a slight decrease in latencies in the presence of the unchanged 1.5 s delay, green terminal link stimulus, again, indicative of behavioral contrast. The separations between terminal link latencies during baseline conditions varied greatly form one presentation to the next (i.e., sessions 9 through 16, 24 through 31, 40 through 47 and 56 through 63). Despite the variability in baseline separations between latencies, the separations between terminal link latencies were attenuated with increasing DRO durations. Similarly, larger separations between terminal link latencies were generated with 2 s DRO initial links.

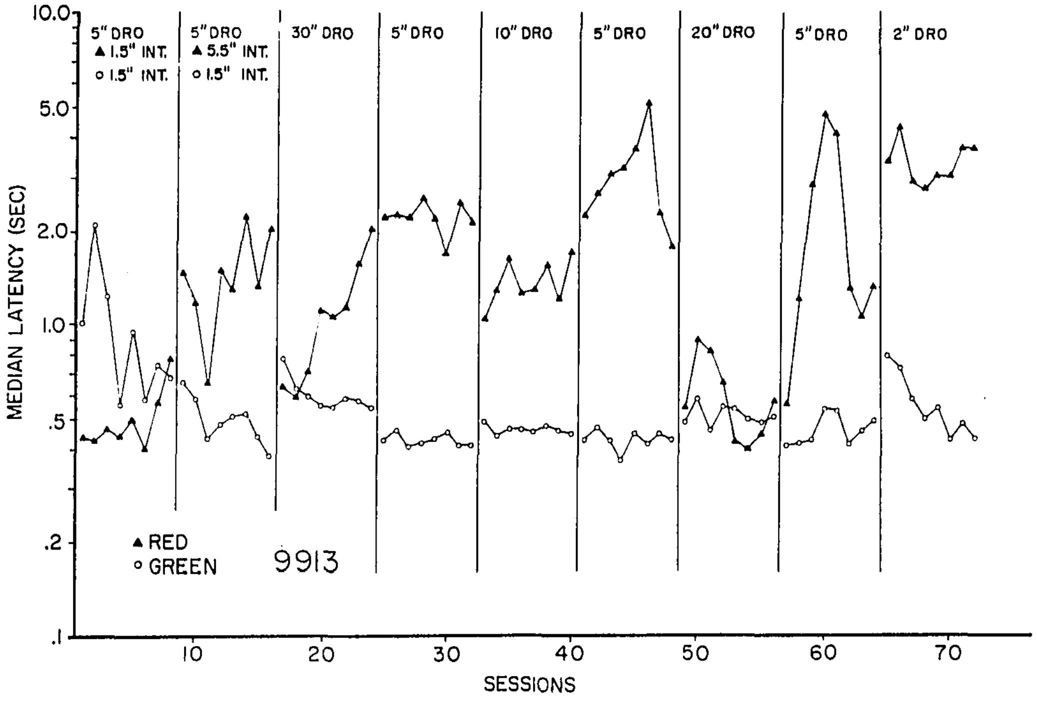

Figure 8. Median session latencies during all experimental conditions for subject 9913 of the Time Delay group.

Lastly, terminal link median latencies for subject 9913, of the Time Delay group, are presented in Figure 8. During sessions 1 through 8, shorter latencies typically occurred in the presence of the red terminal link stimulus. With the increase to a 5.5 s delay interval in the preferred red, terminal link latencies in that stimulus increased and latencies correlated with the unchanged green terminal link stimulus decreased, indicative of behavioral contrast. Manipulation of the initial link DRO duration had an effect consistent with the results reported for the preceding subjects.

Terminal Link Evocative Effectiveness

Though one of the objectives of this study was to replicate and extend the DRO-generated attenuation of separations between terminal link latencies as reported by Michael et al. (1981) and Hesse et al. (1984), the primary concern of this study was to provide an analysis of the DRO attenuation effect in terms of the delay-reduction hypothesis as described in Formula 3.

