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THE EFFECTS OF REINFORCEMENT MAGNITUDE AND TEMPORAL
CONTINGENCIES ON PRE-RATIO PAUSE DURATION

by

Marilyn K. Bonem

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Psychology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1988

ACKNOWLEDGEMENTS

I wish to thank some of the many who contributed to this work. I thank the members of my dissertation committee: Grayson Osborne, whose demand for excellence and skills in editing are exceeded by none; Carl Cheney, who provided encouragement, support, consultation, and who served as a model scientist; Richard Powers, whose ability to analyze from many perspectives led to many relevant questions and constructive suggestions; and to Thomas Johnson, James Blair, and Joan Kleinke, who contributed careful editing and valuable suggestions. I especially thank my major professor, Edward Crossman, whose most valued contributions included patience, encouragement, expertise in experimental design and data analysis, and many long hours of critical discussion.

I am also grateful to my fellow graduate students for listening, suggesting, questioning, and supporting me. Thank-you especially to Adair McPherson, Nancy Trapp, Linda Barnard, Pat Ghezzi, Mike DeWulf, and Michael Gatch. I am also grateful to Renee Magana and Sharon Lawrehr for their assistance. I also wish to acknowledge the encouragement and support of my parents, parents-in-law, and Phyllis Cole. I thank my children, Megan and Garrett, for providing distractive relief.

It would seem trivial to list the numerous contributions given graciously by my husband and colleague, Elliott. It will suffice to say that the dissertation truly could not have been accomplished without his love and support. The satisfaction of the accomplishment could never have been so meaningful without him to share it with.

Marilyn Bonem

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ABSTRACT

The Effects of Reinforcement Magnitude and Temporal
Contingencies on Pre-Ratio Pause Duration

by

Marilyn K. Bonem, Doctor of Philosophy

Utah State University, 1988

Major Professor: Edward K. Crossman
Department: Psychology

The present study was conducted to determine whether conjugate magnitude and temporal contingencies were effective in increasing the pre-ratio pause (PRP) duration and to determine the controlling variables that govern such contingencies. It has been reported in the literature that magnitude of reinforcement, if presented contingently, is effective in controlling performance and that inserting intervals of blackout (BO), during which responding does not lead to reinforcement, virtually always leads to control of responding, even though it has not been presented contingently. The conjugate schedules experimentally arranged reinforcement such that the longer the PRP, the longer was the duration of access to reinforcement and/or the shorter was the BO, located either after reinforcement or after the response.

The results of this study demonstrated that the major independent variable which controlled mean PRP duration on the various conjugate reinforcement schedules studied was the delay between the response and reinforcement. The duration of the PRP was not reliably controlled by a contingency which equated PRP duration with reinforcement duration, nor by a contingency which, through imposition of a delay to trial onset, held the local delay to reinforcement constant. Additionally, cycle-to-cycle variation in reinforcement magnitude, whether presented contingently or noncontingently on PRP duration, had no reliable effect on PRP duration when compared to FR 1. The primary effect of variation in the duration of reinforcement was to reduce the variability, not the duration, of the PRP.

The results of the study are briefly discussed in terms of a number of theories. These include: the maximization account (Logan, 1960); the matching law (Herrnstein, 1970); Harzem and Harzem's (1981) theory describing the unconditioned inhibitory stimulus function of reinforcement; behavioral contrast (Reynolds, 1961); and Dews' (1981) account of the importance of a response-reinforcer contiguity relation.

STATEMENT OF THE PROBLEM

The purpose of the current section is to provide a definitional overview of the experimental literature as it relates to the dependent and independent variables investigated in the current study. The primary independent variables of interest are conjugate magnitude and delay of reinforcement. The current state of the literature regarding these variables is discussed, in detail, within the literature review section that follows.

Dependent Measures on Ratio Schedules

A fixed-ratio (FR) schedule specifies that a set, predetermined number of responses be emitted in order to produce reinforcement. The typical performance generated by an FR schedule consists of a pause interval of no responding, typically termed the post-reinforcement or pre-ratio pause (PRP), followed by a steady burst of high-rate responding until the completion of the ratio (Ferster & Skinner, 1957). The use of the term, pre-ratio pause, refers to the observation that the primary determinant of PRP duration is the size of the upcoming ratio (Findley, 1962; Griffiths & Thompson, 1973).

Magnitude of Reinforcement

As an independent variable, magnitude of reinforcement has been used to refer either to the volume of reinforcement

(e.g., Keesey & Kling, 1961), the percentage concentration of a reinforcing substance (e.g., Guttman, 1953), or the duration of access to reinforcement (Catania, 1963). Catania (1979) has designated that delay, magnitude, and frequency constitute the major parameters of reinforcement and that, theoretically, changes in any one of these should produce changes in performance. That changes in the magnitude of reinforcement do not always produce changes in responding, particularly on simple schedules of reinforcement (Catania, 1963; Jenkins & Clayton, 1949; Keesey & Kling, 1961) suggests that the magnitude of reinforcement parameter is limited by factors which heretofore have not been fully investigated. When examining PRP durations on FR schedules, the effects of reinforcement magnitude appear to be quite inconsistent: two studies have reported increases in PRP duration as reinforcement magnitude was increased (Lowe, Davey, & Harzem, 1974; Stebbins, 1962) and two have demonstrated a decrease in PRP duration (Meunier & Starratt, 1979; Powell, 1969).

Magnitude of reinforcement on concurrent schedules. On a concurrent schedule, two or more, simultaneously available response alternatives are independently reinforced on the basis of the response requirements specified by each independent reinforcement schedule. In consideration of the fact that concurrent schedule manipulations of reinforcement magnitude have consistently produced effects on choice

measures (e.g., Catania, 1963; Dunn, 1982; Neuringer, 1967; Schneider, 1973), Neuringer (1967) proposed that perhaps the sufficient, though not necessary, condition for producing magnitude of reinforcement effects is the response-contingent presentation of different magnitudes. That is, a procedure is established such that some aspect of responding determines which of two or more reinforcement magnitudes will be obtained. For example, on concurrent schedules, the level of reinforcement magnitude obtained is determined by which manipulandum the animal responds on.

The generalized matching law has been useful in predicting relative responding (e.g., rate, time allocation) on concurrently available schedules of reinforcement based on the events programmed on those two schedules. However, the generalized matching law has been of limited value in predicting magnitude of reinforcement effects, because overmatching, or the tendency to favor the greater reinforcement magnitude, frequently occurs (Dunn, 1982). Further, the generalized matching law may be even more limited in predicting the effects of reinforcement magnitude as it interacts with ratio size on concurrent FR schedules, because it has been demonstrated that animals exhibit exclusive preference in favor of the smaller ratio (Herrnstein & Loveland, 1975). A maximization account predicts performance on concurrent and other schedules based on the tendency of subjects to perform in a way which

optimizes the scheduled reinforcers. This theory is also inadequate in predicting concurrent performance because it has been shown that frequency of reinforcement is a more powerful variable than reinforcement magnitude, even at the expense of a decreased level of net reinforcement (Young, 1981).

Correlated schedules. Another paradigm which has been employed in studying the response-contingent effects of reinforcement magnitude is termed, correlated reinforcement. As used in the literature, this term refers to the contingent presentation of different levels of reinforcement (e.g., rate, magnitude, delay) that are experimentally correlated with some quantitative dimension of the response (e.g., rate, pause duration). For example, it has been shown that when the magnitude of reinforcement is contingent upon the speed of runway completion (Brown & Horsfall, 1965; Logan, 1960), the rate of key pecking (Gentry & Eskew, 1984) or the duration of interresponse times (IRTs) on fixed-interval (FI) schedules (Hendry, 1962), these dependent measures are affected. However, a study correlating terminal interresponse times (IRTs) with reinforcement magnitudes on FR schedules failed to produce effects (Hendry & Van-Toller, 1964), presumably because reinforcement magnitude and interreinforcement interval (IRI) were confounded. Studies correlating frequency of reinforcement with responding have also been effective (Baum, 1973).

However, studies of the effects of correlated delay are rare and have only been examined in runways (Logan, 1960). There have been no correlated delay studies which isolated the effects of delay and IRI. There is also no evidence to suggest that the parameters of reinforcement can be effectively correlated with measures of latency, such as PRP duration. Thus, while correlated procedures represent a potentially rich paradigm for the study of magnitude, delay and frequency of reinforcement, investigations in these areas have been limited.

Conjugate schedules of reinforcement. A conjugate schedule of reinforcement is a procedure which is similar to correlated reinforcement, but further specifies that reinforcement and response parameters be correlated along continuous rather than discrete linear dimensions. For example, Lindsley (1957, 1962, 1963) demonstrated the effectiveness of conjugate reinforcement schedules, via an arrangement whereby the rate of responding determined the quality of such conditioned reinforcers as the degree of focus by a film projector. In Lindsley's (1957) procedure the film focus was continually subject to change depending on the immediately preceding response. During periods of nonresponding, the film gradually became blurry. Each response improved the focus slightly. Lindsley (1963) claimed that such a contingency would be sensitive to minute changes along the response dimension; however, the

generalizability of Lindsley's (1957, 1962, 1963) effects is limited to human subjects and variations in the parameters of conditioned reinforcement. On the other hand, correlated reinforcement magnitude procedures entail a more discrete relation between the response dimension and the reinforcer dimension. For example, the Hendry and Van-Toller (1964) procedure, described earlier, established a response-reinforcer correlation by stipulating that a small or large reinforcer would be delivered depending on whether the final IRT in an FR ratio was shorter or longer than a criterion, respectively. In summary, correlated and conjugate procedures have been useful in demonstrating reinforcement magnitude effects. However, the research conducted, thus far, has been limited to response rate, runway speed, and IRT measures of performance.

Temporal Variables

Despite the fact that the contingency in an FR schedule does not stipulate a temporal requirement, it has been demonstrated that temporal factors can substantially affect PRP durations. It has been shown consistently that PRP duration increases with increases in the length of an imposed delay interval, which correlates with the interreinforcement interval (IRI) (Barowsky & Mintz, 1975; Meunier & Ryman, 1974; Morgan, 1972; Neuringer & Schneider, 1968; Topping, Johnson, & McGlynn, 1973). This

susceptibility of PRP duration to increases in the IRI is difficult to interpret because the very existence of a PRP on an FR schedule lengthens the IRI, thereby reducing the maximum rate of reinforcement. The existence of a PRP on FR 1 is even more difficult to explain in terms of the principles of behavior. For instance, reinforcer delivery does not function as a discriminative stimulus signaling that the next response is not likely to be reinforced, as in all other FR schedules. Neither does the reinforcer signal a large upcoming ratio because only one response is required. For these reasons, it appears as though a thorough examination of the effects of various schedule parameters on FR 1 PRPs might improve our understanding of the factors that control this pause as well as comparable pauses on other FR schedules.

Delay and interreinforcement interval. One area of investigation which has not been examined concerns the experimental separation of delay and IRI effects as they affect PRP durations. The studies cited in the previous paragraph all manipulated delay in conjunction with IRI, making it impossible to determine whether increases in delay, increases in IRI, or both contributed to increases in mean PRP. There is some evidence to suggest that delay and IRI differentially affect PRP duration. For instance, Dews (1981) demonstrated that post-response delay (an imposed delay interval between the final response and reinforcement)

and interresponse delay (an imposed delay interval which also lengthens IRI but occurs at some point before the final required response) have different effects on response rate. The isolation of these temporal variables may also have theoretical significance, particularly with respect to the molar vs. molecular controversy. A molar theory attempts to interpret behavioral effects in terms of events operating within an overall context of other events, as compared to a molecular emphasis on the specific location and sequence of events (Baum, 1973). Thus, a molar theory predicts that any decrease in rate of reinforcement will decrease the strength of the response (e.g., seen as an increase in mean PRP duration), regardless of the temporal position of the imposed delay. Therefore, interresponse reinforcement delay or post-response reinforcement delay would equally affect PRP duration. In contrast, a molecular theory would predict that a post-response delay would be a more powerful (or perhaps the only) determinant of response strength because such a delay decreases response-reinforcer contiguity.

The following review describes much of the literature related to the study of magnitude and delay of reinforcement. The purpose, methodology, results and discussion of the research are then presented.

LITERATURE REVIEW

Magnitude of Reinforcement

One independent variable that presumably modulates the effects of reinforcement on behavior is the magnitude of reinforcement. The term, magnitude of reinforcement, as variously used in the literature, refers either to the amount (volume) of reinforcement, such as the number of pellets (Keesey & Kling, 1961; Leventhal, Morrell, Morgan, & Perkins, 1959; Logan, 1960; Young, 1981); the percentage concentration of a reinforcing substance (Guttman, 1953; Lowe et al., 1974; Meunier & Starratt, 1979; Priddle-Higson, Lowe, & Harzem, 1976; Stebbins, 1962; Stebbins, Mead, & Martin, 1959); or to the duration of access to reinforcement (Catania, 1963; Dunn, 1982; Gentry & Eskew, 1984; Neuringer, 1967; Picker & Poling, 1982; Powell, 1969; Shettleworth & Nevin, 1965; Todorov, 1973). These operational definitions of reinforcement magnitude are assumed to be functionally synonymous; but, an empirical test of this assumption is lacking. Manipulation of these variables sometimes affects behavior in a similar manner. For example, changes in volume (Young, 1981), duration (Powell, 1969) and concentration (Meunier & Starratt, 1979) of reinforcement have all, in some instances, been shown to be inversely related to post-reinforcement pause (PRP) duration.

Although the various methods of programming reinforcement magnitude may function similarly under some conditions, there are other factors to be considered when determining whether these methods, are in fact, equivalent. One such factor involves the relative ineffectiveness of reinforcement magnitude contingencies in affecting behavior. Some authors have made the general statement that magnitude is simply not an effective variable, stating that studies that demonstrate its effectiveness are the exception rather than the rule (Gentry & Eskew, 1984; Morse, 1966). Mowrer (1960, p. 387) concluded, "that a small reward or small punishment works just as well as larger reinforcements". Other researchers argue that the presence or absence of a reinforcement magnitude effect relates to specific procedural variables, such as the dependent variable measured (Catania, 1963; Keesey & Kling, 1961; Neuringer, 1967; Powell, 1969); whether choice procedures involve reinforcement delay as well as magnitude (Ainslie, 1974; Green & Snyderman, 1980; Rachlin & Green, 1972); whether choice procedures control for frequency of reinforcement while manipulating reinforcement magnitude (Fantino, Squires, Delbruck, & Peterson, 1972; Schneider, 1973; Walker, Schnelle & Hurwitz, 1970); and whether magnitude of reinforcement changes are programmed within or between sessions (Gentry & Eskew, 1984; Meunier & Starratt, 1979; Staddon, 1970).

Whichever statement is more accurate concerning the effectiveness of reinforcement magnitude, it is clear that the procedural variables mentioned above may be manipulated to change its effectiveness. Yet, a thorough literature search reveals no systematic study comparing the functional effects of duration, volume, and concentration methods of programming magnitude of reinforcement within the same study. In addition, none of the studies cited above investigated how the method of programming reinforcement magnitude might interact with the independent and dependent variables examined. One study (Epstein, 1981) conducted with pigeons on an FI schedule, suggests that although there is a positive correlation between the volume of grain consumed and the reinforcement duration (when the duration of access to the food-hopper is set at a specific duration between 1 and 16 s), this function is not linear. Instead, the volume of grain consumption is described as an ascending, negatively-accelerated function of reinforcement duration (Epstein, 1981). Thus, it may be difficult and inappropriate to compare the effects produced by particular volumes of reinforcement to the effects produced by specific durations of reinforcement.

Another consideration to be made when determining whether to program duration, volume or concentration changes in magnitude is a methodological one. Each programming method involves unique methodological difficulties that may

complicate interpretation of results. For instance, when varying duration of reinforcement, not only is reinforcement magnitude changed, so are the temporal relations between events, thus introducing a possible confound. Gauging the effects of changes in reinforcement volume may require the determination of whether a subject consumes all the pellets delivered, allowance of enough time between trials for each animal to consume all pellets delivered, or the ensurance that pellets remain a uniform size as they pass through the pellet dispenser. Changes in the concentration of a reinforcer (usually liquid) are easier to control, but such changes may be more accurately classified as changes in the quality rather than a quantity of the reinforcer. As such, concentration changes may be functionally quite different from changes in the magnitude of reinforcement.

Unfortunately, with the paucity of data concerning these issues, programming of magnitude changes may often be determined by convenience in instrumentation. Because duration of reinforcement may currently be the most commonly used programming method, using the duration procedure may be the most valuable at this time for researchers primarily interested in being able to compare data between studies.

Factors Influencing Reinforcement Magnitude Effects

Changes in stimulus conditions. According to Gentry and Eskew (1984) one factor that enhances the effects of

changes in reinforcement magnitude is the provision of differing stimulus conditions associated with different reinforcement magnitudes. One group of studies that reported reinforcement magnitude to be effective was the concurrent-schedule group (Catania, 1963; Dunn, 1982; Fantino et al., 1972; Neuringer, 1967; Picker & Poling, 1982; Schneider, 1973; Walker et al., 1970). These studies each found that when two different reinforcement magnitudes were simultaneously available, other factors being equal, subjects would respond on the component that provided the largest reinforcer. For example, the Catania (1963) study presented a two-key concurrent schedule with equal fixed-interval (FI) 2 minute schedules, simultaneously available on separate keys. Keypecks to each key produced different reinforcement durations of either 3.0, 4.5, or 6 s. Response rates increased with increased reinforcement duration. The results from the Catania study have led some researchers (Catania, 1963; Nevin, 1965) to hypothesize that it is essential to provide a different stimulus for each level of reinforcement magnitude presented to obtain an effect. The logic of this hypothesis is strengthened by the fact that simple schedules similar to the concurrent components except that they occurred in the context of only one stimulus situation -- at times, failed to produce magnitude effects (Catania, 1963; Keeseey & Kling, 1961). Similarly, it has been demonstrated that magnitude of

reinforcement also functions as a controlling variable in multiple schedules of reinforcement. Most of these studies simply demonstrated that response rate was elevated during the multiple schedule components that provided the largest reinforcer without showing the ineffectiveness of magnitude changes on behavior under simple schedule comparison conditions (Inman & Cheney, 1974; Jensen & Fallon, 1973; Merigan, Miller, & Gollub, 1975; Powell, 1969). Only two studies found manipulation of the magnitude of reinforcement variable to be both effective on multiple schedules and ineffective on simple schedules that were considered identical to the multiple-schedule components (Mariner & Thomas, 1969; Shettleworth & Nevin, 1965).

Magnitude of reinforcement studies that demonstrated effective control on concurrent or multiple schedules and ineffective control on comparable simple schedules (Catania, 1963; Mariner & Thomas, 1969; Shettleworth & Nevin, 1965) seemingly provide strong support for the importance of a stimulus-magnitude correlation. However, in these studies the simple schedules presented were not truly equal to the component schedules of the more complex arrangements. The simple schedules differed in that stimulus changes did not accompany reinforcement magnitude changes and particular reinforcement magnitude levels were presented for numerous sessions before magnitude changes occurred. In addition, concurrent schedules involve a magnitude of reinforcement

contingency (i.e., the subject's responses determine which reinforcement magnitude will be produced), whereas simple schedules do not. In this context it is important to note that the dependent measure of interest, to determine the effectiveness of magnitude of reinforcement on concurrent schedules, is choice responding. The typical dependent variable studied on concurrent schedules involves the determination of whether matching (relative responding on component schedules) is produced in proportion to the magnitude levels available on the component keys (e.g., Catania, 1963; Neuringer, 1967).

