INDUCTION BY REINFORCER SCHEDULES

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Traditional strategies for determining whether a reinforcer schedule enhances the occurrence of an activity are reviewed and critically evaluated. A basic assumption underlying these strategies is that it is possible to isolate the effect of reinforcer intermittency on schedule induction. It is concluded that this is not, in fact, possible. An alternative approach is proposed that emphasizes the inductive effects of the reinforcer schedule as a unit and the effects of particular aspects of the reinforcer schedule (e.g., interreinforcer interval, repetition of the reinforcer, reinforcer magnitude).

Key words: schedule-induced behavior, reinforcer schedule, intermittency, baseline, schedule-induced drinking, schedule-induced attack, schedule-induced distress calling

Since Falk's (1961) observations of excessive drinking in rats exposed to an interval reinforcement schedule, the terms schedule induced and schedule induction have been applied to activities such as drinking and attack that appear to be augmented in frequency by a reinforcer schedule without a contingent relationship between that activity and the scheduled reinforcer. Due not only to similarities among these activities but also to differences between them and operant or Pavlovian conditioned behavior (cf. Wetherington, 1982), Falk (1971) suggested that such activities comprise a distinct class of responses that he called adjunctive behavior.

Although schedule-induced activities have been defined, in part, in terms of the excessive rate or frequency with which they occur, there has been considerable confusion and disagreement (Roper, 1981; Timber-

lake, 1982; Wetherington & Brownstein, 1982) concerning the criteria for specifying what constitutes excessive behavior and in thus providing a complete set of criteria for defining schedule induction. In this paper we propose such a set of criteria that we believe will be useful in providing an empirical basis for adequate theoretical development in this area. We begin by reviewing and criticizing strategies of trying to isolate intermittency in an unconfounded fashion. We then propose an alternative approach based on the assumption that intermittency cannot be isolated from other aspects of the reinforcer schedule. We conclude that when considered as a unit, a reinforcer schedule may enhance the frequencies of several activities (e.g., attack, distress calling, drinking). Furthermore, it is possible to show that several aspects of a reinforcer schedule contribute to the enhanced frequencies of such activities.

Several strategies have been used to determine whether a reinforcer schedule increases the frequency or rate with which a response occurs. Inherent in all of these strategies is the concept of intermittency. Although this concept has taken on considerable theoretical importance in the research literature, it usually remains undefined. In our subsequent discussion of reinforcer schedule induction, we will use the term to refer to interrupted access to a reinforcer. An interruption, of course, can occur once or repeatedly for a particular organism.

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No-Reinforcer Baseline

This approach (e.g., Staddon, 1977) assesses the effect on a particular activity of the schedule as a unit. Specifically, the level of a potential schedule-induced activity is compared with the level of that activity under otherwise comparable conditions in which no reinforcers are scheduled. If the level of an activity is higher in the presence than in the absence of the schedule, then one can conclude that, generically, the reinforcer schedule induced the behavior. This no-reinforcer baseline has been widely employed to assess the extent to which a reinforcer schedule as a whole augments the level of attack (Looney & Cohen, 1982) and the level of other categories of behavior (e.g., drug injection; see Roper, 1981).

Home-Cage, Massed-Reinforcer, and Fixed-Ratio (FR) 1 Baselines

These strategies have been used primarily to evaluate the levels of prandial and food-related drinking (Kissileff, 1969) in studies of induced drinking (e.g., Falk, 1971). In general, they are designed to assess the level of an activity during a reinforcer schedule relative to a "no-schedule" condition that is assumed to eliminate reinforcer intermittency without eliminating the reinforcer per se.

With the home-cage baseline, the level of an activity during exposure to a reinforcer schedule is compared to the level of that activity when the reinforcer is freely available to the subject, typically outside of the formal testing situation. For example, in the case of induced drinking, the amount of water consumed in the home cage is measured when both food and water are freely available. The logic for using the massed-reinforcer and FR 1 baselines is similar. In the case of the massed-reinforcer baseline, the level of a particular activity during exposure to a reinforcer schedule is compared with that which occurs in a baseline session of equal duration. During the baseline session the subject receives, in one lump sum, all of the reinforcers that it normally would receive during

a comparable period of exposure to the reinforcer schedule. This results in the subject having uninterrupted access to the same quantity of reinforcers during the initial portion of the baseline session.