Figure 9 presents relative latency as a function of programmed DRO durations for subjects 1145, 9860 and 5172 of the Ratio Delay group. For subject 1145 the linear function, $\underline{Y} = .93\underline{X} + .05$, represents the fit between the obtained relative latencies and those values predicted by the proportional reduction in delay to reinforcement, and accounts for only 37% of the variance. In contrast the linear function, $\underline{Y} = 1.30\underline{X} - .22$, for subject 9860 accounts for 92% of the variance. Of particular note, is that the

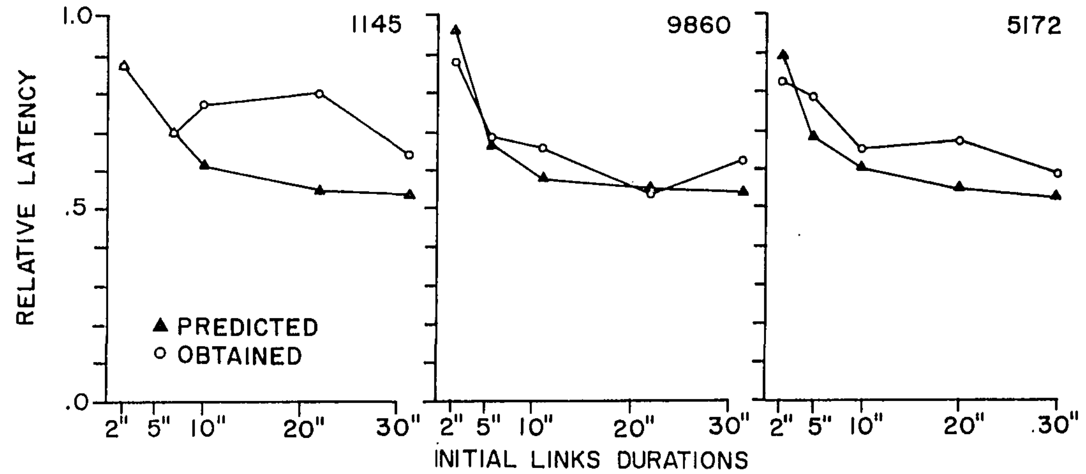

Figure 9. Relative terminal link latency as a function of initial link durations for subjects of the Ratio Delay group.

slope of subject 9860's linear function is greater than 1.00 which indicates over matching. Over matching is defined as a greater evocative effectiveness by the shorter delay terminal link than predicted by the proportional reduction in delay to reinforcement. The linear function, $\underline{Y} = .63\underline{X} + .29$, for subject 5172 accounts for 83% of the variance and with a slope of less than 1.0 indicates under matching. Under matching is less evocative effectiveness by the shorter delay terminal link than predicted by Formula 3.

Expressed in simple terms, for subjects 9860 and 5172, as initial link DRO durations increased the relative separation between terminal link latencies decreased in a manner predicted by Formula 3. For subject 1145 the obtained relative latency did not match the predicted proportional reduction in delay to reinforcement, particularly for 10 s, 20 s and 30 s DRO initial links; however, obtained values are well predicted for DRO durations of 2 s and 5 s.

Figure 10 presents relative latency as a function of programmed

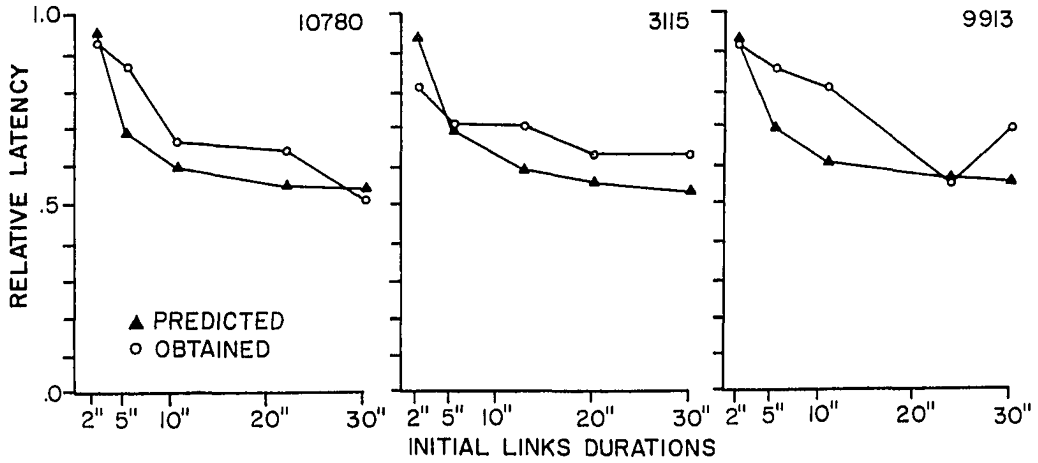

Figure 10. Relative terminal link latency as a function of initial link durations for subjects of the Time Delay group.