If joint stimulus-magnitude variation is an important variable, then it follows that there are several relevant issues related to the presentation of different magnitudes of reinforcement serving a discriminative stimulus function. As a stimulus, it has been maintained that a reinforcer can function as both a discriminative and a reinforcing stimulus (Harzem & Harzem, 1981). It has been demonstrated that established reinforcers can function as discriminative stimuli (Cruse, Vitulli, & Dertke, 1966; Harzem, Lowe, & Spencer, 1978). Yet, it is clear from the information reviewed thus far, that even when different reinforcement magnitudes are associated with different stimulus conditions there is not necessarily an effect. There is some indication in the literature that magnitude of reinforcement may be a more salient stimulus when the range of magnitudes

presented is large. For example, several studies which did not produce effects with reinforcement magnitude employed small ranges of magnitude, ranging in two studies from 0 to a maximum of 0.5 g of food pellets per reinforcement delivery (Leventhal et al., 1959; Young, 1981) and in another case from 1-4 seeds (Keesey & Kling, 1961). Several other studies that report reinforcement magnitude effects employed a relatively large differential between small and large reinforcement magnitudes, ranging from 0.18 to 1.35 g of pellets (Schneider, 1973), from 1.5 to 8 s access to grain (Brownstein, 1971; Catania, 1963; Fantino et al., 1972; Todorov, 1973) and from 30-100 percent milk concentration (Meunier & Starratt, 1979). There are, however, exceptions involving small ranges (Powell, 1969; Jensen & Fallon, 1973) and large ranges (Catania, 1963). It is also possible that by delivering different magnitudes of reinforcement in a response-contingent manner, as during a concurrent schedule procedure, magnitude of reinforcement may function more effectively as a discriminative stimulus (Gentry & Eskew, 1984), contributing to the demonstration of a reinforcement magnitude effect.

Alternating magnitude of reinforcement quantities within vs. between sessions. Meunier and Starratt (1979) stated that the effectiveness of reinforcement magnitude is determined, in part, by the method of programming changes in magnitude. According to Meunier and Starratt (1979), it may

be necessary to present only one level of magnitude for numerous sessions (between session changes), to obtain an effect. Several studies support this claim, in that reinforcement magnitude was varied within sessions, but response changes were not consistent with those presented elsewhere in the literature. For instance, Lowe et al., (1974) studied the effects of within-session changes in percentage sucrose solution on fixed-ratio (FR) post-reinforcement pause (PRP)s. As the concentration of sucrose increased, PRP durations preceding lever pressing increased. In studies that presented each level of magnitude until responding stabilized, the PRP was shown either to decrease when reinforcement magnitude was increased (Meunier & Starratt, 1979; Powell, 1969) or no effect on pausing was produced (Harzem, Lowe, & Davey, 1975; Hatten & Shull, 1983). Investigations involving within- and between-session magnitude changes on response rate have produced similarly mixed results. For example, Staddon (1970) demonstrated that within-session increases in the duration of reinforcement resulted in a decreased response rate. This inverse relation is the opposite of findings presented elsewhere in the literature (Guttman, 1953; Jensen & Fallon, 1973; Lendenman, Myers, & Fantino, 1982; Shettleworth & Nevin, 1965).

In an attempt to contrast the effects of between- and within-session changes of magnitude levels, Meunier and

Starratt (1979) replicated the Lowe et al. (1974) study, utilizing percentage concentration of a milk solution. However, concentration levels were manipulated between-, as opposed to within-sessions. The findings of this study were the opposite of the Lowe et al. (1974) study. That is, PRP duration and percentage concentration were inversely related. No definitive conclusions as to the source of these differences are possible because the two studies (Lowe et al., 1974; Meunier & Starratt, 1979) differed in other respects as well. For instance, different FR baselines were utilized, as well as different reinforcers. An additional difference is that Meunier and Starratt (1979) did not parametrically examine different numbers of sessions per condition at each level of reinforcement magnitude. That is, it was not determined whether it would be sufficient to present a particular magnitude for one session or 60 sessions in order to obtain an effect.

At least two sources of evidence suggest that between-session changes in reinforcement magnitude are not a necessary condition for the effectiveness of the magnitude of reinforcement variable. First, Powell (1969) found that duration of reinforcement on FR schedules produced an inverse effect on PRP duration, whether reinforcement duration changes were programmed within or between sessions. Second, several studies demonstrated the effectiveness of reinforcement magnitude on concurrent schedules (Catania,

1963; Dunn, 1982; Neuringer, 1967; Picker & Polling, 1982) and on multiple schedules (Guttman, 1953; Shettleworth & Nevin, 1965). These schedules would, necessarily, involve the presentation of different levels of magnitude within a session.

Concurrent schedules. Two models of choice applied to concurrent procedures that involve reinforcement magnitude are the maximization model and the generalized matching law. The maximization model was developed to account for the tendency of subjects in discrete-trial situations to respond exclusively with the alternative response that produces the highest probability of reinforcement (Rachlin, Green, Kagel, & Batalio, 1976; Shimp, 1966). In its simplest form, the maximization theory states that subjects respond in such a way as to obtain maximum reinforcement with minimum responding (Gentry & Eskew, 1984; Logan, 1960).

In concurrent schedules in which only magnitude of reinforcement differs between two components, predictions from the maximization model are straightforward: exclusive preference, or at least overmatching (the tendency to respond more frequently on one key than is predicted by the proportion of reinforcement programmed on that key), in favor of the larger magnitude component. In fact, the data support this prediction (Catania, 1963; Dunn, 1982; Fantino et al., 1972; Schneider, 1973; Walker et al., 1970). Although these studies are consistent with the maximization

theory, they do not provide data regarding more complex conditions that involve the manipulation of a number of independent variables. Under these conditions maximum reinforcement may not be preferred because of variables that override the tendency to maximize. For instance, in choice procedures that involve reinforcement magnitude, the maximization model predicts that the smaller reinforcement magnitude will be preferred if selection of this alternative results in an increase in the total amount of reinforcement presented within a session. Young (1981) employed this explanation to account for the results of choice studies in which magnitude of reinforcement was concluded to be relatively ineffective (e.g., Ainslie, 1974; Rachlin & Green, 1972); i.e., when subjects favored the smaller magnitude of reinforcement.

Another explanation, however, is equally plausible. In studies of choice behavior, the choice of the larger magnitude resulted in both decreased frequency and decreased net access to reinforcement. Therefore, it may be that subjects select for the smaller reinforcer, not because the net access to reinforcement is greater, but because frequency of reinforcement overrides the reinforcement magnitude variable. That is, subjects may prefer to be reinforced more frequently, even at the expense of a decrease in net reinforcement.

The maximization model also predicts that a relatively large reinforcer will be preferred in cases where the rate of reinforcement is lower but the net value (volume, access or concentration) of reinforcement is equal to, or greater than, reinforcement produced by responses on the key signaling the smaller reinforcer. Employing this logic, a recent experiment revealed inadequacies in this model. Young (1981) utilized pigeons on a concurrent, discrete-trial choice procedure during which a response on a red key always produced reinforcement, initially consisting of 5 pellets. A response on a green key produced a 10-pellet reinforcement delivery on 50% of the trials and no reinforcement on the remainder of trials. Blocks of single-key trials intervened between choice trials in order to ensure proper distribution of reinforcement for each key, equate red-key exposure and counterbalance for key-color position. It was found that the smaller reinforcer delivered at the higher rate was preferred over the larger reinforcer delivered at the lower rate, even when the net magnitudes of reinforcement were equal. Thus, frequency of reinforcement was a more important determinant of choice responding than was reinforcement magnitude.

The second model of choice that relates to reinforcement magnitude is a derivative of the matching law (Herrnstein, 1970). The generalized matching law was developed to take into account parameters of reinforcement

other than probability. The generalized matching law predicts that choice of a particular manipulandum will occur in proportion to the relative reinforcement magnitude produced in association with that component (Baum, 1973). According to Young (1981), the generalized matching law (Baum, 1973) more closely fits the data presented in choice studies of magnitude than does the maximization theory because the generalized matching law takes probability, frequency, and magnitude of the reinforcer into account. However, magnitude effects appear to function in a non-linear manner that theoretically accounts for the occurrence of overmatching in some studies (Catania, 1963; Dunn, 1982) and undermatching in others (Navarick, 1979; Young, 1981). This non-linear function makes it difficult to incorporate a constant into the generalized matching formula that accommodates data produced at various levels of reinforcement magnitude.

Response-contingent magnitude changes. The effectiveness of reinforcement magnitude on concurrent schedules has been discussed previously. Concurrent procedures are mentioned in the context of the contingency factor because concurrent schedules of reinforcement magnitude necessarily involve response contingencies in the sense that different choices produce different magnitudes of reinforcement (Catania, 1963; Dunn, 1982; Neuringer, 1967; Schneider, 1973). As such, they might be classified as

studies. On the other hand, the majority of studies which have examined reinforcement magnitude simply varied the parameters of reinforcement magnitude without requiring different behaviors for each level of magnitude obtained (Keesey & Kling, 1961; Lowe et al., 1974; Meunier & Starratt, 1979; Powell, 1969; Staddon, 1970, 1972). Thus, the presence versus the absence of a contingency is yet another factor that distinguishes concurrent reinforcement magnitude studies from simple schedule studies, which on the whole are less likely to produce magnitude effects.

A series of studies, designed to provide a paradigm for the empirical study of self-control, are also noteworthy in regard to reinforcement magnitude, as affected by response contingencies (Ainslie, 1974; Duus, 1982; Green & Snyderman, 1980; Rachlin & Green, 1972). Although not designed specifically to investigate the effectiveness of reinforcement magnitude, these studies did examine the effectiveness of magnitude as it interacted with reinforcement delay. That is, they determined the interactions that developed when responding on one key produced relatively short delays to reinforcement and short access-time to grain and responding on the other key produced relatively long delays to reinforcement and long access-time to grain.

There are only a few studies that directly manipulated

There are only a few studies that directly manipulated contingencies by programming changes in magnitude associated with changes in dependent variables such as response rate or speed. For instance, Logan (1960) used the term, correlated reinforcement, to refer to an arrangement in which some quantifiable property of the reinforcer (rate, magnitude, quality, etc.) is determined by some quantifiable property of the response (e.g., rate, topography, force, pattern, latency, etc.). In two studies of correlated reinforcement with runway performance (Brown & Horsfall, 1965; Logan, 1960), the magnitude of reinforcement delivered at the conclusion of each trial was positively correlated with the speed at which the run was completed. The magnitude of reinforcement contingency was effective in producing faster runway completion.

Several studies conducted similar experiments using the rate of key pecking (Gentry & Eskew, 1984), or the rate of bar pressing (Hendry, 1962; Hendry & Van-Toller, 1964) as the contingent response. Traditionally, the term, differential reinforcement, means the administration of a reinforcer following a member of one response class and a withholding of the reinforcer after members of any other class. Gentry and Eskew refer to this relation as a step function, or an all-or-none relation. In describing correlated and conjugate procedures, Gentry and Eskew introduced the term, graded-differential reinforcement.

Gentry and Eskew programmed a direct relation between the number of responses emitted during an 8-s trial and the duration of access-time to grain following the trial. The minimum access-time to grain was 0.25 s (if no response occurred) and was incremented by 0.25 for each response emitted. This procedure was considered effective, in that more responses were produced during the 8-s trial than during either a yoked, non-contingent, variable-duration reinforcement cycle presented at the conclusion of an 8-s trial or a yoked, non contingent variable duration reinforcement cycle contingent on the emission of at least one response.

Hendry (1962) employed a procedure that correlated the number of pellets (from 1 to 10) delivered on a fixed interval (FI) 2-m schedule with terminal-IRT duration. The contingency specified a positive relation between the duration of the terminal IRT and the number of food pellets delivered. Hendry found that this contingency resulted in both an increase in the duration of the terminal IRT as well as a decrease in overall response rate. Because the same decreases in terminal IRT duration and overall response rates were not observed in yoked-control subjects obtaining the same schedule of variable-pellet delivery independent of behavior, it was concluded that the contingency (terminal IRT duration and number of pellets), not the reduction in

reinforcement density, was responsible for the decrease in overall response rate observed on this procedure.

In a second procedure, the contingency between the duration of the terminal IRT and the number of food pellets was reversed such that the number of pellets delivered increased as terminal IRT duration decreased. In this case, it was apparently more difficult to produce IRT duration differences when compared to control conditions. It should be noted that in both procedures the correlated procedure was also an adjusting one: In each session the number of pellets delivered was determined by how much shorter terminal IRTs were than the mean terminal IRT from the previous session. Thus, Hendry's procedure was similar to an IRT shaping procedure (Anger, 1956; Blough, 1966; Weiss & Laties, 1964) because across sessions, it was necessary for terminal IRTs to become shorter to produce the same number of pellets. Unlike IRT shaping studies, duration of the terminal IRT controlled the number of pellets, not the presence or absence of reinforcement delivery. Thus, Hendry's procedure eliminated a confound between reinforcement omission, which alone would decrease IRT durations, and lowering the probability of reinforcement, which alone would be expected to increase IRT durations (Catania, 1970).

Hendry and Van-Toller (1964) conducted a comparable experiment on an FR 9 schedule. In this procedure, a small

amount of water (either 0.02 or 0.05 ml) or a large amount of water (either 0.1, 0.16, or 0.25 ml) was delivered dependent on whether the terminal IRT in a ratio was shorter or longer than a criterion, respectively. The criterion was the median terminal IRT from the previous session. If the correlated contingency was effective, terminal IRT durations would increase. Instead, mean IRT durations decreased across sessions. The authors stated that the correlated procedure was probably ineffective because the contingency determining the amount of water was confounded with the incidental contingency determining frequency of reinforcement. That is, a long terminal IRT would produce more water; however, on ratio schedules, long IRTs would also decrease the rate of reinforcement. Hendry and Van-Toller (1964) concluded that the reinforcement frequency variable is more powerful than the reinforcement magnitude variable, a conclusion which is strongly supported elsewhere in the literature (Rachlin & Green, 1972; Young, 1981).

Although there are no studies that correlate PRP duration with dimensions of reinforcement, there is a series of PRP shaping studies that utilizes differential omission procedures. An omission procedure involves presenting reinforcement when a PRP duration meets the minimum or maximum duration criterion; an intertrial interval equal to the duration of reinforcement is presented whenever PRP duration fails to meet criterion. It was demonstrated that

FR PRP durations may be increased (Catania, 1970; Kelleher, Fry, & Cook, 1959) as well as decreased (Catania, 1970; Williams & Shull, 1982) via this procedure. However, these studies confounded omission with both intertrial blackouts which alone would be expected to decrease pause duration (Staddon, 1970; Staddon & Innis, 1969) and decreases in the probability of reinforcement, which would be expected to increase PRP durations (Catania, 1970).

Lindsley (1957) utilized the term, conjugate, to refer to a paradigm that is similar to correlated reinforcement. In Lindsley's (1957, 1962, 1963) procedures the quality of the conditioned reinforcer varied in direct proportion to the rate of the response. Lindsley's (1957, 1962, 1963) procedure also differed from correlated reinforcement in that reinforcement was presented continuously (i.e., not only following but also during responding) and thus its quality could change instantaneously dependent on responding. Although not empirically tested, Lindsley (1963) suggested that this characteristic of conjugate reinforcement allowed behavior to be strengthened via a very sensitive reinforcement contingency.

Dependent variables on fixed-ratio schedules. The effectiveness of reinforcement magnitude may be determined by the particular dependent variable chosen for study (Powell, 1969). Shull (1979) has implied that PRP duration and response rate are determined by two entirely independent

sets of variables. Shull (1979) discusses the importance of the correlation between response rate following the first response and the immediacy of the reinforcer. According to Shull (1979) any variable that changes the length of the interreinforcement interval (IRI) or the immediacy of the reinforcer is likely to influence response rate. These variables include: the FR response requirement (Crossman, Heaps, Nunes, & Alferink, 1974); the FI requirement (Neuringer & Schneider, 1968); and the introduction of blackouts (Morgan, 1972).

Shull (1979) describes a constellation of motivational variables, that increase PRP duration, but have a limited effect on response rate and IRT variables. These variables include: decreasing the deprivation level (Sidman & Stebbins, 1959); decreasing the magnitude of reinforcement (Powell, 1969; Stebbins, 1962) and scheduling shock during an FR schedule (Dardano & Sauerbrunn, 1964). Meunier and Starratt (1979) described the category of independent variables which have an effect on PRPs, as those variables which change the attractiveness of the reinforcer. Unlike Shull (1979), Meunier and Starratt (1979) make no claim as to the existence of an independent set of variables which produce effects on PRPs but not on responding thereafter. In contrast, Meunier and Starratt (1979) include the following variables that both increase PRP durations and decrease response rate: increasing the number of responses

required (Felton & Lyon, 1966; Powell, 1969) and introducing a delay before reinforcement (Morgan, 1972). These variables both decrease the attractiveness of the reinforcer and increase the IRI.

Summary. Two theories have been extended to account for reinforcement magnitude effects, particularly on concurrent schedules. These are the maximization theory and the generalized matching law. The maximization theory is discounted in two ways. First, it cannot account for the existence of a lengthy PRP on ratio schedules (Gentry & Eskew, 1984) and second, in some cases, preference for increased frequency of reinforcement outweighs the effects of reinforcement magnitude even at the expense of a decreased level of net reinforcement (Young, 1981). The generalized matching law does not explain the occurrence of undermatching and overmatching (e.g., Catania, 1963; Dunn, 1982; Schneider, 1973). Clearly, an empirically sound theory that accounts for the various effects of reinforcement magnitude, is needed. However, such a theoretical account may not be forthcoming until the variables controlling magnitude of reinforcement effects are clearly identified.

Numerous studies report little or no effect of reinforcement magnitude, particularly on simple schedules of reinforcement (Catania, 1963; Jenkins & Clayton, 1949; Keesey & Kling, 1961) or when measuring response rate

(Neuringer, 1967; Powell, 1969; and Staddon, 1970). In fact, the results from such studies are so prevalent in the literature that some authors conclude that the effects of amount of reinforcement are inconsequential: "A small reward or small punishment works just as well as a larger reinforcement" (Mowrer, 1960, p. 387). However, other studies demonstrate robust and lasting effects of magnitude of reinforcement (Fantino et al., 1972; Jenkins & Clayton, 1949; Staddon & Innis, 1966; Stebbins et al., 1959).

Several explanations are posited in order to identify the source of disparity between these two sets of results. Because concurrent schedule manipulations of reinforcement magnitude consistently produce stronger effects (Cataniala, 1963; Dunn, 1982; Neuringer, 1967; Schneider, 1973), several hypotheses have been presented. One such explanation is that providing different stimuli associated with different reinforcement magnitudes is important in producing a magnitude of reinforcement effect. This argument is strengthened by the fact that multiple schedule manipulations of reinforcement magnitude produce PRP changes (Staddon, 1970) and response rate changes (Jensen & Fallon, 1973; Merigan et al., 1975; Shettleworth & Nevin, 1965). Contrary to these studies of multiple schedules and concurrent schedules, which suggest that within-session changes in reinforcement-magnitude levels may be important in producing magnitude of reinforcement effects, at least

one study suggests that under some conditions between-session changes in reinforcement magnitude levels may also be effective (Meunier & Starratt, 1979).