With the FR 1 baseline, the level of behavior during exposure to a reinforcement schedule is compared with that which occurs during a session in which the subject receives reinforcers on a FR 1 schedule. There are three ways in which this type of baseline can be arranged. In one case, the baseline can be terminated immediately after the subject has obtained the same number of reinforcers as are available under the reference schedule condition, in which case session length is shorter in the FR 1 baseline. It is also possible to equate the baseline session length to that of the reference schedule condition in one of two ways. In one case, the number of obtained reinforcers in the baseline can be equated to that of the schedule condition. If this is done, the subject is exposed more or less continuously to reinforcers while the FR 1 schedule is in effect, followed by a transition to no reinforcement for the remainder of the session. A second possibility is that reinforcers can be made available throughout the entire baseline session, resulting in more obtained reinforcers in that condition.

Combined No-Reinforcer and Massed-Reinforcer Baselines

Roper (1981) has suggested that only the combined use of both the no-reinforcer and massed-reinforcer baselines is adequate to determine whether a reinforcer schedule increases the level of a type of behavior. For Roper, as for others, schedule induction is thought to be uniquely linked to reinforcer intermittency. Although the no-reinforcer baseline eliminates reinforcer intermittency, it also eliminates reinforcer availability and is thus confounded. In contrast, the massed-reinforcer baseline has been thought to eliminate the critical variable, reinforcer intermittency, without eliminating the reinforcers. Although Roper (1981) finds the massed-reinforcer baseline attractive for this reason, he finds fault with using it alone

because it is possible for an activity to occur at a higher rate under the schedule condition than under the massed baseline but for that activity to occur at an even higher rate under the no-reinforcer condition. In short, the massed-reinforcer baseline may simply suppress the activity more than the schedule condition. For this reason, Roper concludes that both the no-reinforcer and massed-reinforcer baselines must be used in demonstrating schedule induction.

CRITIQUE OF TRADITIONAL APPROACHES FOR SPECIFYING SCHEDULE INDUCTION

As discussed previously, two basic approaches have been used for determining whether a reinforcer schedule induces an activity. One approach determines whether, over a finite period of time, a particular type of behavior is related to the presence and absence of the schedule. This is the rationale for using the no-reinforcer baseline. The utility of this baseline depends upon whether the reinforcer schedule that is compared with this baseline is viewed as a whole or in terms of its component parts (e.g., intermittency, interreinforcer interval). If a reinforcer schedule is viewed as a unit with no distinction made between its constituent parts, then the no-reinforcer baseline is appropriate for determining whether, generically, the schedule enhanced the level of a particular activity.

The no-reinforcer baseline has not always been used in this generic fashion but rather has been used, inappropriately, in evaluating the effect of reinforcer intermittency (Azrin, Hutchinson, & Hake, 1966). Recently, Roper (1981) and Timberlake (1982) have pointed out problems with using the no-reinforcer baseline in this way. Their main objection is that the no-reinforcer baseline does not allow one to assess whether the reinforcer per se or the intermittency enhances the level of a particular type of behavior. This issue has been most apparent in the case of induced drinking because it is known that a physiological water deficit and

dry mouth that accompany the eating of dry food can enhance drinking. The second approach to defining schedule induction makes use of the massed, home-cage, FR 1, or combination baselines, discussed above, in an attempt to eliminate the intermittency from other aspects of reinforcement in an unconfounded fashion. The assumption, of course, is that this is an experimentally feasible thing to do. We suggest that this assumption is false and has led to confusion and erroneous conclusions regarding the definition of schedule induction. To illustrate this point, we will show that this basic assumption is not satisfied by the massed-reinforcer, home-cage, or FR 1 baselines, and that consequently these baselines when used alone or in combination with the no-reinforcer baseline are inadequate for determining the extent to which reinforcer intermittency per se enhances a particular type of behavior.

Massed-Reinforcer Baseline

The massed baseline is thought to reflect nonintermittent reinforcement or a non-schedule condition against which an intermittent reinforcement schedule can be evaluated. This assumption is unjustified regardless of whether the baseline reinforcer is presented only once (Starr, 1978) to a subject (within-session intermittency) or repeatedly on a daily basis (both within- and between-session intermittency), as is usually the case. Because intermittency is not eliminated in either case, behavior that accompanies the massed baseline could just as easily be attributed to within- and between-session intermittency as to endogenous effects of the reinforcer itself (e.g., the tendency for dry food to enhance drinking). Conversely, studies that have focused on prandial or food-related drinking (e.g., Kissileff, 1969) must consider the possibility that drinking that accompanies the ingestion of discrete meals may be induced in part by the onsets and offsets of those meals.