DRO durations for subjects 10780, 3115 and 9913 of the Time Delay group. For subject 10780 the linear function, $\underline{Y} = .84\underline{X} + .18$, represents the fit between the obtained relative latencies and those values predicted by the proportional reduction in delay to reinforcement and accounts for 76% of the variance. Similarly the linear function, $\underline{Y} = .42\underline{X} + .41$, for subject 3115 accounts for 88% of the variance. Of interest is the extremely shallow slope of subject 3115's linear function, indicative of under matching. The linear function, $\underline{Y} = .70\underline{X} + .29$, for subject 9113 accounts for only 62% of the variance.

Expressed simply, the obtained relative latency best matched the values predicted by the proportional reduction in delay to reinforcement for subjects 10780, and 3115. The obtained function, for subject 9113, also matched that predicted, but to a lesser extent, as evidenced by only 62% of the variance accounted for by the linear function. The obtained fuctions for all the subjects under matched the predicted values but most pronouncedly for subjects 3115 and 9113. Interestingly, the only initial link DRO value where under matching was not obtained for the three Time Delay subjects was the 2 sec DRO.

As a digression, the reader should note that the negatively decelerating functions of predicted values, in Figures 9 and 10, should be identical for all subjects (Fantino, 1977), but varies from subject to subject. The variation was a function of actual initial link durations exceeding those programmed as a result of key pecks resetting and therefore lengthening the DRO timer (see Figures

1 and 2).

A second implication of the delay-reduction hypothesis when applied to the evocative effectiveness of the terminal link stimuli is that the relative terminal link running rates should become increasingly similar with increasing initial link durations. Figure 11 presents the relative terminal link running rates for the Ratio Delay subjects 1145, 9860 and 5172. Formula 4 was used to compute the obtained relative terminal link running rates and the values predicted by the proportional reduction in delay to reinforcement.

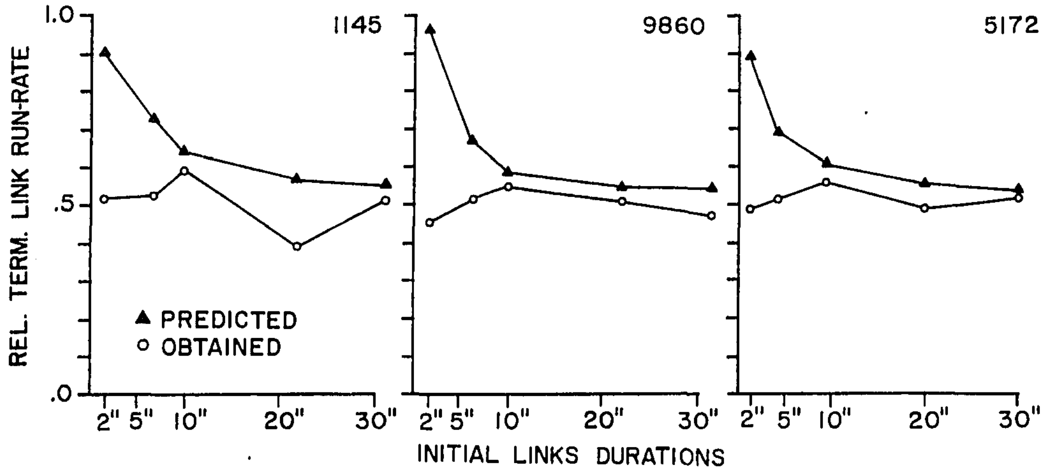

Figure 11. Relative terminal link running rate as a function of initial link durations for the subjects of the Ratio Delay group.

The obtained relative running rate does not vary as predicted by Formula 4 for the three subjects in the Ratio Delay group. No line of best fit were calculated since the data did not fit a linear model. For the three Ratio Delay subjects the relative running rate in the shorter delay terminal link was greatest for the 10 s DRO initial links. Additionally, relative running rates decreased with

DRO values moving away, in either direction, from the 10 s DRO initial links.

In contrast, in Figure 12 for subjects 3115 and 9913, of the Time Delay group, the obtained relative terminal link running rates matched the values predicted by Formula 4. For subject 3115 the