A second explanation is that different dependent variables are not equally sensitive to magnitude of reinforcement changes. A survey of the literature reviewed in this paper indicates that response rates on concurrent schedule components are always affected by reinforcement magnitude, but sometimes are not predicted by a strict matching formula (Lowe et al., 1974; Priddle-Higson et al., 1976; Staddon, 1970). It was also demonstrated that on simple schedules of reinforcement, rate measures are only affected in approximately two-thirds of the studies.

Another variable proposed to enhance the effectiveness of reinforcement magnitude is the range of magnitudes presented. Dunn (1982) proposed that the greater the difference between levels of reinforcement magnitude presented, the greater the difference in behavior produced at those levels. He cited several effective reinforcement magnitude studies employing large ranges and several ineffective studies utilizing small ranges. However there are many exceptions to this generalization and at least two studies provided some support for a satiation (rate declining) effect at larger magnitudes of reinforcement values (Guttman, 1953; Walker et al., 1970).

A reinforcement magnitude contingency has been employed to enhance the effectiveness of reinforcement magnitude and has been effective in all but one study in which it was employed (12 in all cited in this review). The disparate results may be attributed to the existence of a confound between frequency and magnitude of reinforcement. The choice studies, correlated reinforcement studies and conjugate studies would all be classified under this category because the subject's responses did, in some manner, determine the level of reinforcement magnitude produced. Although the presence of a reinforcement magnitude contingency may not be a necessary condition for producing reinforcement magnitude effects, it appears to be the only sufficient condition identified thus far in the literature.

Temporal Independent Variables

Another parameter of reinforcement is the relative immediacy, or reciprocally, the delay of reinforcement. The term, reinforcement delay, has been used, interchangeably, to refer either to procedures interjecting an interval of time between the response to be reinforced and reinforcement (Azzi, Fix, Keller, & Rocha e Silva, 1964; Sizemore & Lattal, 1978); to the inter-reinforcement interval (IRI) as a whole (Dews, 1962, 1965, 1966; Morse, 1966); or to procedures imposing time intervals at any position relative to responding on schedules of reinforcement (e.g., Barowsky

& Mintz, 1975). This interchange of definitions is presumably due to the assumption that any delay to reinforcement is aversive and therefore, functions in the same manner, whether the delay to reinforcement occurs before, during or after responding. However, because it has been empirically demonstrated that, at least on FR schedules, the potency of the reinforcement delay effect is based on where that delay occurs in relation to responding (Barowsky & Mintz, 1978), various temporal intervals will be treated here as separate variables. Delay to reinforcement will be used generically, referring to time intervals experimentally imposed at any point in relation to responding. Interreinforcement interval (IRI) will refer to the interval between reinforcers, whether determined primarily by responding (e.g., ratio schedules) or by experimental control (e.g., fixed-time schedules). In addition, three other variables will be examined. A post-reinforcement delay to reinforcement will refer to an experimentally-imposed time interval following reinforcement, before the occurrence of a response. An interresponse delay is a delay which is experimentally imposed between two responses (e.g., Barowsky & Mintz, 1978). A post-response delay will refer to an interval imposed between the terminal response and reinforcement.

In contrast to the magnitude of reinforcement parameter, delay of reinforcement is, with rare exception,

effective in producing behavior change. It has been demonstrated in numerous experiments that overall response rate is an inverse function of the delay of reinforcement (e.g., Azzi et al., 1964; Ferster, 1953; Richards, 1981; Sizemore, & Lattal, 1978). Whereas the literature on reinforcement magnitude has focused on determining the necessary and sufficient variables for ensuring the effectiveness of magnitude of reinforcement, the literature regarding the reinforcement delay variable has instead emphasized the experimental isolation of the various temporal factors comprising the delay of reinforcement. Consequently, research on reinforcement delay has had far-reaching conclusions which are relevant to such theoretical questions as the necessity of response-reinforcer contiguity (Lattal, & Ziegler, 1982; Sizemore, & Lattal, 1977); the molar vs. molecular controversy (Lacey & Rachlin, 1978); and the explanation of schedule performance such as that produced by fixed-interval schedules (Dews, 1962, 1965, 1966; Morse, 1966).

Factors Influencing Delay of Reinforcement Effects

Reinforcement Delay and the necessity of response-reinforcer contiguity. The first studies of delayed reinforcement (Ferster, 1953; Skinner, 1938) emphasized maintenance of behavior as a function of the length of the post-response delay to reinforcement. Skinner (1938)

demonstrated that responses could be originally conditioned and thereafter sustained under FI schedules with post-response delay to reinforcement intervals varying from 2 to 8 s. However, response rates decreased approximately 50 per cent when the 8 s reinforcement delay condition was compared to the immediate reinforcement condition. By demonstrating the inverse relation between response rate and length of the post-response delay to reinforcement interval, this study showed the importance of response-reinforcer contiguity.

In contrast, other studies have employed delay procedures to demonstrate that a close response-reinforcer contiguity is not always critical in maintaining responding. Utilizing blackout during the post-response delay to reinforcement, Ferster (1953) demonstrated that responding could be maintained with delays as long as 120 s. Ferster and Hammer (1965) demonstrated that post-response delays as long as 24 hours could maintain responding provided that large amounts of food were delivered and that a discriminative stimulus originally paired with food delivery was presented periodically during the delay to reinforcement. Bloomfield (1972) has argued that these studies did not demonstrate that response-reinforcer contiguity was unimportant because it was necessary either to prevent responding with blackout or to shape subjects to respond by gradually lengthening the delay to reinforcement and periodically presenting conditioned reinforcers.

Delay of reinforcement procedures. Delays to reinforcement have been programmed via several different procedures, each of which is accompanied by potential methodological difficulties. According to one procedure, reinforcement is presented after a certain time has elapsed following the response which meets the reinforcement contingency (Sizemore, & Lattal, 1977). This procedure entails a possible confound because the actual post-response delay to reinforcement, which is determined by the subject's responding following the last required response, may be shorter than the programmed post-response delay. As a result, exact changes in response-reinforcer contiguity cannot be experimentally controlled. Some researchers have demonstrated a close relation between the actual and the programmed delay (Sizemore, & Lattal, 1978) and others have not (Dews, 1960). However, even if actual delays to reinforcement closely approximate programmed delays, post-response delay functions can only be established post hoc.

A procedure correcting for this confound might involve resetting the post-response delay timer whenever a response occurs between the time of the final required response and reinforcement (e.g., Azzi et al., 1964). This procedure is typically referred to as the delay-reset procedure. However, one problem with this procedure is that it is impossible to determine whether the resulting decrease in response rate is due to a reduction in the effectiveness of

the delayed reinforcer or to reinforcement contingencies which reinforce not responding (Nevin, 1965). Dews (1981) noted that this procedure also confounds post-response delay to reinforcement and IRI effects, because increases in delay to reinforcement typically involve correlated increases in IRI.

Another method of programming delay has been utilized to eliminate the confounds described above. This method has been called: "signaled-delay-to-reinforcement" and involves preventing responses during the delay either by scheduling a blackout during the delay (Chung & Herrnstein, 1967; Ferster, 1953) or by removing the response manipulandum (Meunier & Ryman, 1974). One procedural problem with this method of programming is that if the delay to reinforcement occurs immediately preceding reinforcement such environmental changes may become conditioned reinforcers, thus possibly confounding the effects of delay. However, whereas presentation of a conditioned reinforcer would be predicted to strengthen responding (i.e., shorten PRP durations or increase response rate), the presentation of a delay to reinforcement would be predicted to weaken responding (i.e., lengthen PRP or decrease response rate). Thus, the two effects may be counteractive producing no net effect on responding. However, if responding did change with changes in reinforcement delay, it would be possible to

determine whether the conditioned reinforcer or the delay to reinforcement was more powerful.

Effects of post-response delay vs. interresponse delay to reinforcement. Dews (1981) separated the effects of post-response delay and IRI by comparing the effects of two FR 50 schedules followed by X s intervals of no responding. The delay to reinforcement procedure programmed reinforcement immediately after the delay; the postponement (or interresponse delay to reinforcement) procedure required a final response following the delay. Thus, minimum IRIs were equal in both the post-response delay and interresponse delay to reinforcement conditions, but one imposed a delay between the final response and reinforcement (post-response delay) and the other (interresponse delay) maintained a close response-reinforcer contiguity. Results indicated that as X (the number of seconds required with no responding) increased, overall response rates on both interresponse delay and post-response delay to reinforcement procedures decreased. However, response rates decreased more rapidly during the post-response delay to reinforcement procedure, declining four-fold for each 10-fold increase in delay to reinforcement. Dews' (1981) major conclusion was that any increase in IRI reduces response rate, but that such effects can be maximized by increasing the IRI via a delay to reinforcement following the terminal response.

This study also emphasized the theoretical importance of response-reinforcer contiguity.

Delay and frequency of reinforcement. Another important result obtained by Dews (1981) involved the interaction between reinforcement delay and reinforcement rate. It has been suggested that, because increases in either IRI or delay generally decrease the rate (and density) of reinforcement, the IRI and delay to reinforcement variables are encompassed by the rate of reinforcement variable. It would be predicted that as reinforcement rate declined, so would response rate. However, Dews (1981) demonstrated that post-response delay could be isolated from reinforcement rate. In this experiment, as X (the time period requiring no responses) was increased, reinforcement frequency declined on both the post-response delay and the interresponse delay to reinforcement schedules, but declined most dramatically on the interresponse delay schedule. Yet, the post-response delay schedule produced the largest drop in response rate. These data indicate that in this experiment, the effects of delay were not due simply to changes in the relative frequency of reinforcement.

Signaled vs. unsignaled delay to reinforcement. A signaled delay to reinforcement, as discussed previously, is one in which a stimulus change occurs at the beginning of the delay period. Usually the stimulus change involves some

provision such as blackout, for the disruption of responding (Pierce, Hanford, & Zimmerman, 1972; Richards, 1981; Richards & Hittesdorf, 1978). But, several other procedures have been employed, including: removal of the response manipulandum (Meunier & Ryman, 1974), and the presentation of a stimulus light (Pierce et al., 1972). Pierce et al. (1972) have provided an empirical summary of these different methods of programming signaled, post-response delay on variable-interval (VI) schedules. They concluded that the type of reinforcement delay signal has very little effect on the overall rate of responding exclusive of the delay. An unsignaled delay simply involves an increase in the value of the variable-interval schedule.

Two studies have compared the effects of signaled vs. unsignaled delay to reinforcement. One study (Richards & Hittesdorf, 1978) compared response rates produced on a multiple VI 60 VI 60 during which a 10 s post-response delay was either signaled or unsignaled. The results were that the signaled delay produced a higher response rate than the unsignaled delay. Extending these findings, Richards (1972) investigated the effects of various reinforcement-delay durations when delays were signaled or unsignaled. These procedures were examined on both VI 60 s and differential-reinforcement-of-low-response-rate (DRL) 20 s schedules. Responses during the delay did not reset the delay interval. As reinforcement delay duration was increased from 0.5 to

10.0 s, overall response rates decreased on both reinforcement schedules. This effect occurred during the signaled delay condition, but was much more dramatic during the unsignaled condition.

In the Richards (1981) study, even though the relative number of responses per minute differed on the two schedules, the decreased response-rate effect was found on both VI 60 s and DRL 20 s schedules. This effect is relevant to a discussion of the interaction of delay and rate of reinforcement variables. A decrease in response rate on a VI schedule may result in a decrease in overall rate of reinforcement; in contrast, a decrease in response rate on a DRL schedule may result in an increase in overall rate of reinforcement. Thus, increases in delay may produce decreases in response rate independent of concomitant decreases in rate of reinforcement.

Delay of reinforcement duration. One exception to the inverse function of delay on overall response rate, is the introduction of brief delay intervals (e.g., < 0.5 s), which, if unsignaled by blackout or other stimulus change and not restricted by a delay reset contingency on responding during the delay, can increase mean overall response rate as much as 50 percent (Lattal & Ziegler, 1982; Richards, 1981; Sizemore & Lattal, 1978). This effect has been obtained on a variety of reinforcement schedules, including variable-interval, differential reinforcement of

zero responses (DRO), and tandem variable-interval fixed-time (VI FI) schedules (Lattal & Ziegler, 1982). Lattal and Ziegler (1982) proposed that this response-rate increase was due to the absence of constraints on responding during the delay.

Lattal and Ziegler (1982) utilized a variable-interval (VI) schedule to compare the effects of a variety of procedures that differed in the extent to which they prevented or disrupted further bursts of responding. They found that delay signaled blackout which constrains responding by disrupting the response pattern, produced the fewest short IRTs (0-0.5 s); that delay-reset conditions, which restrict, but, do not disrupt responding, produced more short IRTs than the blackout delay, but, fewer than the immediate reinforcement or unsignaled delay procedures; and that brief (0.5 s) unsignaled, no-reset delay conditions, which left responding during the delay completely unrestricted, substantially increased the frequency of short IRTs. Lattal and Ziegler (1982) concluded that the more complete was the disruption of responding during the delay, the longer were the IRTs produced by that particular delay procedure.

Unlike brief unsignaled delays to reinforcement, short signaled delays (greater than 0.5 s but less than 5 s) do produce response rate decreases, compared to a 0 s delay condition. Such response-rate reductions are, however,

often only moderate (Lattal & Ziegler, 1982; Pierce et al., 1972; Richards, 1972, 1981; Sizemore & Lattal, 1978; Wilkie, 1971). Compared to immediate reinforcement, the largest response rate reductions appear to be produced by unsignaled, relatively long (greater than 5 s) delays to reinforcement (Richards, 1981; Sizemore & Lattal, 1977, 1978; Williams, 1976).

Reinforcement delay on FR schedules. The most relevant reinforcement delay literature in regard to the present study involves the effects of delay during FR schedules on PRP duration. The FR reinforcement delay studies presented here all utilized a blackout (BO) procedure during reinforcement delay. When long delays (30 s or 60 s) are scheduled immediately following reinforcement (pre-response delays), it has generally been demonstrated that the post-blackout pauses (PBPs) are shorter than PRPs (Ferster & Skinner, 1957; Mazur & Hyslop, 1982). Furthermore, this difference between PBP and PRP increases as FR size increases from FR 50 to FR 150 (Mazur & Hyslop, 1982). The most common explanation of this effect is that the BO simply occurs during a time when the subject would typically be pausing; i.e., the BO replaces the PRP. Because the BO periods in these studies are much longer than typical PRPs on large FRs (50, 100, or 150), the subject may simply pause during the BO and respond once the key light is illuminated. Another explanation (Perone, 1985) is that behavioral

contrast accounts for shorter PRPs; i.e., that alternation of BO and non-BO intervals evokes shorter duration PRPs.

When a delay is presented in the middle of an FR (interresponse delay to reinforcement), PRP duration is positively correlated with delay duration (Barowsky & Mintz, 1978). It has also been demonstrated that the later in the ratio the delay occurs (following the 50th versus the 10th response of an FR 60), the longer the PRP duration (Barowsky & Mintz, 1975). These conclusions are limited to moderate length BO intervals (e.g., 2.5 and 10 s). When a BO delay to reinforcement is inserted between the last response and reinforcement (post-response delay), mean PRP duration also increases as reinforcement delay duration increases (Meunier & Ryman, 1974; Morgan, 1972), even on a variety of FR schedules with delays as long as 180 s (Topping et al., 1973) or as short as .75 s (Morgan, 1972).

The major difficulty with the design of each of these studies was that IRI was not controlled; as reinforcement delay increased, IRI increased at the same time. The question of which independent variable was responsible for the PRP increase is theoretically important, particularly when the reinforcement delay is imposed between the terminal response and reinforcement. A molecular theory (Lacey & Rachlin, 1978; Navarick, 1979) places importance on a decrease in the effectiveness of the reinforcer due to decreased temporal contiguity of the terminal response and

the reinforcer. A molar account (Lacey & Rachlin, 1978) would predict that IRI is the controlling variable, because as IRI increases, the overall density of reinforcement decreases.

Summary. Increases in the delay of reinforcement, i.e., the duration of time experimentally imposed before, during, or after responding on reinforcement schedules, have with rare exception, produced decreases in the rate of responding on fixed-interval (FI) schedules (Azzi et al., 1964; Ferster, 1953; Richards, 1981; Sizemore & Lattal, 1978). Different procedures such as delay-reset contingencies (Azzi et al., 1964), the scheduling of blackout during the delay (Ferster, 1953), and the removal of the response manipulandum (Meunier & Ryman, 1974) have been used in order to reduce responding during post-response delays and thus enable the examination of the necessity of response-reinforcer contiguity (Lattal & Ziegler, 1982; Sizemore & Lattal, 1977).

The importance of several factors involved in delay of reinforcement has been demonstrated. For instance, the decrease in response rate which occurs as reinforcement delay duration increases, appears to be more dramatic when delay is un signaled by blackout or other stimulus change (Richards, 1981). However, this effect fails to separate the possible confounding variables of reinforcement delay and number of responses. That is, as the delay to

reinforcement increases, the number of responses also increases. Increasing the number of responses on FR schedules has been found to decrease response rate within certain parameters (Mazur, 1983) and increase PRP (Crossman et al., 1974). Another factor that appears to affect response rate on FR schedules is the positioning of the interresponse delay to reinforcement interval within a ratio (Dews, 1981). Dews (1981) demonstrated that a delay between the last response and reinforcement produced larger decreases in overall response rate than when the reinforcement delay occurred earlier in the ratio.

Of most relevance to the experiments conducted in this study are the consistent effects that have been demonstrated on FR schedules when examining PRP durations. That is, in general, as the reinforcement delay duration increases, PRP length increases (Barowsky & Mintz, 1975, 1978; Meunier & Ryman, 1974; Morgan, 1972; Topping et al., 1973). In addition, PRP duration increases most, the further into the ratio the delay-to-reinforcement is presented (e.g., following the 50th versus the 10th response). The major problem with these studies was that reinforcement delay and IRI effects were confounded; thus, the importance of the temporal contiguity between terminal response and reinforcer could not be determined.

PURPOSE

A conjugate schedule is one in which some quantitative dimension of the response (e.g., rate, latency, force) is continuously correlated with some quantitative aspect of the reinforcer to be delivered (e.g., rate, magnitude, delay). The goals of the current study involved the use of conjugate schedules to examine research questions germane to the interaction of response-contingent magnitude and delay of reinforcement. The importance of controlling certain temporal variables is emphasized in the research questions formulated below.

As discussed in the literature review, the effects of reinforcement magnitude on PRP durations on FR schedules are inconsistent. Two studies have reported a positive correlation between PRP duration and reinforcement magnitude levels (Lowe et al., 1974; Stebbins, 1962) and two have reported PRP durations and magnitude of reinforcement to be inversely related (Meunier & Starratt, 1979; Powell, 1969). The effectiveness of reinforcement magnitude manipulations on correlated and concurrent schedules suggests that response-contingent magnitude changes may be the only sufficient variable for producing a magnitude effect. However, response-contingent magnitude of reinforcement effects have not been successfully demonstrated on FR PRP durations.

The effects of reinforcement magnitude on concurrent FR schedules have not been previously investigated, presumably because the tendency for exclusive choice of one FR component (Herrnstein & Loveland, 1975) would not allow the comparison of PRP durations between components. Even if exclusive choice did not occur, magnitude of reinforcement would not be contingent on PRP duration. The effects of reinforcement duration contingent on FR PRP durations have not been studied either. However, one study that ineffectively correlated terminal IRTs with reinforcement magnitude by volume (Hendry & Van-Toller, 1964) indicated that on correlated FR schedules it may be important to control IRI. Thus, one purpose of the present study was to determine whether a conjugate schedule would provide a paradigm for the study of response-contingent magnitude of reinforcement effects on FR PRP durations. A complementary purpose was to determine the necessity of controlling the frequency of reinforcement to obtain such effects. One condition maintained a fixed mean temporal interval by interjecting variable-duration post-reinforcement delays; another condition maintained a fixed temporal interval between reinforcers by imposing a conjugate post-response reinforcement delay contingency; and another controlled IRI via a post-response reinforcement delay.

Because a response contingency was placed on PRP durations, in a sense, the conjugate schedules in this study

were PRP shaping procedures. It has been demonstrated that longer PRP durations on large FR schedules could be shaped via a reinforcement omission procedure during which blackout occurred in lieu of reinforcement when a given PRP duration was shorter than criterion (Kelleher et al., 1959).

However, in these procedures, omission was confounded with intertrial blackouts, which alone would be predicted to decrease PRP durations (Staddon, 1970; Staddon & Innis, 1969) and decreases in the probability of reinforcement, which would be predicted to increase PRP durations (Catania, 1970). Therefore, another purpose of the proposed study was to determine whether conjugate FR 1 schedules, which correlated pre-ratio pause (PRP) duration with magnitude of reinforcement, delay of reinforcement, or both, produced mean PRP durations longer than those produced on FR 1 with immediate fixed-duration reinforcement.

As stated in the preceding literature review, it has been shown that overall response rate is an inverse function of the delay to reinforcement (e.g., Azzi et al., 1964; Dews, 1981; Ferster, 1953; Richards, 1981). It has also been demonstrated, using FR schedules, that PRP and delay to reinforcement durations are positively correlated, whether reinforcement delay is interjected within the ratio (Barowsky & Mintz, 1975, 1978) or follows the last required response (Meunier & Ryman, 1974; Morgan, 1972; Topping et al., 1973). The major criticism of these studies is that

increases in PRP duration were correlated with both increases in delay and increases in IRI. With this confound present it is impossible to determine whether increases in PRP durations were simply due to lengthening the IRI or whether it was essential to disrupt the temporal contiguity of the response-reinforcer relation. Therefore, a third objective of the present study was to demonstrate the effects of response-contingent post-response delays on FR PRP durations while IRIs remained constant.

The preceding literature review suggests that after years of research, the question of whether reinforcement magnitude is or is not effective in controlling responding, remains open to debate. Further, researchers do not agree as to the necessary and sufficient conditions for producing reinforcement magnitude effects, especially on FR schedules. Regarding the delay of reinforcement, the issue of the necessity of response-reinforcer contiguity also remains controversial, which is not surprising given the paucity of studies that have controlled temporal factors essential to the demonstration of such a necessity. This criticism is particularly valid regarding the effects of delay to reinforcement on FR PRP durations. Given the significance of these issues, it is important to an understanding of behavior to demonstrate empirically the utility of alternative paradigms to systematically manipulate and control the parameters of reinforcement as they interact.

Toward this end, the objectives of the proposed experiments were: a) to determine whether a conjugate reinforcement-magnitude procedure provided a means for investigating response-contingent magnitude of reinforcement effects on FR PRP durations; b) to determine the necessity of controlling other factors in obtaining such effects; c) to demonstrate that conjugate schedules were effective in shaping PRP durations while eliminating the confounds inherent in the omission procedure; and d) to demonstrate the usefulness of the conjugate delay-to-reinforcement schedule in investigating parameters of response-contingent reinforcer contiguity while controlling for other temporal factors.

METHOD

General Procedure

Subjects

Eight experimentally naive mixed-breed pigeons (M11-M18) served. Each pigeon was fed freely until its weight was stable and then it was maintained within ± 15 g of 80% of its free-feeding weight for the duration of the study. If a pigeon was not within ± 15 g of its 80% weight, an experimental session was not conducted on that particular day.

Apparatus

The four chambers used were similar (Coulbourn Instruments Modular Small Animal Test Cage, model E10-10) with response keys 8 cm apart, 2.5 cm in diameter, and 18.5 cm from the grid floor. The center key, located directly above the hopper, was transilluminated with 8 lumens of red light (Kodak Wratten Filter #23A). Only the center key in each chamber was operable. Each center key necessitated a key-throw force of 5 N over a distance of 1 mm. The interior of each chamber measured 28.5 by 29 by 24 cm and was enclosed in a ventilated, light- and sound-attenuated box with an ambient noise level of approximately 60 db.

All chamber events were controlled by a Commodore VIC-20 microcomputer via a custom-designed interface (Crossman, 1984). Each chamber event and response was recorded in real

time (0.067-s resolution) on a Commodore 1541 Disk Drive and later transferred to a Commodore 8050 Disk Drive for data analysis via a Commodore CBM 8032 computer.

Pretraining

Each pigeon was trained to peck a red center key via an autoshaping procedure, which continued until it pecked the lit key on 100% of the trials in a session. Each autoshaping session consisted of 30-50 trials and each trial began with a 54 s blackout intertrial interval (ITI), followed by a 6 s interstimulus interval (ISI), followed by 3 s access to pigeon checkers (Purina Racing Checkers). If a peck occurred on the red key during the ISI, 3 s access to grain was immediately presented followed by the ITI. If a pigeon did not emit a response during the ISI for 30 consecutive trials of 2 autoshaping sessions, that subject was dropped from the study. (However, this did not occur.) One subject (Mil) was dropped during the last condition because it was not possible to maintain its 80% body weight for two consecutive sessions.

Following the autoshaping phase, each condition involved a conjugate schedule of reinforcement, in which some quantitative dimension(s) of a particular reinforcer was proportionally contingent upon the duration of the immediately preceding pre-ratio pause (PRP) on a fixed-ratio (FR) 1 schedule (see Figure 1). The order of conditions was varied (see Table 1); all subjects were exposed to all

Figure 1. A graphic depiction of the conjugate reinforcement magnitude and delay procedures, hypothetically demonstrating the linear relation between pre-ratio pause (PRP) and reinforcement magnitude (top) and delay (bottom) durations.

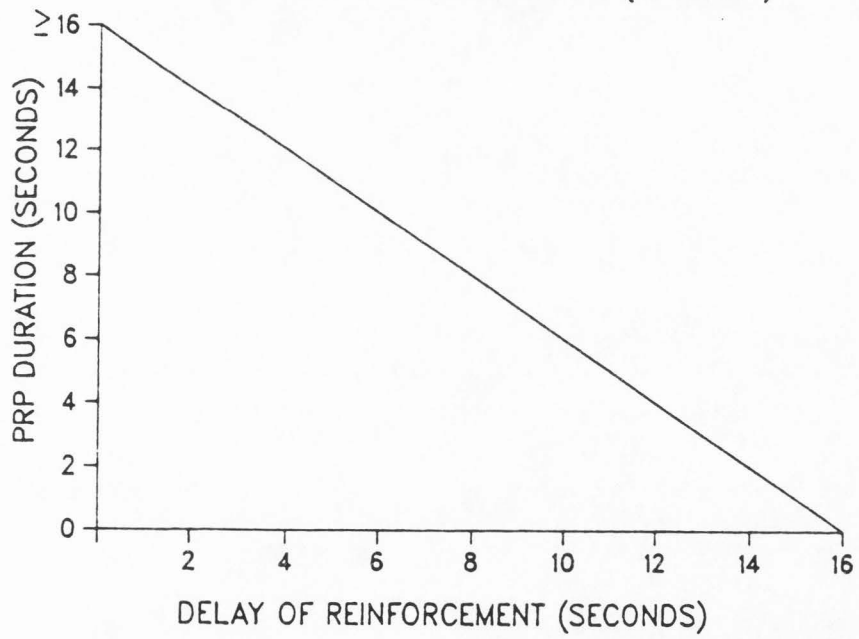
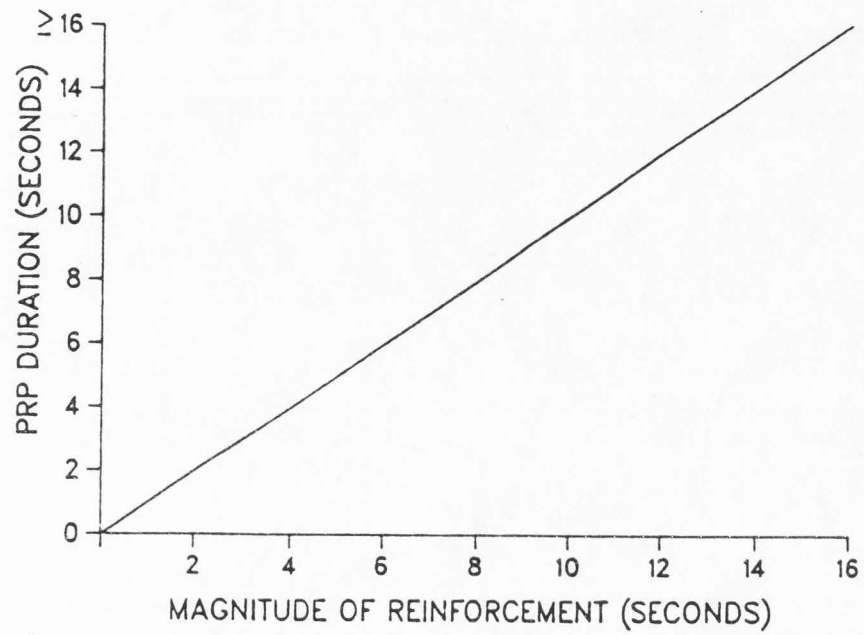


Table 1

Numerical Order of Experimental Conditions and the Number of Sessions to Stable Performance, in Parentheses, for Each of 8 Subjects.

Condition	Subjects							
	M11	M12	M13	M14	M15	M16	M17	M18
CONJ MAG	2(30)	5(18)	4(28)	3(23)	2(23)	5(25)	4(15)	3(36)
VARIABLE MAG	8(19)	7(37)	8(22)	9(18)	8(18)	7(19)	9(15)	8(27)
CONJ MAG FIX ITI	6(22)	4(22)	9(29)	6(29)	6(31)	6(46)	5(15)	5(39)
FR 1	1(24)	1(20)	1(19)	1(26)	1(20)	1(18)	1(17)	1(10)
CONJ MAG ITI	4(15)	3(27)	3(29)	2(16)	4(15)	3(16)	3(15)	2(26)
VARIABLE ITI	9(16)	8(16)	6(15)	8(17)	9(19)	8(18)	7(15)	7(22)
CONJ MAG FIX IRI	5(19)	6(33)	5(35)	4(15)	5(19)	4(23)	6(62)	4(32)
CONJ DELAY MAG	3(21)	2(13)	2(18)	5(32)	3(35)	2(25)	2(25)	9(21)
CONJ DELAY	7(23)	9(18)	7(19)	7(22)	7(48)	9(16)	8(26)	6(17)

conditions (except M11 as discussed above). In the series of conditions conducted, the contingent presentation of various parameters of reinforcement was systematically varied across conditions. That is, the durations of the following parameters were determined by the duration of the PRP: the reinforcer, the post-response blackout (BO); and the post-reinforcement BO. For the purpose of comparison, some of these parameters were also presented non-contingently both with varying and fixed durations (see Figure 2 for a diagrammatic representation). Sessions terminated after the delivery of 120 s of hopper duration, or when 150 m of session time had elapsed. A condition terminated only after more than 15 sessions (after ten for two birds on one condition); after the last five sessions of a condition had produced no new high or low mean PRPs; and when there was no consistent upward or downward trend of more than 3 days, in mean PRPs. The maximum length of a condition was 62 sessions, however, in fact all but 3 conditions were less than 40 sessions.

Conjugate Schedules

Experimental Conditions

Conjugate magnitude (CONJ MAG). The eight pigeons were exposed to a condition, during which the duration of the PRP on an FR 1 schedule exactly equaled the magnitude of reinforcement, i.e., the duration of the hopper

Figure 2. Set of diagrams exemplifying the hopper and blackout durations that would have been programmed for each experimental condition, should the emitted FR 1 responses have resulted in PRPs of 5 s and then 8 s.

presentation. Figure 1 (top), depicts the proportional relations between PRP duration and reinforcement magnitude duration. Examples of obtained reinforcer durations are diagrammed in Figure 2. As PRP lengthened, up to 16 s, hopper duration increased up to a maximum of 16 s. The minimum hopper duration for the condition involved a brief flash of hopper light as the hopper was raised and immediately lowered. The shortest obtained hopper duration was 0.17 s. In this manner, the response contingency favored the production of long PRPs. If this magnitude of reinforcement contingency was the only factor controlling PRP duration, the optimal PRP duration would be 16 s.

Conjugate delay (CONJ DELAY). During this condition, the duration of a particular PRP on an FR 1 schedule determined the duration of the delay to the next reinforcer. The delay to reinforcement, in this instance, referred to the BO time between the response terminating a particular PRP and the onset of reinforcement. All chamber and key lights were off during the delay. The longer the PRP, up to 16 s, the shorter was the delay. Figure 1 (bottom) shows the delay function produced by specific PRP durations. The minimum delay was 0 s (for a 16-s PRP) and the maximum delay was theoretically 16 s (for a 0-s PRP). Thus, in terms of minimizing delay, the optimal PRP was 16 s. The IRI was always 16 s, independent of responding (see Figure 2).

Conjugate delay and reinforcement magnitude (CONJ DELAY MAG). The purpose of this condition was to investigate the interactions between conjugate magnitude and conjugate delay schedules of reinforcement. Such examination focused on the interaction between reinforcement delay, reinforcement magnitude, and the interreinforcement interval (IRI). During this condition the duration of a PRP simultaneously determined both the duration of the delay to reinforcement following the response and the duration of food access following the delay (see Figure 2). The duration of the delay to reinforcement was inversely related to the duration of the immediately preceding PRP such that the delay varied from 0 s (when the PRP was 16 s or greater) to almost 16 s (when the PRP approached 0 s). As in other conjugate magnitude conditions, the duration of food access equaled the duration of the preceding PRP. Each IRI during this condition equaled 16 s.

Comparison Conditions

Conjugate magnitude of reinforcement, fixed intertrial interval (CONJ MAG FIX ITI). As during other conjugate magnitude of reinforcement conditions, the duration of the hopper was programmed to match the duration of the PRP and ranged from 0 to 16 s. However, in this condition the hopper presentation was followed by a fixed 3-s BO. Thus, this condition differed from other conjugate magnitude of reinforcement conditions, as follows: from CONJ MAG

condition, in that, it had a BO; from the CONJ MAG ITI condition, in that, the duration of the post-reinforcer BO was not contingent on responding; from CONJ DELAY MAG, in that, the BO occurred after the reinforcer instead of after the response and BO duration was fixed; and from the CONJ MAG FIX IRI condition, in that, the temporal interval between reinforcers was not fixed (see Figure 2).

Conjugate magnitude and intertrial interval (CONJ) MAG ITI). During this condition, as in others, the duration of the PRP on an FR 1 schedule determined the magnitude of reinforcement, i.e., the duration of the hopper presentation. However, in this condition, the density of reinforcement was fixed, occurring on the average every 16 s. The procedure involved the introduction of a BO period (all lights off) following reinforcement, the duration of which was 16 s, minus the duration of the preceding PRP. Thus, individual IRIs varied in duration, but the overall density of reinforcement was fixed and independent of PRP duration, which was not the case in the CONJ MAG condition. As in the CONJ MAG condition, the longer the PRP, the longer the duration of food-access time. The hopper duration ranged from the length of a brief flash of the hopper light up to 16 s. Unlike the CONJ MAG condition, this condition permitted subjects to emit long duration PRPs without creating an increase in the IRI. Optimal PRP durations were thus, 16 s.

Conjugate magnitude of reinforcement, fixed interreinforcement interval (CONJ MAG FIX IRI). As in other conjugate reinforcement magnitude conditions, the duration of food access was the same as the PRP duration, ranging from 0 to 16 s. In addition, the duration of the IRI was experimentally held constant by inserting a post-response BO. The BO duration was programmed such that together, the PRP, BO, and ensuing reinforcer constituted a 16-s period. This condition was similar to the CONJ MAG ITI condition in that the frequency of reinforcement was held constant via a BO, the duration of which was inversely related to the PRP duration. It differed from the CONJ MAG ITI condition in that the BO occurred before, rather than after, the reinforcer. Thus, the IRI, as measured from the end of one reinforcer to the end of the next, was held constant.

Variable intertrial interval (VARIABLE ITI). During the VARIABLE ITI condition, the conjugate magnitude of reinforcement contingency was in effect. In addition, a noncontingent, variable duration, post-reinforcer BO was scheduled. The durations of the BOs were yoked to the CONJ MAG ITI condition, where BO duration had been determined by the duration of the PRP.

Fixed Versus Variable Reinforcement Duration

Variable magnitude (VARIABLE MAG). During the VARIABLE MAG condition the duration of magnitude on an FR 1 was

varied independent of the duration of the PRP. The hopper durations presented were yoked to response contingent hopper durations which had occurred on the CONJ MAG ITI condition.

Fixed ratio 1 (FR 1). Subjects were first exposed to an FR 1 schedule of reinforcement, whereby one keypeck response produced a fixed amount of hopper time, i.e., 3 s. No other events were programmed. Forty reinforcers were presented, per session.

RESULTS

The primary dependent variable was the mean pre-ratio pause (PRP). Mean PRP durations are presented both for individual subjects. All measures represent the last five sessions of a stable condition. The mean, rather than the median, PRP was examined because there were few extreme values and the distributions were not excessively skewed.

To provide a within-subject measure of any change in mean PRP duration across conditions, Figure 3 displays mean PRP duration as a function of the conditions studied for individual subjects. The order of conditions displayed in Figure 3 does not reflect the order in which the conditions were presented in the experiment (see Table 1). The line that intersects each bar (error line) represents one standard deviation below, and one standard deviation above the mean PRP. Two conditions are evaluated as different from one another whenever the PRP durations within the range of one standard deviation above and below the mean for a particular condition are not also included within the range of one standard deviation above and below the mean for a separate condition (i.e., standard deviations do not overlap between conditions). The numerical values of the PRP standard deviations are presented in Table 2 for all conditions for each subject.

Figure 3. Mean pre-ratio pause duration, in seconds, across the last 5 sessions of each condition, for each individual subject.