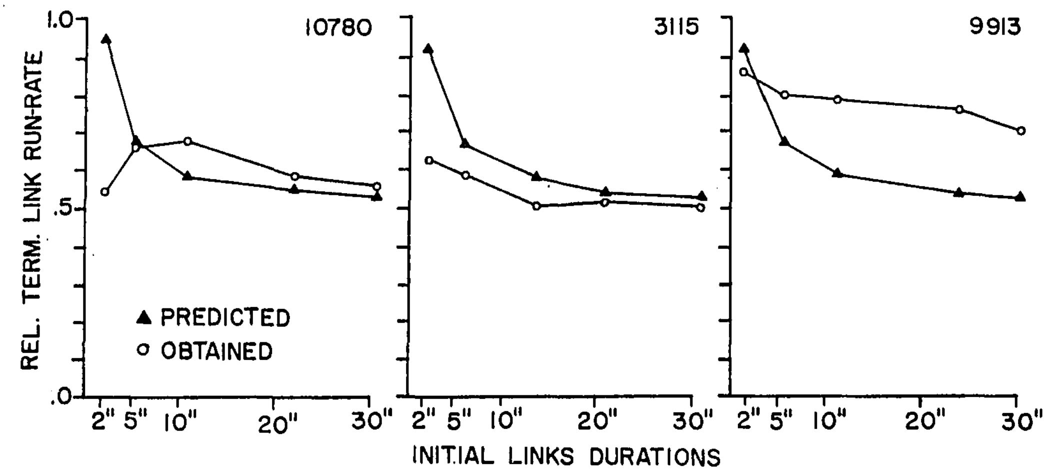

Figure 12. Relative terminal link running rate as a function of initial link durations for all the subjects of the Time Delay group.

linear function, $\underline{Y} = .35\underline{X} + .31$, represents the fit between the obtained relative terminal link running rate and the values predicted by the proportional reduction in delay to reinforcement, and accounts for 96% of the variance. Likewise the linear function, $\underline{Y} = .32\underline{X} + .57$, for subject 9913, accounts for 82% of the variance. For subject 10780 the linear function, $\underline{Y} = -.09\underline{X} + .67$, accounts for only .06% of the variance indicating little correspondence between the obtained and predicted values.

Terminal Link Reinforcing Effectiveness

The delay-reduction hypothesis when applied to the conditioned reinforcing effectiveness of the terminal link stimuli in this study would predict more DRO key pecks in the initial link preceding the longer terminal link delay. That is, the longer terminal link delay would function as weaker conditoned reinforcement, relative to the stimulus correlated with the shorter terminal link delay, and therefore generate weaker DRO performance and more initial link key pecks.

Table 2 presents the precentage of DRO key pecks in the initial link preceding the longer delay for the eighth session of each experimental condition listed in Table 1. For all subjects more DRO key pecks occurred in the initial link preceding the longer terminal link as predicted by the delay-reduction hypothesis.

Table 2

Percent Initial Link Key Pecks Preceding the Longer Delay

	Subjects					
	Ratio Delay			Time Delay		
	1145	9860	5172	10780	3115	9113
Percent Key Pecks	62%	54%	70%	68%	54%	100%

DISCUSSION

Delay-Reduction Analysis

In a general sense, the results of this study are consistent with past findings (Stebbins, Mead & Martin, 1959; Cross & Lane, 1962; Terrace, 1963; Heinz & Eckerman, 1974) which counter Skinner's (1961) conclusion that latency is not a dependent measure sensitive to changes in independent variables. Also the results are consistent with, and extend the DRO- or ITI-generated attenuation of separations between terminal link latencies, initially reported by Michael et al. (1981) and Hesse et al., (1984).

With respect to latency as a dependent measure one of the features which characterizes the data is the variability, particularly for longer latencies. Though steps were taken in this study to improve stablilty, the data in Figures 3 through 8 illustrate the high degree of variation, from session to session, in long latencies. In contrast, response rate has been found to be a dependent measure characterized by less session to session variation. A possible explanation of the difference in stability may be found in the number of instances each dependent measure is based upon. In the case of latency, using this study as an example, only 30 instances are sampled to determine the median latency for each terminal link stimulus. For running rate, however, hundreds of responses contribute to the determination of for each terminal link stimulus.

Perhaps the limited size of the distribution of latency values contributes to the variability of median latency in much the same way that sample size affects the degree of sampling error in inferential statistics. The reason long latencies may be particularly affected by this sampling error is because they are free to vary, while short latencies are limited by a floor effect; that is, the response of latency cannot be emitted faster than the physical limitation of the subject.

More importantly, the delay-reduction hypothesis of evocative effectiveness, as expressed in Formula 3, provides a plausible and adequate analysis of the DRO interaction with terminal link separations between latencies, with the notable exception of subject 1145's data, as seen in Figure 9. This conclusion is further strengthened by the observation that the analysis of terminal link separations between latencies held, whether the terminal link delays were programmed by FRs or by response-initiated delay intervals.