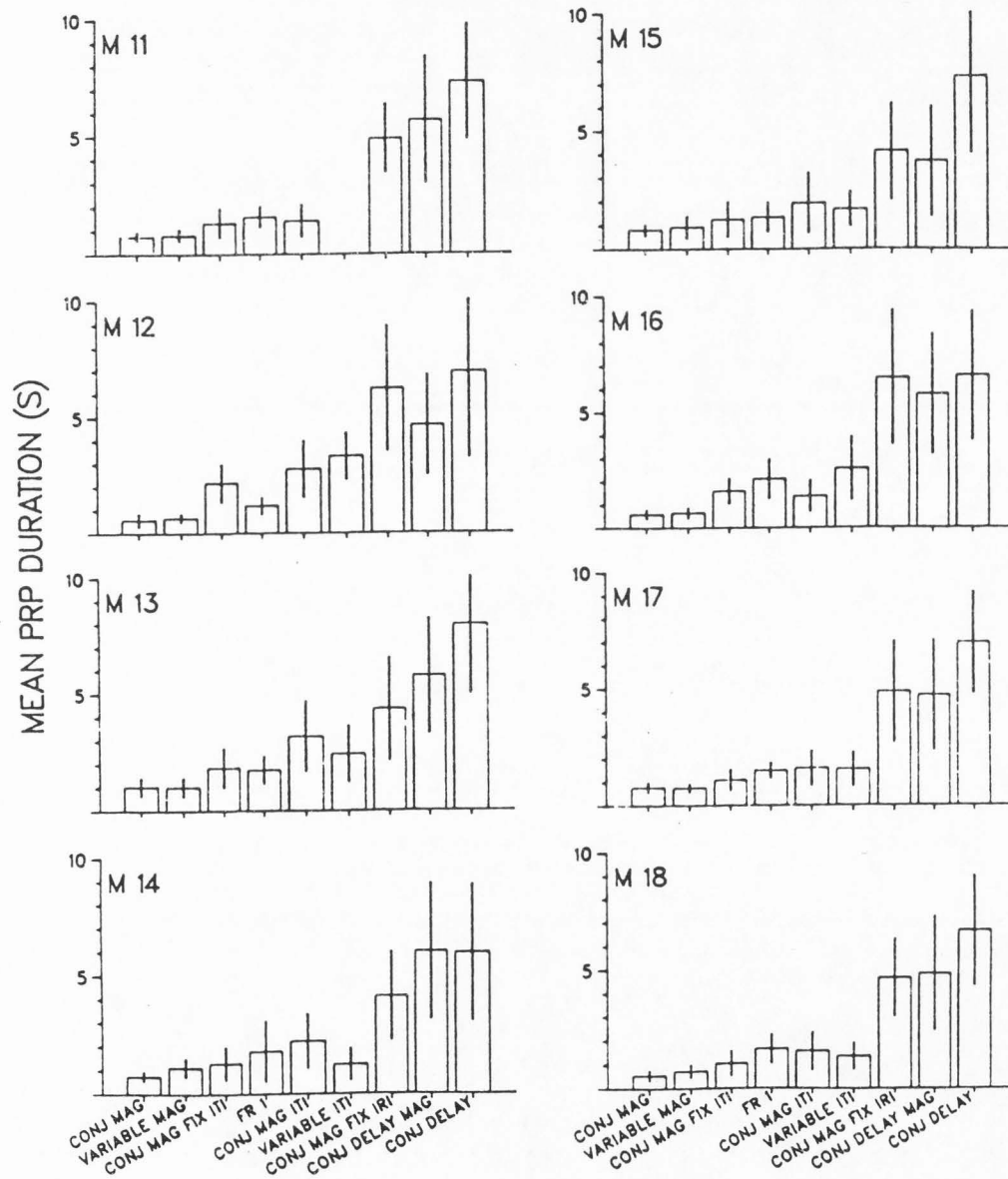


Table 2

Summary of Central Tendency and Variability Measures for all
Subjects on all Reinforcement Schedules Studied

Sub- ject	Condition	Mean PRP	PRP		
			Standard Deviation (SD)	Mean PRP -1 SD	Mean PRP +1 SD
M11	CONJ MAG	0.75	0.17	0.58	0.92
	VARIABLE MAG	0.80	0.24	0.56	1.04
	CONJ MAG FIX ITI	1.32	0.62	0.70	1.94
	FR 1	1.58	0.43	1.15	2.01
	CONJ MAG ITI	1.41	0.68	0.73	2.09
	VARIABLE ITI	--	--	--	--
	CONJ MAG FIX IRI	4.88	1.47	3.41	6.35
	CONJ DELAY MAG	5.66	2.71	2.95	8.37
	CONJ DELAY	7.31	2.45	4.86	9.76
M12	CONJ MAG	0.58	0.27	0.31	0.85
	VARIABLE MAG	0.66	0.17	0.49	0.83
	CONJ MAG FIX ITI	2.03	0.99	1.35	2.99
	FR 1	1.99	0.36	0.83	1.55
	CONJ MAG ITI	2.77	1.23	1.54	4.00
	VARIABLE ITI	3.33	1.01	2.32	4.34

(table continues)

Sub- ject	Condition	Mean PRP	PRP		
			Standard Deviation (SD)	Mean PRP -1 SD	Mean PRP +1 SD
M13	CONJ MAG FIX IRI	6.24	2.70	3.54	8.94
	CONJ DELAY MAG	4.65	2.15	2.50	6.80
	CONJ DELAY	6.95	3.71	3.24	10.66
	CONJ MAG	1.03	0.38	0.65	1.41
	VARIABLE MAG	1.02	0.39	0.63	1.41
	CONJ MAG FIX ITI	1.84	0.84	1.00	2.68
	FR 1	1.75	0.59	1.16	2.34
	CONJ MAG ITI	3.18	1.50	1.68	4.68
	VARIABLE ITI	2.43	1.21	1.22	3.64
	CONJ MAG FIX IRI	4.36	2.21	2.15	6.57
M14	CONJ DELAY MAG	5.77	2.46	3.31	8.23
	CONJ DELAY	7.97	2.97	5.00	10.94
	CONJ MAG	0.74	0.18	0.56	0.92
	VARIABLE MAG	1.11	0.37	0.74	1.48
	CONJ MAG FIX ITI	1.28	0.68	0.60	1.96
	FR 1	1.78	1.27	0.51	3.05
	CONJ MAG ITI	2.20	1.13	1.07	3.33
	VARIABLE ITI	1.23	0.66	0.57	1.89
CONJ MAG FIX IRI	4.10	1.87	2.23	5.97	

(table continues)

Sub- ject	Condition	Mean PRP	PRP		
			Standard Deviation (SD)	Mean PRP -1 SD	Mean PRP +1 SD
M15	CONJ DELAY MAG	5.99	2.89	3.10	8.88
	CONJ DELAY	5.93	2.90	3.03	8.83
	CONJ MAG	0.82	0.24	0.58	1.06
	VARIABLE MAG	0.93	0.47	0.46	1.40
	CONJ MAG FIX ITI	1.26	0.74	0.52	2.00
	FR 1	1.36	0.62	0.74	1.98
	CONJ MAG ITI	1.95	1.26	0.69	3.21
	VARIABLE ITI	1.68	0.73	0.95	2.41
	CONJ MAG FIX IRI	4.13	3.28	2.08	6.16
	CONJ DELAY MAG	3.71	2.33	1.38	6.04
M16	CONJ DELAY	7.33	3.28	4.05	10.61
	CONJ MAG	0.59	0.19	0.40	0.78
	VARIABLE MAG	0.65	0.22	0.43	0.87
	CONJ MAG FIX ITI	1.60	0.55	1.05	2.15
	FR 1	2.12	0.86	1.26	2.98
	CONJ MAG ITI	1.37	0.68	0.69	2.05
	VARIABLE ITI	2.56	1.37	1.19	3.93
	CONJ MAG FIX IRI	6.46	2.90	3.58	9.38
CONJ DELAY MAG	5.77	2.60	3.17	8.37	

(table continues)

Sub- ject	Condition	Mean PRP	PRP		
			Standard Deviation (SD)	Mean PRP -1 SD	Mean PRP +1 SD
M17	CONJ DELAY	6.57	2.78	3.79	9.35
	CONJ MAG	0.78	0.20	0.58	0.98
	VARIABLE MAG	0.75	0.17	0.58	0.92
	CONJ MAG FIX ITI	1.09	0.44	0.65	1.53
	FR 1	1.50	0.33	1.17	1.83
	CONJ MAG ITI	1.60	0.74	0.82	2.34
	VARIABLE ITI	1.55	0.73	0.82	2.28
	CONJ MAG FIX IRI	4.86	2.17	2.69	7.03
	CONJ DELAY MAG	4.71	2.36	2.35	7.07
	CONJ DELAY	6.97	2.19	4.78	9.16
M18	CONJ MAG	0.55	0.21	0.34	0.76
	VARIABLE MAG	0.73	0.26	0.47	0.99
	CONJ MAG FIX ITI	1.05	0.52	0.53	1.57
	FR 1	1.65	0.60	1.05	2.25
	CONJ MAG ITI	1.56	0.78	0.78	2.34
	VARIABLE ITI	1.35	0.55	0.80	1.90
	CONJ MAG FIX IRI	4.64	1.65	2.99	6.29
	CONJ DELAY MAG	4.82	2.42	2.40	7.24
	CONJ DELAY	6.64	2.34	4.30	8.98

Across subjects, two conditions were judged as different from one another only when, for six of eight subjects, the PRP standard deviations (plus-or-minus one standard deviation from the mean PRP) did not overlap between conditions. The current study consisted of nine conditions, permitting 36 pairwise comparisons. Thirteen of these comparisons yielded mean differences when criteria for within- and between-subject variability were considered. Table 3 presents a summary of all conditions in which the PRP standard deviations did not overlap for a minimum of six of eight birds. Figures 4 through 11 present the relative frequency distributions of PRP durations. For each subject, relative frequency distributions are derived from data collapsed across the last 5 sessions of a condition. Frequency distributions of selected conditions are analyzed in the text to the extent that such analyses further understanding of the variables controlling PRP durations.

The Effects of Reinforcement Magnitude

Reinforcement Magnitude Contingency

By comparing the mean PRP durations produced by various conditions, it becomes apparent that when reinforcement magnitude (duration of access to food reinforcement) was dependent on the duration of the PRP such that long PRP durations were optimal, the mean PRP duration was not systematically different from the mean PRP duration produced

Table 3

Matrix Summarizing all Conditions that Differed in Mean PRP
Duration

Schedules of Reinforcement

	CONJ MAG	VARIABLE MAG	CONJ MAG FIX ITI	FR 1	CONJ MAG ITI
CONJ MAG FIX IRI	*	*	*	*	---
CONJ DELAY MAG	*	*	*	*	---
CONJ DELAY	*	*	*	*	*

Note: An asterick indicates that the standard deviations of the mean PRP did not overlap between two conditions for six of eight subjects.

Figure 4. Relative percentage distribution of pre-ratio
pause durations occurring in the last 5 sessions
of each condition for M11.

BIRD - M 11

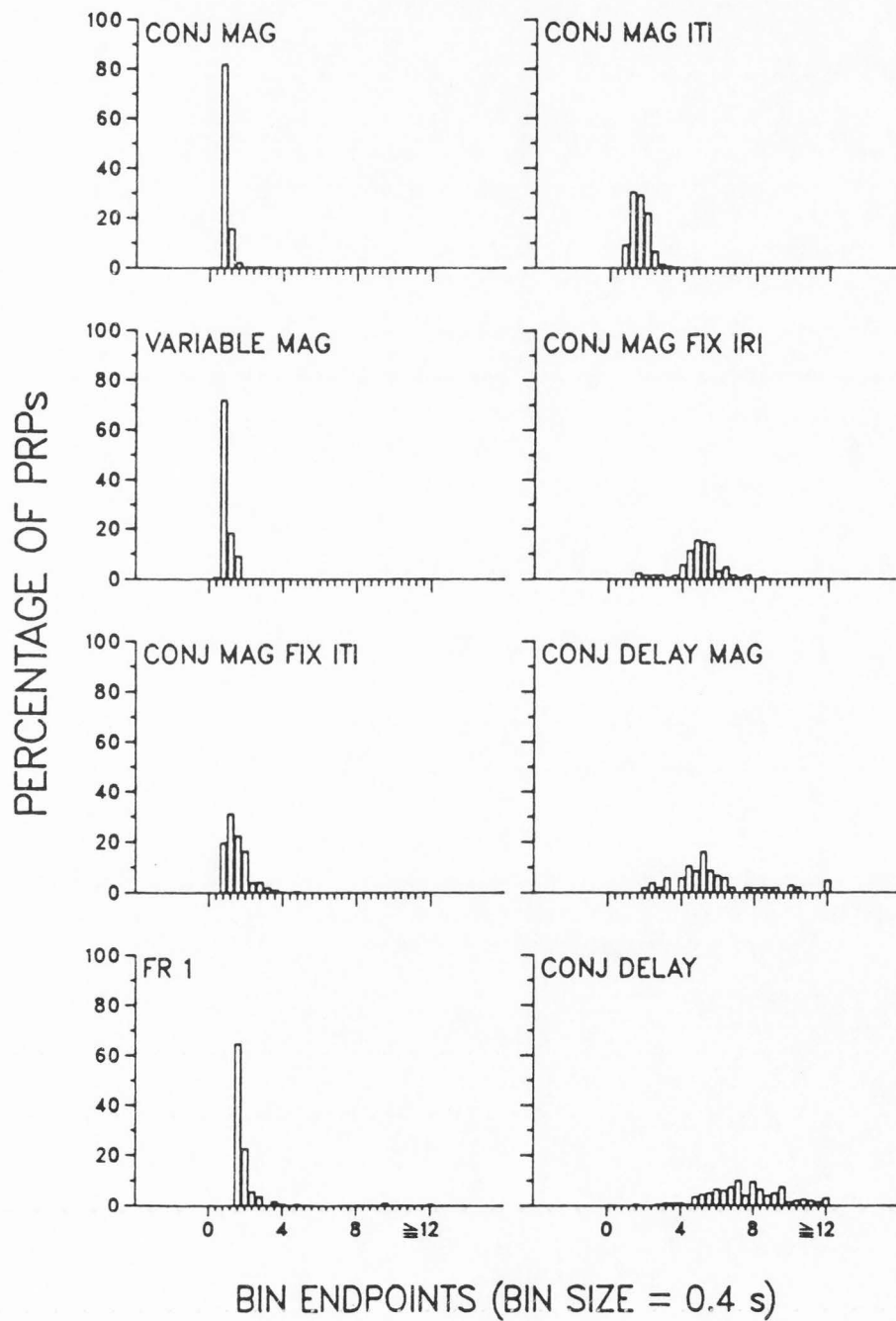


Figure 5. Relative percentage distribution of pre-ratio pause durations occurring in the last 5 sessions of each condition for M12.

BIRD - M 12

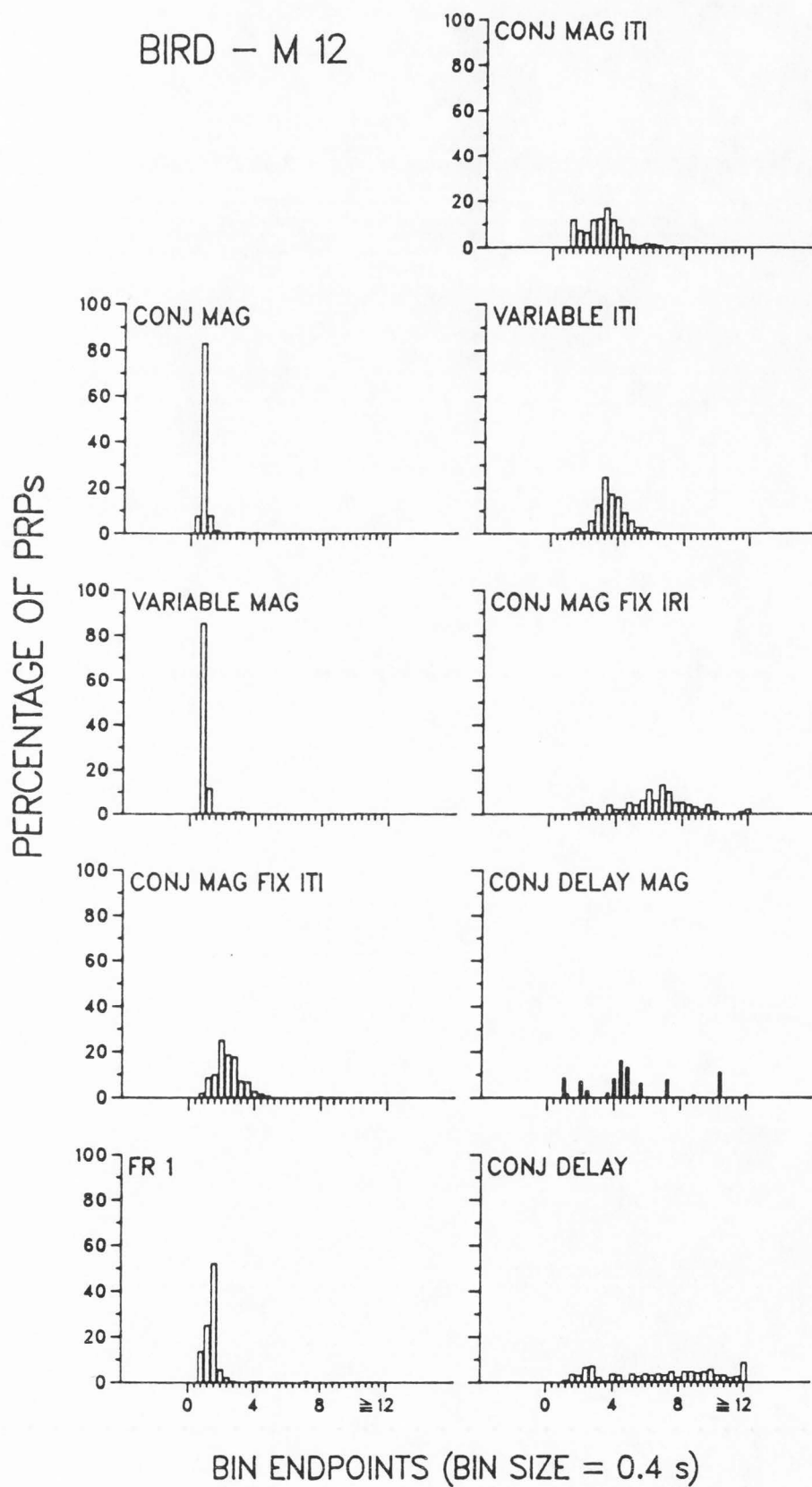


Figure 6. Relative percentage distribution of pre-ratio pause durations occurring in the last 5 sessions of each condition for M13.

BIRD - M 13

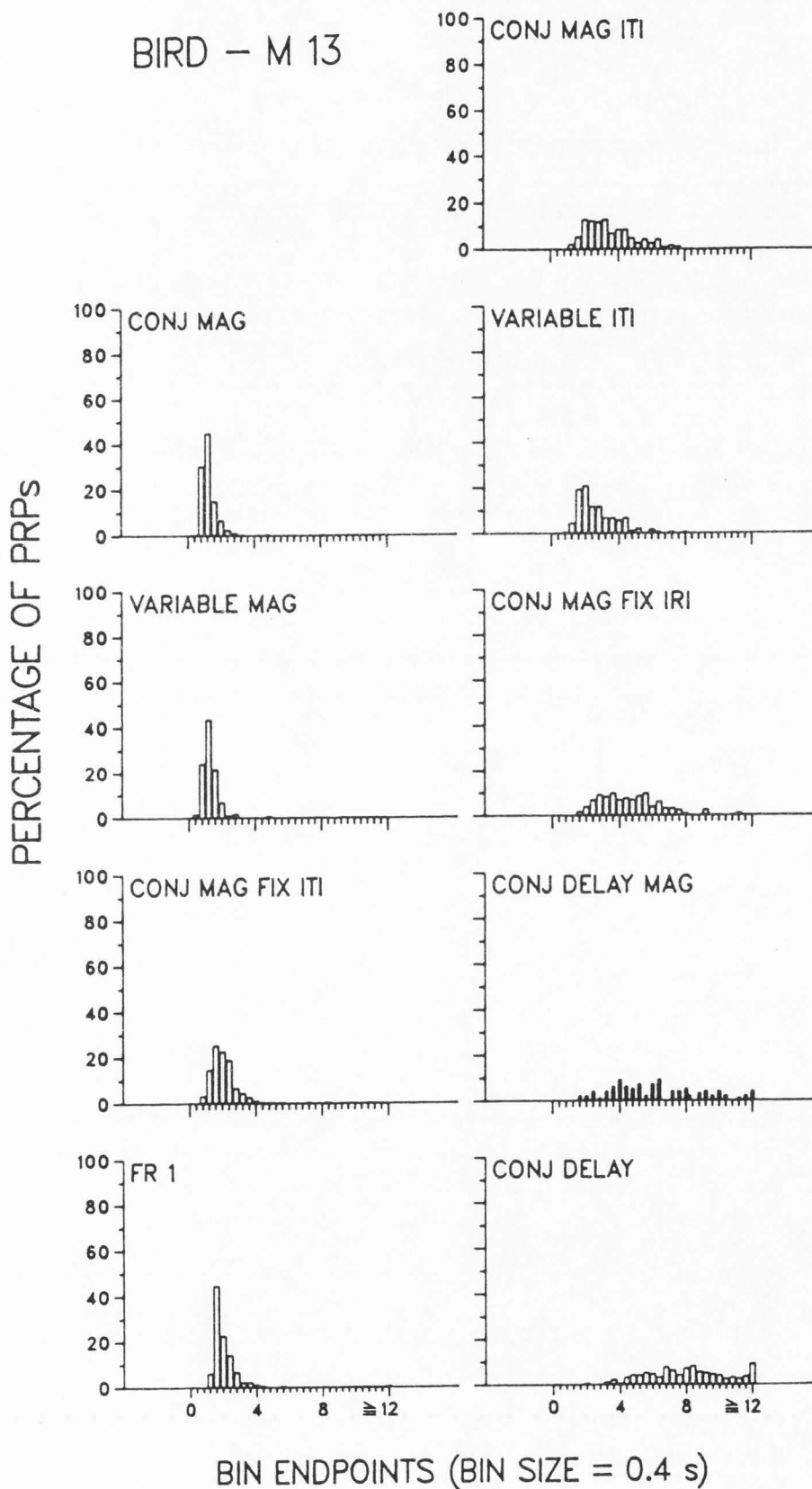


Figure 7. Relative percentage distribution of pre-ratio pause durations occurring in the last 5 sessions of each condition for M14.

BIRD - M 14

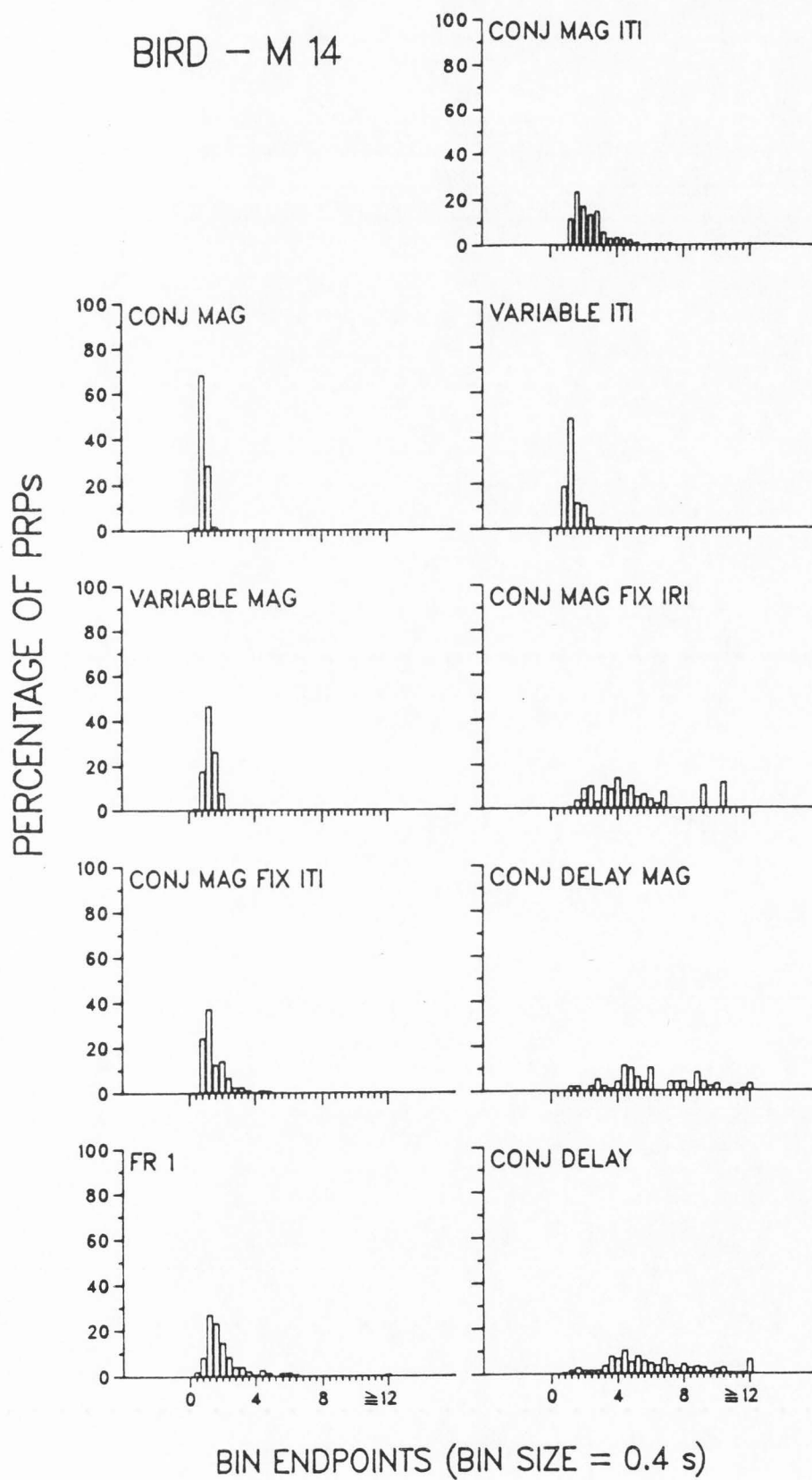


Figure 8. Relative percentage distribution of pre-ratio pause durations occurring in the last 5 sessions of each condition for M15.

BIRD - M 15

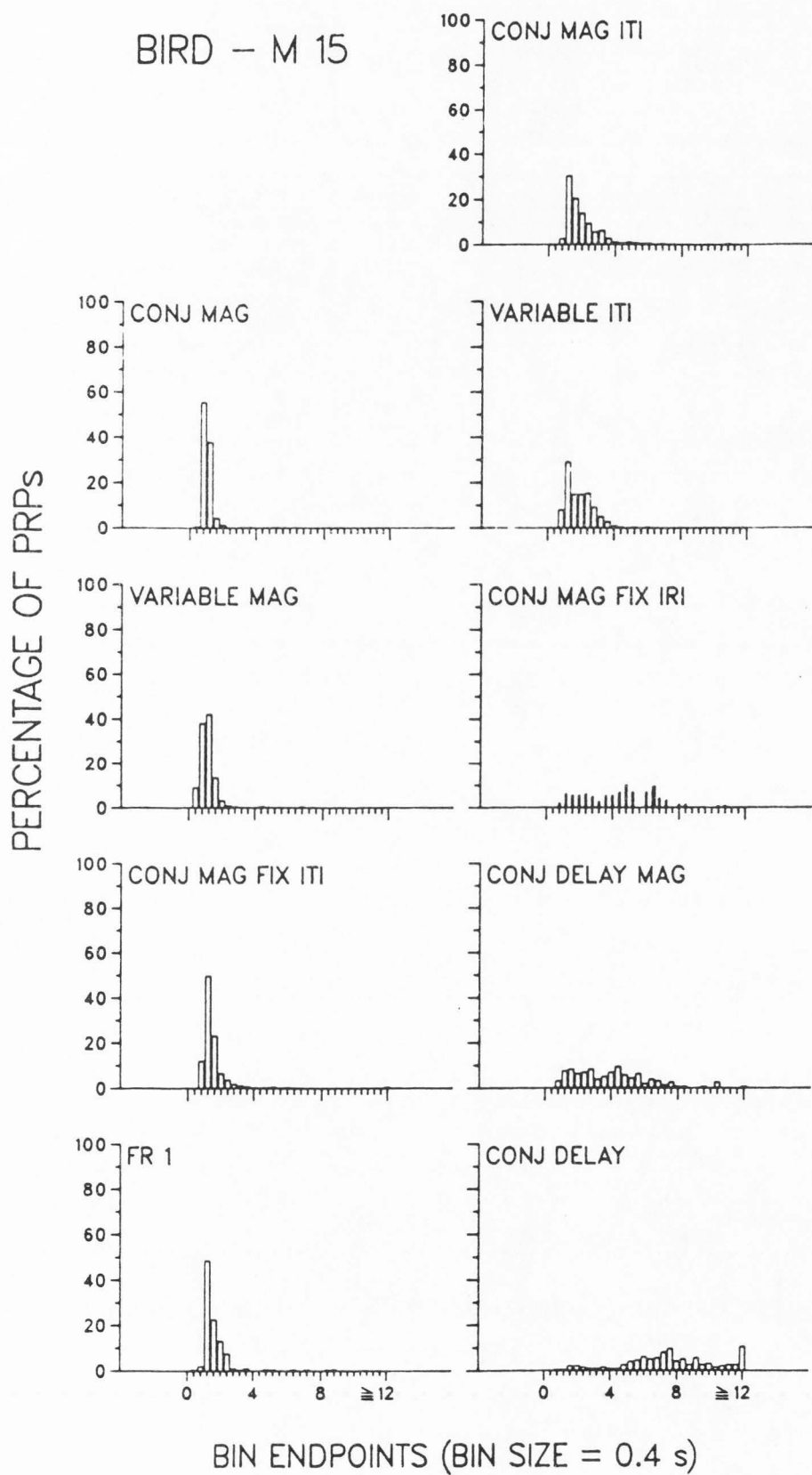


Figure 9. Relative percentage distribution of pre-ratio pause durations occurring in the last 5 sessions of each condition for M16.

BIRD - M 16

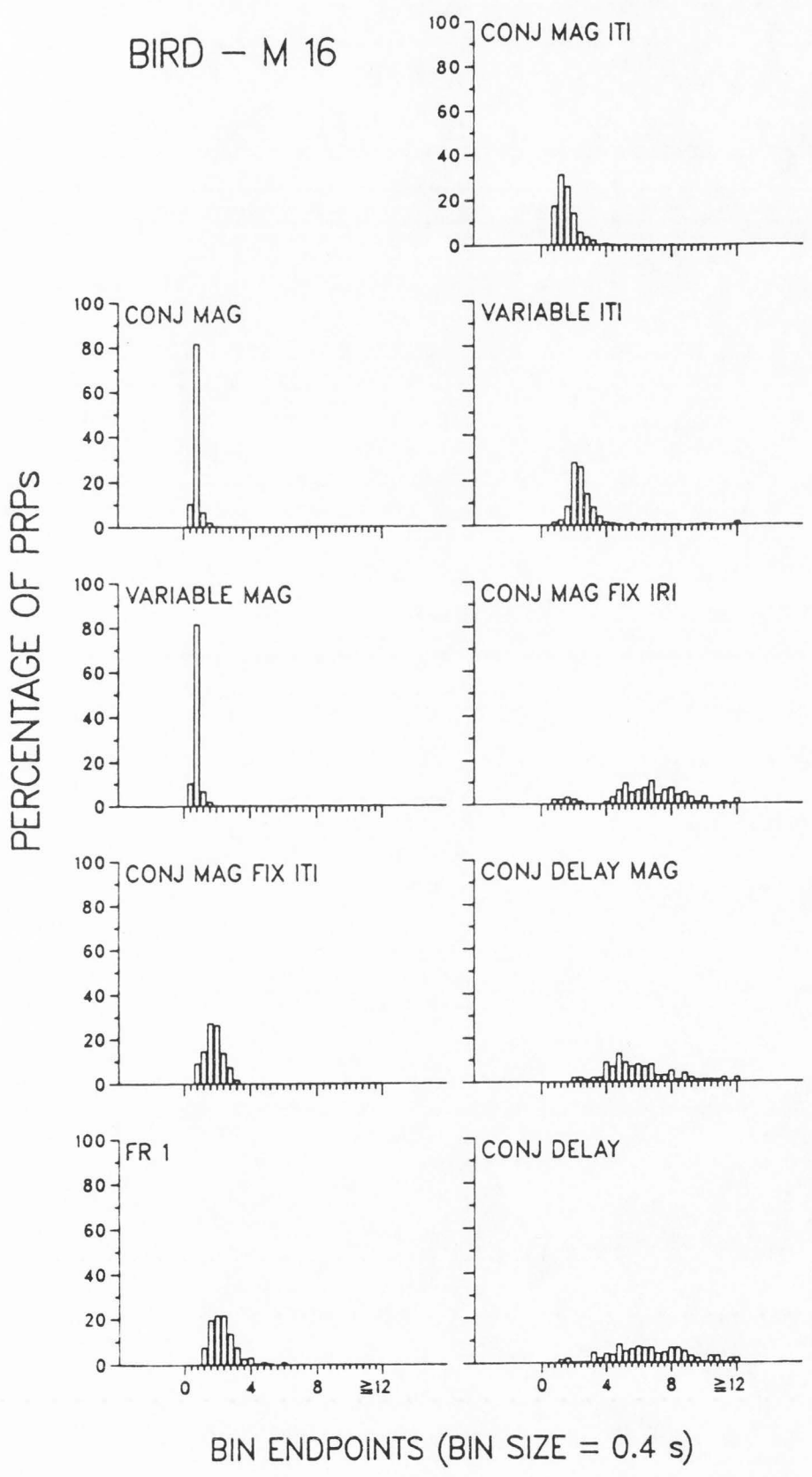


Figure 10. Relative percentage distribution of pre-ratio
pause durations occurring in the last 5 sessions
of each condition for M17.

BIRD - M 17

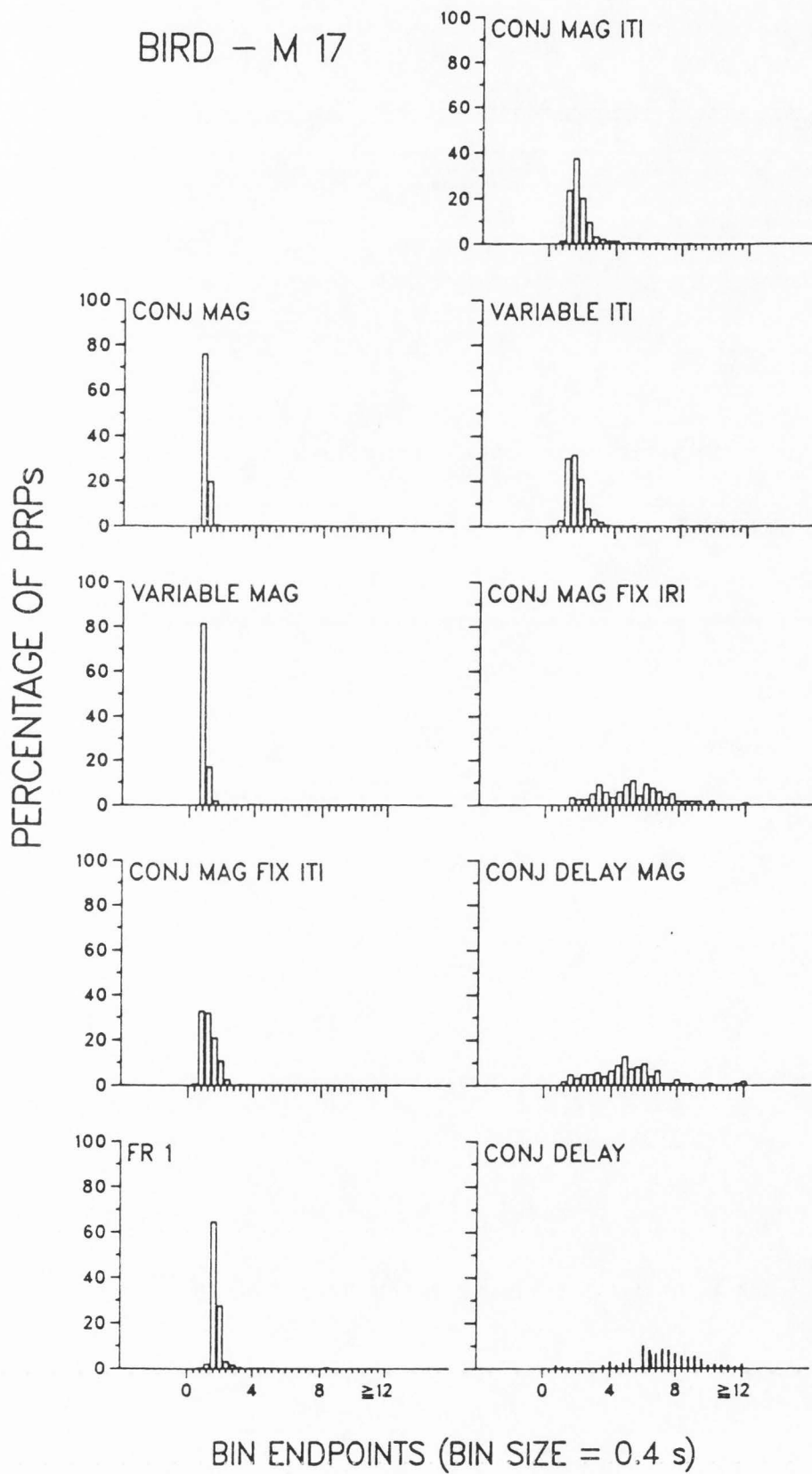
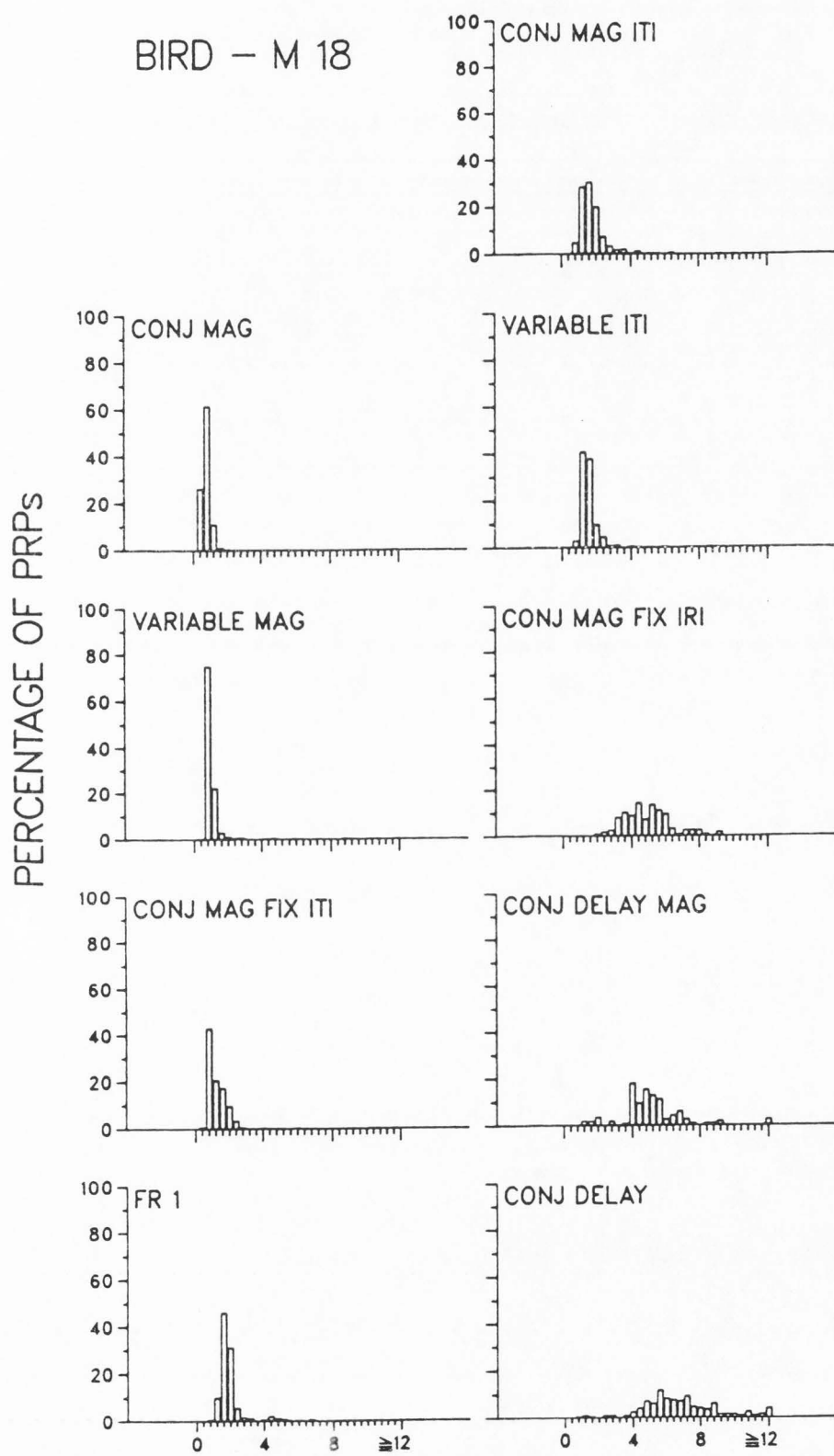


Figure 11. Relative percentage distribution of pre-ratio
pause durations occurring in the last 5 sessions
of each condition for M18.