The adequacy of the delay-reduction hypothesis of evocative effectiveness is more complex when analyzing relative terminal link running rates. The delay-reduction hypothesis, as expressed in Formula 4, does account for the relative terminal link running rates for two of the three Time Delay subjects (i.e., 3115 and 9913), as seen in Figure 12. However, Formula 4 does not account for the relative terminal link running rates for the three subjects of the Ratio Delay group, as seen in Figure 11. Perhaps some aspect of FR schedules may account for the discrepancies between the predicted and obtained relative terminal link running rates, since the only difference between the Ratio and Time Delay procedures was that in the former FRs were scheduled as terminal links.

Ferster and Skinner (1957) experimentally illustrated that the difference in ratio and interval schedule response rates could be explained by the differential reinforcement of interresponse times (IRTs). In FR schedules, with the presentation of reinforcement more likely to occur during a burst of responding, shorter IRTs tend to be differentially reinforced generating a higher response rate than observed in interval schedules. Perhaps in this study, the larger terminal link FR (i.e., FR 15) affords a greater opportunity for reinforcement to be delivered during a burst of responding, relative to the smaller terminal link FR (i.e., FR 5); thereby, resulting in the differential reinforcement of shorter IRTs in the larger FR and generating such high running rates that differences between the two terminal link FRs are obscured.

Another possible explanation may be found in the data selection criterion used in this study. That is, only the eighth session of each experimental condition was used in the analysis of relative terminal links running rates, posing the possibility that the data selected are not representative. Such an explanation is unlikely given the adequate delay-reduction predictions of the latency data obtained from the same sessions. Secondly, the relative terminal link running rate as a function of various initial link durations in Figure 11 are orderly, although not in the manner predicted by Formula 4. Specifically, the largest relative running rate, for the shorter terminal link delay, occurred with 10 s DRO initial links and decreased with increasingly dissimilar initial link durations. The variables and conditions which may explain this performance are unclear and an issue for future experimental analysis.

Despite the failure to account for the relative terminal link running rate for the Ratio Delay subjects, the plausibility of the delay-reduction hypothesis, as a general analysis, is further supported when applied to the conditioned reinforcing effectiveness of the terminal links. The data in Table 3 indicate that more key pecks occurred in initial links preceding the longer delay terminal link than in the initial links preceding the shorter delay terminal link. These findings indicate that the longer delay terminal link functions as weaker conditioned reinforcement, relative to the shorter delay terminal link, and therefore maintains weaker DRO performance as predicted by the delay-reduction hypothesis of condition reinforcement.

In summary, the delay-reduction hypothesis of conditioned reinforcement and evocative effectiveness provides a plausible and adequate analysis of this study's heterogeneous-chain multiple schedule procedure, with the notable exception of relative terminal link running rates for the Ratio Delay group. An implication of this conclusion, other than providing one possible explanation of the phenomenon initially noted by Michael et al. (1981) and Hesse et al., (1984), is the proposition that many discrete trial procedures are best described in the terminology of free operant schedules.

Discrete Trial and Free Operant procedures

Skinner (1961) in arguing for response rate and against latency as "the basic datum of learning" (p. 42) suggested that with the typical runway discrete trial procedure the opening of the runway door does not constitute a stimulus change controlling behavior, but a change in the situation permitting the occurrence of the response of interest. This "physically disabling a response" (Logan & Ferraro, 1970, p. 111) is contrasted with a free operant procedure where a "response may be emitted in the absence of what is regarded as a relevant stimulus" (Skinner, 1961, p. 43). While these observations are central to the differentiation of free operant and discrete trial procedures, they are not consistently applied in the description of experimental procedures.

The use of state notation (Snapper et al., 1982) to diagrammatically represent experimental control procedures may eliminate the erroneous identification of procedures as discrete trial procedures. This study's experimental procedure, though described by Michael et al. (1981) and Hesse et al., (1984) as a discrete trial procedure, when expressed in state notation in Figures 1 and 2, premits a description in free operant terminology.

This error in identification is perhaps a function of specifying a re-occurring period where the primary experimental response form (e.g., key pecking) is not to occur. But the fact that the primary experimental response form does not occur during certain defined periods, does not justify identifying the experiment as a discrete trial procedure. If the primary experimental response form does not occur because it is physically impossible then the use of the discrete trial description is appropriate. If, however, the primary experimental response form does not occur as a function of a schedule of reinforcement (e.g., DRO), then the free operant description is appropriate.