BIRD - M 18



BIN ENDPOINTS (BIN SIZE = 0.4 s)

no contingency was in effect between PRP duration and duration of reinforcement. This statement was derived from comparison between experimental conditions which contained a contingency equating PRP duration and food-hopper duration with experimental conditions which did not specify a relation between food-hopper and PRP durations. The present experiment permits evaluation of three such between-condition comparisons. These comparisons yield the following results: (a) PRP durations do not reliably differ between CONJ MAG and FR 1; (b) PRP durations on CONJ DELAY MAG and CONJ DELAY did not reliably differ; and (c) PRP durations on CONJ MAG FIX IRI did not reliably differ from the mean PRP duration on CONJ DELAY (see Table 2). That is, because reinforcement duration did not reliably exert control over PRP duration, the behavior of subjects did not produce the maximum duration of food-hopper presentations. For example, whereas the maximum food-hopper duration was 16 s per cycle on CONJ MAG, subjects consistently produced a mean hopper duration less than 1 s (except B13 with a mean PRP of 1.03 s).

The variability of different PRP durations can be analyzed both from the numerical value of the SDs presented in Table 2 and, in more detail, from the PRP distributions presented for individual subjects in Figures 4 through 11. The PRP distributions shown represent the percentage of responses during the last five days of each condition that

fell into one of 30 bins. Bin size was 0.4 s, except for the largest bin, which included all PRP durations 11.6 s and longer.

Relative frequency distributions of PRP durations were compared to further evaluate the effect on PRP duration of a reinforcement magnitude duration contingency. The FR 1 condition (no reinforcement magnitude contingency), produced a more platykurtic distribution and greater variability among conditions than did the CONJ MAG condition (reinforcement magnitude contingency). That is, on the FR 1 condition, a reduced percentage of PRP durations fell into just one bin and PRP durations were distributed within a larger number of bins for all subjects. This relation was also presented in numerical form in Table 2, which indicates that for all subjects, the standard deviation of PRPs is larger for FR 1 than for CONJ MAG. Additionally, the shapes of both sets of PRP distributions are unimodal, with the largest percentages of PRP durations falling in one bin (M16 represents an exception).

When comparing the CONJ MAG FIX IRI and CONJ DELAY MAG conditions (both including a reinforcement magnitude contingency) to the CONJ DELAY (no contingency) condition, relative frequency distributions of PRP durations do not reliably differ. Recall, comparisons among these same conditions also showed no reliable differences in mean PRP duration. Examination of Figures 4 through 11 show that

although some subjects show a shift toward longer PRPs in the CONJ DELAY condition (M11, M13, M15, M17, M18), the difference is not reliably present in three of the eight subjects (M12, M14 and M16).

Reinforcement Magnitude Variability

A number of comparisons are available to evaluate the effect of variable versus fixed hopper duration (reinforcement magnitude variability). That is, the trial-to-trial variation in the duration of food-hopper presentation may control PRP duration irrespective of the absolute duration of the food-hopper or its contingent relation to PRP. To evaluate the effect of varied- versus fixed-hopper duration within sessions, the most direct comparison is between the VARIABLE MAG and FR 1 conditions, which differ only in whether the food-hopper is presented for a variable versus a fixed duration. From Figure 3 and Table 2 it can be concluded that due to overlap in standard deviations, PRP durations on VARIABLE MAG and FR 1 do not reliably differ. In addition, the duration of PRPs on VARIABLE MAG are nearly identical to those produced on CONJ MAG. This similarity between mean PRP durations demonstrates that variation in the duration of food-hopper presentations does not differentially control mean PRP duration and provides further evidence that the reinforcement magnitude contingency fails to control mean

PRP durations. The lack of control exerted by reinforcement magnitude variability is also seen in the similarity of PRP durations between CONJ MAG FIX IRI and CONJ DELAY, and between CONJ DELAY MAG and CONJ DELAY.

Numerical comparisons of the standard deviations presented in Table 2 and visual examination of Figure 3 suggest that for all subjects, the VARIABLE MAG and CONJ MAG conditions produced similarly smaller standard deviations relative to all other conditions. In addition, Figures 4 through 11 also show that, for all subjects, the CONJ MAG and VARIABLE MAG distributions were the least variable of all conditions studied, with PRP durations distributed among fewer bins than in any other condition. In summary, the primary effect of reinforcement magnitude variability, on conditions which exclude blackout (BO), is to reduce the variability, not the mean of the PRP durations. In addition, the similarity of CONJ MAG and VARIABLE MAG PRP frequency distributions provides further evidence of the lack of control of the reinforcement magnitude contingency over PRP durations.

The Effects of Blackout (BO)

BO After Reinforcement: ITI

Fixed-duration BO versus no BO. The duration of the mean PRP did not change when a fixed duration BO (after reinforcement) was added to the conjugate magnitude

procedure. Both visual representations presented in Figure 3 and numerical comparisons in Table 2 demonstrate that because of the variability of PRPs, the duration of the mean PRP on CONJ MAG FIX ITI was not reliably different from that on CONJ MAG.

Some differences between conditions are apparent upon inspection of the relative frequency distributions for these conditions. For each subject, the CONJ MAG FIX ITI procedure produced a more variable, platykurtic distribution than the corresponding CONJ MAG condition. That is, PRP durations were distributed within a larger number of bins and the percentage of PRP durations categorized within any one bin was smaller. This implies that the primary effect of inserting a fixed-duration blackout after reinforcement, thereby increasing the IRI, was to increase the variability, not the mean duration of the PRP. Furthermore, comparisons among conditions presented in Figures 4 through 11 demonstrate that the platykurtic shape of the relative frequency distribution of PRPs is present in all conditions which present a BO, irrespective of whether the BO was before or after the response. The platykurtic shape is not present in the three conditions, FR 1, CONJ MAG, and VARIABLE MAG, which did not include a BO. Irrespective of whether its duration was (a) variable or fixed, (b) contingent or noncontingent on responding, or (c) before or after reinforcement, the most consistent consequence of

Inserting a blackout into an FR 1 schedule was to an increase PRP variability, but not necessarily PRP duration. That is, as IRI increased, the variability of the PRP also increased.

Varied duration versus fixed-duration BO. The effect of variable duration blackout was determined by comparing mean PRP durations on CONJ MAG ITI and VARIABLE ITI to PRP durations produced on CONJ MAG FIX ITI. In general, there was no reliable difference between mean PRP durations on the basis of whether the BO after reinforcement was of fixed (CONJ MAG FIX ITI) or variable (CONJ MAG ITI and VARIABLE ITI) duration (see Figure 3 and Table 2). For all subjects except M11 and M14, the relative frequency distributions show a relatively minimal range (fewer bins), with a platykurtic shape for the fixed duration condition (CONJ MAG FIX ITI) condition, with more variability and a more pronounced platykurtic shape among the conditions presenting a variable duration BO (CONJ MAG ITI and VARIABLE ITI).

BO Before Reinforcement:
Delay to Reinforcement

Comparison between conditions with and without BO. When a contingent, variable-duration BO occurred before reinforcement (i.e., following a response), the mean PRPs for all subjects were of longer duration than on any condition which did not include a BO (See Figure 3 and Table 2). This finding was consistent both when the BO was

relatively short and of fixed duration (CONJ MAG FIX IRI), whether a reinforcement magnitude contingency was included (CONJ DELAY MAG), as well as when BO duration was contingent on PRP duration (CONJ DELAY). These conditions can be compared to those conditions that included no BO (CONJ MAG, VARIABLE MAG, AND FR 1) all of which produced shorter mean PRPs with no standard deviation overlap for at least 6 of 8 subjects. The size of the difference in mean PRP durations is large enough to make this conclusion, despite larger SDs on the CONJ MAG FIX IRI, CONJ DELAY MAG, and CONJ DELAY conditions. It is evident that as PRP duration increased, the variability of PRP duration also increased.

Comparison between conditions with BO located after reinforcement. The effects of BO location on PRP duration can be evaluated by comparison among conditions in which a BO was presented either after the response (CONJ MAG FIX IRI, CONJ DELAY MAG, AND CONJ DELAY), to conditions in which the BO was presented before the response (CONJ MAG FIX IRI, CONJ DELAY MAG, and CONJ DELAY). In all conditions in which a BO was presented before reinforcement (CONJ MAG FIX IRI, CONJ DELAY MAG, and CONJ DELAY) there were systematic differences in PRP durations from those conditions in which a BO was presented after reinforcement (CONJ MAG FIX ITI, CONJ MAG ITI, and VARIABLE ITI). However, separate comparisons between pairs of conditions suggest that interactions between BO location and the other independent

variables examined are reflected in the data. Examination of Figure 3 and Table 2 show that the mean duration of the PRP on the CONJ MAG FIX ITI condition was less than the mean PRP on any of the conditions in which a BO was presented between the response and reinforcement (CONJ MAG FIX IRI, CONJ DELAY MAG, AND CONJ DELAY). Similarly, PRP duration on CONJ MAG ITI (BO before the response) was shorter than on CONJ DELAY (BO after the response).

It cannot, however, be concluded that the position of BO controls PRP duration. This is because consistent differences are not present between all conditions in which a BO was presented before the response and conditions in which a BO followed the response (i.e., between CONJ MAG ITI and CONJ MAG FIX IRI, between CONJ MAG ITI and CONJ DELAY MAG, VARIABLE ITI and CONJ MAG FIX IRI, between VARIABLE ITI and CONJ DELAY MAG, and between VARIABLE ITI and CONJ DELAY). In the present study in all three delay conditions a BO duration, which was contingent on PRP duration, was presented. A fixed IRI might also be a necessary condition in obtaining the heightened PRP effect, because this factor, as well, was common only to the three delay conditions. However, mean IRI, which was controlled in the CONJ MAG ITI condition, produced relatively short PRPs. Thus, fixed IRI alone could not account for the shorter duration PRP on the CONJ DELAY condition. An analysis of the relative frequency distributions (Figures 4 through 11) indicates that, in all

three delay conditions (CONJ MAG FIX IRI, CONJ MAG ITI, and CONJ DELAY MAG), variability was large, frequently lacking a distinctive primary mode. This supports the notion that the primary effect of increasing the IRI, whether with a BO before or after the response, was to increase the variability, not the duration of the PRP.

A Summary of the Findings

The current study examined the effects of a number of FR 1, conjugate reinforcement procedures, measured in terms of mean PRP durations and relative PRP frequency distributions. Examination of conjugate reinforcement magnitude and delay effects consisted of varying the duration of several parameters of reinforcement contingent on responding. The current study consisted of nine conditions, permitting 36 pairwise comparisons. Thirteen of these comparisons yielded mean differences when criteria for within and between subject variability were considered. The effects obtained are summarized as follows:

1. A contingently varied BO before reinforcement (following the response) produced the longest duration mean PRPs and the PRP distributions with the most variability.
2. Insertion of a BO after reinforcement, whether varied or fixed, contingent or not, did not produce mean PRP durations reliably different from conditions with no BO. No consistent differences in variability of the distribution of

PRPs were found between conditions with BO located before the response and conditions without BO.

3. A BO inserted after reinforcement (ITI), whether variable or fixed duration, did not differentially affect the duration of the mean PRP. That is, the position of BO did not, in and of itself, control PRP duration since consistent differences were not present between those conditions in which a BO was presented before the response and conditions in which a BO followed after the response.

4. The primary effect of inserting a fixed-duration blackout, thereby increasing the IRI, was to increase the variability, not the mean duration of the PRP. That is, as the IRI increased, the variability of the PRP also increased.

5. Varying reinforcement magnitude, contingently or not, did not reliably affect mean PRP duration when compared to mean PRP duration obtained on FR 1. The primary effect of reinforcement magnitude variability was to reduce the variability, not the duration, of the PRP.

DISCUSSION

The results of this study demonstrated that the major independent variable which controlled mean PRP duration on the various conjugate reinforcement schedules studied was the delay between the response and reinforcement. The duration of the PRP was not reliably controlled by a contingency which equated reinforcement duration with PRP duration, nor by a contingency which, through imposition of a delay to trial onset, decreased the overall density of reinforcement while holding the local delay to reinforcement constant. Additionally, cycle-to-cycle variation in reinforcement magnitude, whether presented contingently or noncontingently on PRP duration, had no reliable effect on PRP duration when compared to FR 1. The primary effect of variation in the duration in reinforcement was to reduce the variability, not the duration, of the PRP.

Conjugate Delay and ITI: Controlling Factors

One purpose of the present experiment was to determine whether conjugate schedules, designed to contingently manipulate the temporal parameters of reinforcement (i.e., the duration of a BO following or preceding the response) would be effective in shaping longer PRPs on FR schedules. The results of this experiment suggested that the effect of BO was dependent on its position relative to the response

and reinforcement. Specifically, a contingently varied BO before reinforcement (following the response) produced the longest duration mean PRP and the PRP distribution with the most variability. A contingently varied BO after reinforcement (before the response) did not consistently increase mean PRP duration or variability of the relative frequency distribution of PRPs. That is, the effect of an increase in IRI duration through the use of BO was dependent on the location of the BO relative to the response and reinforcement. Neither the insertion of a contingent-duration BO (or delay) between the response and reinforcement increased PRP duration, nor the insertion of a contingent-duration BO after reinforcement (before the response) increased the IRI duration but the BO after reinforcement did not produce an increase in mean PRP duration or variability of the relative frequency distribution of PRPs.

This general finding is consistent with the majority of the BO literature. The most typically reported result is that BO weakens responding, either by decreasing response rate (e.g., Richards, 1981) or by increasing PRP (e.g., Meunier & Ryman, 1974). The only exception to this general finding occurred when BOs followed reinforcement on FR schedules. In this case post-blackout pauses (PBPs) were shorter than PRPs (Mazur & Hyslop, 1982; Richards & Blackman, 1981). In these studies, it was not apparent

whether this effect was due to BO position on an FR schedule, within-session variation of BO duration, or some combined effect of the two independent variables. However, in the current study, BO position clearly accounts for the shorter PRPs produced by the contingent-duration BO following reinforcement.

BO After the Response:
Delay to Reinforcement

The major finding of the current study was that when BO duration following a response varied contingent on PRP duration, PRP duration increased (i.e., from 1.5 or 2 s to approximately 7 s for all subjects). This change is much larger than has been demonstrated via non-contingent manipulation of BO duration (Meunier & Ryman, 1974; Morgan, 1972; Topping et al., 1973). One advantage of the current study was that BO was manipulated independently of concomitant changes in the IRI. This confound is frequently not controlled on FR schedules (e.g., Meunier & Ryman, 1974).

Despite the relatively large effect of conjugate delay on PRP, compared to conjugate magnitude procedures, the question to be addressed is: Why did subjects not emit the maximum duration PRP (16 s) during the conjugate delay condition, thereby resulting in immediate presentation of the food-hopper? During the delay conditions, PRPs of 16 s produced immediate reinforcement, did not increase the IRI,

and therefore were optimal. The answer is not that the delay contingency was not sampled, because variability of PRP durations increased dramatically during delay conditions. Nor was the less than optimal performance due to insufficient exposure to contingencies, because stability criteria were strict and conditions were usually conducted for 20-30 sessions.

One, post-hoc hypothesis is that the delay contingency was counteracted by the tendency for PRPs to be shortened by short delays. In other words, short delays alone would produce an excitatory effect, shortening PRPs (e.g., Barowsky & Mintz, 1978; Meunier & Ryman, 1974). Therefore, a subject might emit a long PRP, thereby producing almost immediate reinforcement. In turn the immediacy of that reinforcer would create an excitatory effect, which would tend to shorten PRP, but via the contingency, also increase the BO delay. That this cycle would maintain, is consistent with the variability of PRPs produced during delay conditions. Additional research is needed to test this hypothesis. Perhaps the simplest test would be a contingency reversal, whereby a positive PRP-delay correlation (a contingency which would differentially reinforce relatively short PRP durations) was experimentally maintained.

BO Before the
Response: ITI

Although the current study found that PRP contingent BO located after the response, reliably increased mean PRP duration, PRP increases were much less consistent when the contingent duration BO was inserted immediately preceding the response, that is directly following reinforcement (ITI). This finding is consistent with the findings of Barowsky and Mintz (1975), who reported that the earlier the delay to reinforcement is inserted in a ratio (e.g., after the 10th versus the 50th response), the shorter are the pre-ratio pauses. However, other researchers have demonstrated that increases in ITI duration do not result in corresponding changes in PRP duration (i.e., when BO was located before the response). The decrease in mean PRP duration reported in studies associated with a decrease in ITI duration (Mazur & Hyslop, 1982; Richards & Blackman, 1981), may reflect behavioral contrast due to within session variation of BO durations thereby indirectly affecting reinforcement density.

Another possible explanation for the effect of contingent post-response BO, compared to contingent post-reinforcement BO is provided by Dews (1981). Dews demonstrated that breaking the contiguity of the response-reinforcer relation was a more important determinant of responding than was decreasing the frequency of reinforcement. Dews reported that a much lower rate of

responding resulted from the schedule that interrupted the response-reinforcer contiguity than from an otherwise equivalent schedule that lengthened IRI duration equally, without disrupting contiguity. The results of the current study support the interpretation of the effect of BO proposed by Dews (1981). Although procedures which located BO before and after the response presented identical overall densities of reinforcement, the BO that disrupted the temporal association between the response and reinforcer (delay) was more effective in increasing PRP duration than the BO that did not impose a delay between the response and reinforcer.