Correctly identifying the experimental procedure as free operant or discrete trial is important "and indeed failure to do so could be misleading because the procedures are not equivalent" (Logan & Ferraro, 1970, p. 111). Perhaps by expressing experimental procedures in terms of state notations (Snapper et al., 1982) the distinction between discrete trial and operant procedures may be revealed. Correct identification of a procedure may clarify the operant principles involved in a given experimental procedure.

Behavioral Contrast and the Delay-Reduction Hypothesis

With respect to latency, positive behavioral contrast is the shortening of latencies to a stimulus with an unchanged schedule as a function of a change in the schedule of reinforcement (i.e., decrease in the rate of reinforcement) correlated with the other stimulus of a multiple schedule. Positive contrast, with latency as the dependent measure, has been reported by Schuster (1959) and Terrace (1963). Other latency studies (Moody, Stebbins & Iglauer, 1971; Mackintosh, 1974) have reported failures to obtain results indicative of positive contrast. These failures may be a function of the floor effect, previously described, associated with short latencies. Possibly the short latencies could not get shorter, because of the physical limitations of the subject, obscuring the contrast effect.

However in this study, one of the effects of increasing the delay to reinforcement in one terminal link, either by the change to FR 15 or 5.5 s delay interval in sessions 9 through 16, was the decrease in latencies correlated with the unchanged terminal link stimulus. That is, clearly with four out of six subjects (i.e., 5172, 10780, 3115 and 9913), and arguably with a fifth (i.e., 1145), positive behavioral contrast was observed (see Figures 3 through 9). Indeed, the separation between terminal link latencies is perhaps more accurately described as the contrast between terminal link latencies. If the separation between terminal link latencies is a contrast effect and varies as a function of initial link durations, then perhaps the delay-reduction hypothesis of evocative effectiveness may provide an analysis of behavioral contrast.

With two-component multiple schedules, typically used in studies of contrast, positive contrast is observed with the decrease in the rate of reinforcement correlated with one of the components of the schedule. The decrease in reinforcement rate is equally well described as an increase in the delay to reinforcement. With an increase in the delay to reinforcement the delay-reduction hypothesis would predict an increase in the relative evocative effectiveness of the stimulus correlated with the unchanged component. Specifically, the unchanged component stimulus would be correlated with a reduction in the average delay to reinforcement. Formula 5 formally describes this relation.

$$\frac{R_U}{R_U+R_C} = \frac{tC/T}{(t_C/T)+(t_U/T)} \qquad (5)$$

Where R_U and R_C are the response rates in the unchanged and changed components of the multiple schedule, respectively. The average time to reinforcement from the onset of the components (i.e., termination of reinforcement) is T. The time or averge delay to reinforcement for the changed and unchanged components are t_C and t_U, respectively. The reduction in the average delay to reinforecment for the changed component is represented by t_C/T.

Formula 5 predicts with increased delays to reinforcement in the changed component the response rate in the unchanged component would correspondingly increase. This admittedly simplistic treatment of behavioral contrast, as described in Formula 5, though limited to positive contrast, and delays of a finite nature (i.e., not extinction), does serve to illustrate the potential application of the delay-reduction hypothesis to the phenomenon of behavioral contrast typically observed in two component multiple schedules.

Future Research and Summary

Future research efforts should not only replicate the finding of this study but attempt to extend the delay-reduction hypothesis of evocative effectiveness, with latency as a dependent measure. Concurrent-chain choice procedures may provide an interesting extended evalution of the delay-reduction hypothesis of evocative effectiveness. This may be done by using three response keys, with the two side keys as initial link choice keys and the center key as a common terminal link key; response latency to the center key could be a dependent variable. Similarly, the evaluation of behavioral contrast as predicted by Formula 5 would extend the generality of the delay-reduction hypothesis of evocative effectiveness.

The puzzling order observed in relative terminal link running rates for the Ratio Delay subjects requires further experimental analysis. Lastly, a technical issue, yet unresolved, involves the increase in the variability associated with long latencies. Perhaps by reducing the limited hold period (see Figures 1 and 2) a ceiling may be created generating stable session to session latencies common with short latencies.

The results of this study replicated and extended the findings initially reported by Michael et al. (1981) and Hesse et al., (1984). Analysis of the results are consistent with the predictions of the delay reduction hypothesis of conditioned reinforcement (Fantino, 1977) and evocative effectiveness (Fantino, 1981) and the contention that the experimental procedures are best described in the terminology of free operant schedules. An implication of this conclusion is the speculation that the delay-reduction hypothesis of evocative effectiveness may provide a plausible explanation of behavioral contrast.

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