Reinforcement Duration and Other Temporal Variables

The results of pilot research (Bonem & Crossman, 1984) conducted prior to the current study indicated that although a reinforcement magnitude contingency effect could be obtained when the reinforcer duration was 2, 4, 8, or 16 times the duration of the PRP, no effect was seen when the ratio of hopper to PRP duration was 1:1. It was thought that the lack of an effect with the original procedure may have been due, either, to a fixed BO following the reinforcer or to the fact that although long PRPs produced longer hopper durations they also decreased the overall frequency of reinforcement. Both hypotheses have support from different literatures. Mazur and Hyslop (1982) and

Richards and Blackman (1981) had both demonstrated that fixed-duration BOs, located following reinforcement, reduced PRPs on FR schedules. Hendry and Van-Toller (1964), who did not obtain an effect when attempting to lengthen interresponse times (IRTs) on FR schedules, had suggested that the correlated magnitude contingency was counteracted by the stronger, frequency of reinforcement factor. That is, long IRTs produced more reinforcement, but longer IRIs.

The current study tested these two hypotheses by conducting several comparison conditions. As reported in the results, a reinforcement magnitude contingency that programmed a contingent-duration, post-reinforcement BO did not produce longer duration PRPs than occurred during the condition presenting contingent magnitude of reinforcement without a BO. Thus, the hypothesis that a post-reinforcement BO had countered a magnitude effect in the original procedure, was unfounded.

This conclusion, although differing from some reported in the literature, is not inconsistent with reinforcement theory. If BO is aversive, signaling the unavailability of reinforcement, then it is not surprising that BOs produce longer PRPs. Perhaps reports of shorter PRP durations on procedures interpolating periods of BO are more surprising (Mazur & Hyslop, 1982; Richards & Blackman, 1981). The authors of these studies suggested that their results may

have been due to behavioral contrast. On the other hand, the current study may have precluded a contrast effect by varying blackout and nonblackout between experimental conditions rather than within sessions. That BO lengthened PRP durations in the present study, again contradicts Harzem and Harzem's (1981) inhibitory aftereffect theory that predicts that the inhibitory effect of the reinforcer should dissipate during post-reinforcer BO, thus reducing PRP. Harzem and Harzem's (1981) BO studies may have also been examples of behavioral contrast, having varied BO and no BO components within sessions.

The second hypothesis, which tested whether manipulating reinforcement frequency produces a reinforcement magnitude effect, compared reinforcement magnitude contingency conditions which differed in that one condition varied the duration of a post-reinforcer BO to prevent PRP duration from influencing the frequency of reinforcement. Under these conditions the theory of maximization predicts that longer PRPs would be produced during the procedure that fixed reinforcement frequency independent of PRP. During the reinforcement magnitude condition which fixed reinforcement frequency, PRPs were not longer than during the reinforcement magnitude procedure that allowed reinforcement frequency to vary. It was determined that the mean PRP durations produced during this condition were not longer in duration than on the FR 1

condition. Thus, the maximization model was inadequate to predict the obtained results.

Other procedures presented here utilized variable duration BOs before the reinforcer to equate IRIs from one ratio to the next. In these cases, the effect was larger. However, one cannot definitively conclude that the increased duration of the mean PRP was due to the increased effectiveness of the reinforcement magnitude contingency because no evidence of a reinforcement magnitude effect was found in this study. A more parsimonious conclusion is that the increase in mean PRP duration was the result of an additive effect of the delay contingency.

Conjugate Magnitude: Controlling Factors

At the outset of the study, it was predicted that the addition of a reinforcement magnitude contingency to an FR 1 schedule would increase mean PRP duration. The magnitude of reinforcement contingency stipulated a direct relation between duration of access to reinforcement and duration of the PRP. A detailed review of the literature had indicated that while some researchers had reported difficulty in producing a reinforcement magnitude effect (e.g., Catania, 1963), magnitude of reinforcement could produce an effect, provided certain conditions were maintained. Indeed, the literature indicated that the most likely method of ensuring

a reinforcement magnitude effect was to incorporate a contingency on magnitude of reinforcement.

Although a reinforcement magnitude contingency had not been applied on FR PRPs, it had been successfully applied on a variety of other procedures. Reinforcement magnitude effects have repeatedly been produced on both concurrent (e.g., Catania, 1963; Dunn, 1982; Young, 1981) and correlated schedules (Gentry & Eskew, 1984; Hendry, 1962). In the present study, a conjugate reinforcement procedure was not effective as a means of producing a reinforcement magnitude effect on an FR schedule. That is, varying reinforcement magnitude, contingently or not, did not reliably affect mean PRP duration when compared to FR 1. The primary effect of variation in the magnitude of reinforcement was to reduce the variability, not the duration, of the PRP.

One question to be addressed is why mean PRP duration was not affected by the magnitude of reinforcement contingency. A reexamination of the literature which has reported magnitude of reinforcement effects reveals several methodological differences from the present study. Harzem and Harzem (1981) reported increases in PRP durations as a function of reinforcement magnitude, using concentration of a liquid reinforcer, not duration of access to the food-hopper as the operational definition of reinforcement magnitude. In fact, nearly all of the studies which Harzem

and Harzem (1981) cite in support of the unconditioned inhibitory interpretation of reinforcement magnitude effects are restricted to studies involving reinforcer concentration. The present study does not definitively contradict the notion of unconditioned inhibitory effects of reinforcement on mean PRP because the results of the study might simply reflect an ineffective contingency, i.e., a contingency which was never contacted. If this were the case, the obtained reinforcers were no different in duration than on FR 1.

There is, however, evidence that the contingency was contacted. All subjects produced occasional, long PRPs. Long PRPs would not only expose responding to the contingency but, according to the unconditioned inhibitory account, would produce a local inhibitory effect which would be expected to spread with continued exposure to the procedure. Both the contingency and the inhibitory effects would produce longer PRP durations. Therefore, the results of the current study do not support Harzem and Harzem (1981). The magnitude effects reported by Harzem and Harzem may be specific to the method of manipulating the magnitude of reinforcement.

Variable Duration Reinforcement

An important question must now be raised: Why was the reinforcement magnitude duration contingency not effective in lengthening PRP? Thus far, it has been determined that

the effect was not prevented by the various temporal factors that can come to control responding. In hypothesizing about which aspects of a PRP contingency that determine magnitude duration might contribute to a magnitude effect, it was noted that the CONJ MAG condition differed from an FR 1 schedule in that reinforcement magnitude duration was both contingent and variable in duration. To separate the effects of contingency from magnitude variation, a condition which varied magnitude, independently of responding (yoked to a conjugate magnitude condition) was programmed. That the magnitude contingency and the variable magnitude conditions produced PRPs of durations similar to FR 1 provides strong evidence that variable duration reinforcement does not have an effect when presented as part of a magnitude contingency designed to increase PRP duration.

The findings of the present investigation are consistent with a study by Essock and Reese (1974), which found that varying reinforcement duration resulted in increased overall response rates on multiple and concurrent FR schedules. However, the other magnitude contingency procedures reported in the previous literature review were effective even though they involved within-session variation of magnitude. These studies involved measures other than PRP such as: (a) IRTs (Hendry, 1962); (b) running speed (Logan, 1960); (c) frequency of choice of a concurrent

component (e.g., Gentry & Eskew, 1984); and (d) time allocation (Brownstein, 1971). Furthermore, reinforcement magnitude contingency studies did not frequently involve FR schedules. In fact, Hendry and Van-Troller (1964) reported the only failure involving a contingent arrangement between magnitude of reinforcement and responding. Thus, from the present study, one can conclude that the contingency, that specified reinforcement magnitude as a function of PRP duration, did not reliably reduce the duration of the mean PRP. This demonstrates a reinforcement magnitude contingency is neither a necessary, nor a sufficient condition for producing a reinforcement magnitude effect on mean FR PRP duration.

Response-Independent Magnitude of Reinforcement Duration

The majority of studies, investigated in the review section of this manuscript, manipulated reinforcement duration independently of responding (e.g., Powell, 1969). When a PRP reinforcement magnitude effect was demonstrated, it was generally found that increased reinforcer durations produced decreased PRP durations. Thus, it was possible that the reinforcement magnitude contingency was confounded with an excitatory effect of reinforcer duration which has been invoked to explain the failure to obtain effects in manipulating response-independent reinforcement magnitude. However, when one considers the findings of this study,

there is no evidence to support this claim. For instance, the CONJ MAG contingency produced extremely short reinforcer durations, somewhat shorter than those obtained during FR 1. It was predicted that short hopper durations would contribute to the production of long PRPs, which was clearly not the result obtained here. It was possible however, that a reinforcement magnitude contingency effect was obviated in those procedures that delivered longer duration hopper presentations (e.g., CONJ MAG FIX IRI and CONJ DELAY MAG). However, in these instances, this interpretation appears inaccurate, because reinforcer duration was longer on the CONJ DELAY MAG (than on the CONJ MAG FIX IRI) condition, yet PRPs were longer. Thus, in this experiment, neither response-contingent nor an excitatory (PRP decreasing) effect of reinforcement duration produced the predicted effect.

Concluding Remarks and Suggestions for Future Research

The research presented here examined some unusual kinds of contingencies, and, as such, provides data that are useful to an understanding of the interplay of various factors in determining how contingencies of reinforcement come to control behavior. Generally, a contingency is designed such that a set of response requirements can be fulfilled, or not, depending on factors related to the experimental situation and the organism. If the criteria

are met, reinforcement is delivered; if the criteria are not met, reinforcement is withheld. Gentry and Eskew (1984) have referred to this type of procedure as, all-or-none. However, such a description does not encompass the functional relations established via correlated and conjugate schedules. The current research was designed to extend the concept of contingency to include a wider variety of functional relations. Toward this end, this experiment systematically determined several variables important in establishing functional reinforcement magnitude and temporal contingencies.

As described earlier in this section, the function of a reinforcement magnitude contingency depends, in part, on the proportional PRP-reinforcement magnitude relation (Bonem & Crossman, 1984); the variability of reinforcement magnitude; the frequency of reinforcement; and whether and when BO is scheduled. Future research can provide a more complete description of how these variables operate, by further manipulating these and other parameters. For instance, one might examine how large and small reinforcement magnitude values determine the impact of reinforcement magnitude variability. One could also examine the effect of a reversal of the contingency investigated in this experiment (that is, a contingency which favors short-duration PRPs), or extend the schedule to manipulate the probability of reinforcement.

This study also determined that the control exerted by various contingencies was dependent on the following factors: (a) The relative relation between PRP and reinforcement delay (Bonem & Crossman, 1984); (b) the location of the delay; (c) whether the reinforcement magnitude and temporal contingencies were simultaneously manipulated; (d) the obtained delay durations; and (e) response-independent BO effects. In terms of the delay contingency, one direction for future research would be to evaluate whether response-independent variability of BO duration alone, could affect mean PRP duration on FR schedules. The goals of the current research were to provide a descriptive analysis of some of the variables that operate in temporal patterning of reinforcement and magnitude of reinforcement contingencies.

This experiment chose a more descriptive, less theory-testing track, for two reasons: first, at the onset of the research, it was not known which variables would need to be theoretically accounted for; and second, few theories encompass such unusual contingencies. Although, theories were not formally tested, the theoretical implications of the data were discussed earlier in this section. In brief, the findings presented here were, in part, interpretable in terms of the theory of behavioral contrast (Reynolds, 1961) and Dews' (1981) theory describing the role of response-reinforcer contiguity in determining the function of

contingency. Data here were inconsistent with the theory of the unconditioned inhibitory stimulus function of reinforcement (Harzem & Harzem, 1981) and the theory of maximization (Gentry & Eskew, 1984). The matching law (Herrnstein, 1970), having been extended from a model for predicting performance on concurrent schedules to account for multiple and concurrent chain performance, is probably the most generally applicable model of schedule performance. However, the procedures investigated in the current research do not fit the matching formulae that describe choice responding. For instance, the matching law predicts the rate or allocation of responding based on predetermined quantified properties of reinforcement obtained on several alternative schedules. The questions raised here are fruitful questions for future research: Can the matching law be extended to be relevant to ratio schedules?; Can the matching law be extended to predict PRP as the dependent variable?; and can the matching law be extended to the contingency procedures described here, where the number of "choices" available is limited only by the number of different PRP durations which can be emitted and measured and the number of different reinforcement durations that can logistically be programmed?

Together, the conjugate schedules programmed by Lindsley (1957, 1962, 1963); the correlated schedules investigated by other researchers (Gentry & Eskew, 1984;

Hendry, 1962; Hendry & Van-Toller, 1964; Logan, 1960) and the work presented here, represent only a few of the quantitative dimensions along which response-reinforcer relations might be programmed when reinforcement contingencies are manipulated as continuous, rather than discrete events. The current research establishes the independent variable, delay to reinforcement, as perhaps the most powerful determinant of PRP duration on conjugate reinforcement schedules.

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Academic Background

1978	B.A.	Western Washington University Psychology
1980	M.A.	Drake University Applied Behavior Analysis
1988	Ph.D.	Utah State University Analysis of Behavior

Professional Experience

1987-present	Assistant Professor: Eastern Michigan University. Courses taught include: Experimental Analysis of Behavior (graduate) and undergraduate courses in Self-Analysis and Control; Behavior Modification; and General Psychology.
1986-1987	Research Assistant: Outreach, Development, and Dissemination Project-Preschool Transition and Social Integration Projects. Developed behavior observation systems, curriculum, and teacher training materials for handicapped preschool children.
1984-1986	Psychology Specialist: Clinical Services Program of the Developmental Center for Handicapped Persons, Utah State University. Responsibilities included: psychoeducational evaluation and treatment of children and supervision of graduate level interns from psychology, special education, and social work.

- 1984-1985 Computer Consultant: Utah State University Joint Computer Lab, Colleges of Family Life and Education. Responsibilities included: teaching workshops (SPSS-X, Wordstar, d-BASEII, Expert, SLMicro, Tellagraf), work on various data gathering and demonstration projects, consulting to computer lab users.
- 1983-1984 Teaching Assistant: Utah State University Psychology Department, Introductory Psychology. Responsibilities included: test generation, grading, supervision of undergraduate proctors, and lectures.
- 1982-1983 Animal Lab Manager: Utah State University Psychology Department. Responsibilities included: acquisition of equipment and supplies, maintenance and repair of experimental equipment, training and supervision of research assistants, development of computer software for use in research.
- 1981-1982 Graduate Instructor: Utah State University Psychology Department, Learning and Behavior course.
- 1979-1980 Extern: Des Moines Developmental Day Care Center. Responsibilities included: treatment of behavior problems of children.
- 1978-1979 Teaching Assistant: Drake University Psychology Department, Introductory Psychology. Responsibilities included: teaching topical discussion groups, supervision of testing center and undergraduate assistants, and computer file management.

Areas of Specialization

Experimental Analysis of Behavior

My graduate training focused on human and animal research design (both group and single-subject) and the experimental literature. I have conducted research on language, schedules of reinforcement, and magnitude and delay of reinforcement. My dissertation topic involved basic research, manipulating delay and

magnitude of reinforcement as correlated with the latency of the response.

Applied Behavior Analysis and Clinical Experience

I have had extensive training and experience in evaluating psycho-educational-behavioral problems and treatment of behavior problems, completing approximately 150 comprehensive and screening evaluations, each involving intelligence testing and academic testing.

Teaching

I am currently teaching experimental analysis of behavior, self-analysis and control, general psychology, and behavior modification. In the past, I taught general psychology, learning, and assisted in two different introductory psychology courses. Both courses involved programmed systems of instruction, that is, individually based mastery systems. Other teaching includes discussion groups on nursing applications and social psychology; workshops on the use of computer software; inservice classes on individual intelligence testing, adaptive behavior assessment, and perceptual and aptitude testing.

Language

My thesis research involved training creative language in preschoolers by praising novel descriptions of photographs. The results of this research were disseminated during professional meetings, and guest lectures. I have co-authored a published paper which was a citation analysis of the experimental impact of the book Verbal Behavior (Skinner, 1957). I am currently preparing a critical review of the literature in this area.

Computer Applications

I have had a variety of computer-related experiences. As manager of an animal lab facility, I was responsible maintenance of micro-computer based systems for operating experimental animal chambers for research. I have experience writing programs in BASIC for data analysis and utilizing computer graphics

systems. I have taken graduate level classes in artificial intelligence and computer simulation. I have used the following languages and software packages: M1, XLISP, Expert, Dbase II, Wordstar, TellaGraph, BASIC, FORTRAN, PASCAL, and SL Micro. I've worked as a computer lab consultant providing approximately 150 hours of consultation.

Publications

- Bonem, M. K. & Bonem, E. J. (1980). Why a rational approach to ethics? The Behavior Analyst, 3, 57-62.
- Bonem, M. K., & Crossman, E. K. (in press). Elucidating the effects of reinforcement magnitude. Psychological Bulletin.
- Cheney, C. D., Bonem, M., & Bonem, E. (1982). Analysis of behavior: Basic Processes. Lexington, Massachusetts: Ginn.
- Cheney, C. D., Bonem, E., & Bonem, M. (1985). Change-over cost and switching between concurrent adjusting schedules. Behavioral Processes, 10, 145-155.
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- Fiechtl, B., Bonem, M., Innocenti, M., Morgan, J., Rule, S., & Stowitschek, J. (1986). Coincidental teaching: A manual and packet for training preschool staff. Logan, Utah: Outreach, Development, and Dissemination.
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- Rule, S., Bonem, M. K., Innocenti, M. S., Coor, K. J., and Stowitschek, J. J. (in press). Kindergartners' entry level preacademic skills and mainstreamed teachers' knowledge of their skills: Implications for special educators. Journal of the Division for Early Childhood.

Presentations

- Bonem, M., Bonem, E., & Cheney, C. D. (1983). The effects of change-over responses on concurrent adjusting variable-ratio schedules. Poster presented at the Rocky Mountain Psychological Association in Snowbird, Utah.
- Bonem, M. K. & Crossman, E. K. (1982). A temporal analysis of responding on multiple schedules with small fixed-ratio components. In E. K. Crossman (chair), Development of temporal patterns in small FRs: A microanalysis. Symposium presented at the meeting of the Association for Behavior Analysis, Milwaukee, Wisconsin.
- Bonem, M. K. & Crossman, E. K. (1983). Schedule interactions on multiple fixed-ratio schedules. Poster presented at the Rocky Mountain Psychological Association in Snowbird, Utah.
- Bonem, M. K. & Crossman, E. K. (1983). The effects of conjugate delay and magnitude schedules on pre-ratio pause duration. Paper presented at Rocky Mountain Psychological Association in Las Vegas, Nevada.
- Bonem, M. K. & Crossman, E.K. (1985). The separate and interactive effects of conjugate magnitude and conjugate delay on fixed-ratio 1 schedules. In E. K. Crossman (chair), Current research with ratio schedules. Symposium presented at the meeting of the Association for Behavior Analysis, Columbus, Ohio.
- Cheney, C. D., Bonem, E. J., & Bonem, M. K. (1983). Multiple determinants of giving-up time in a foraging model. Paper presented at the Western Psychological Association in San Francisco, California.
- Osborne, J. G., McPherson, A., Bonem, M., Green, G., Nittrouer, S., McConaughy, K., Petrelli, J., Serna, R., & Trapp, N. (1984). Verbal behavior: A preliminary study of its impact on research. In M. Sundberg (chair), Verbal behavior: its effects on the field of behavior analysis. Symposium presented at the meeting of the Association for Behavior Analysis, Nashville, Tennessee.

Honors/Awards

- 1980 Drake University-Special Commendations for Ethics
section of written comprehensive exams
- 1986 Utah State University- Pam Cheney Memorial
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