The potential for ambiguity in interpreting the results of a massed baseline is illustrated by the fact that such schedules have been interpreted differently across studies.

Interpretations of schedule-induced drinking typically attribute drinking that accompanies a massed baseline to an endogenous tendency for rats to drink and to eat dry food in close temporal proximity and not to intermittency. In contrast, in studies of schedule-induced aggression, the role of intermittency is emphasized. In their classic study of induced aggression in pigeons, for example, Azrin et al. (1966) attributed attack during a massed-like schedule condition (extinction-FR 1-extinction on a daily basis) to reinforcer intermittency (see the discussion of FR 1 baselines that follows).

In addition to failing to eliminate reinforcer intermittency as intended, the massed baseline differs from a standard reinforcer schedule in basic ways that have usually been overlooked. Relative to a standard schedule, the massed baseline confounds both duration of the reinforcer (one large versus several small ones) and the number of transitions from reinforcement to nonreinforcement. Recently, Timberlake (1982) proposed two advantages of using a massed baseline. First, he proposed that the massed baseline eliminates reinforcer intermittency, a point with which we disagree for reasons discussed earlier. Second, he argued that the massed baseline produces the same degree of behavioral competition with induced behavior as would a standard schedule. We find this second conclusion questionable as well because, as noted earlier, the massed baseline is itself a reinforcer schedule that can induce activities that compete with one another. There is no *a priori* reason to suppose that behavioral competition produced by two very different reinforcer schedules (e.g., the massed baseline and another schedule) would be comparable (Azrin et al., 1966). An additional problem with Timberlake's notion of behavioral competition is that it would be necessary to identify and assess all sources of competition produced by each schedule—such as those stemming from ingestion, from conditioned responses, and from other schedule-induced activities. Practically speaking, we suspect that such an

enterprise would be difficult if not impossible to carry out.

Taken together, all of these considerations lead us to conclude that the massed baseline has no special empirical or logical status as a control condition for assessing reinforcer schedule induction. Although this is the case, the massed baseline is still useful for determining whether an activity engendered by reinforcement developed without a contingent relationship between it and the schedule reinforcer (Solomon, 1980).

Home-Cage Baseline

Like the massed baseline, the home-cage baseline is thought to reflect nonintermittent reinforcement or a nonschedule condition against which an intermittent reinforcement schedule can be evaluated. The main problem with using this particular baseline is that it, like the massed schedule, does not in fact eliminate reinforcer intermittency as intended. Although a reinforcer such as food is continuously available, the subject ingests it intermittently in discrete bouts or meals (Richter, 1927; Zeigler, Green, & Lehrer, 1971). For this reason alone, the home-cage baseline is not a useful tool for assessing the contribution of reinforcer intermittency to schedule induction. Furthermore, the procedural differences (e.g., deprivation, session length) between a home-cage baseline and a corresponding experimental schedule condition could, under some circumstances, complicate the interpretation of results (Roper, 1981).

FR 1 Baselines

None of the possible FR 1 baselines described above is useful in isolating the contribution of reinforcer intermittency to schedule induction. Each of the three FR 1 baselines involves intermittent presentation of reinforcers. Reinforcer intermittency is an inherent aspect of all FR 1 schedules because such schedules require a brief time period between reinforcer deliveries.

When an effort is made to keep session length constant across conditions, the FR 1

baseline results in either a transition from reinforcement to extinction or an increased number of obtained reinforcers. In general, the FR 1 baseline is very much like the massed baseline. It not only involves reinforcer intermittency but, in effect, also confounds across conditions the reinforcer magnitude and the number of transitions from reinforcement to nonreinforcement.

AN ALTERNATIVE APPROACH

In general, our analysis suggests that none of the baselines that have been employed is suitable either singly or in combination for determining the extent to which reinforcer intermittency enhances an activity. We conclude that it is not feasible to experimentally extricate intermittency from other aspects of a reinforcer schedule. We believe that a more constructive approach is to acknowledge this fact and to approach the subject of schedule induction in one of two ways. One way is to assess induction in terms of the effectiveness of a reinforcer schedule as a unit in enhancing the frequency of an activity relative to a no-reinforcer baseline. A second way is to determine how changing a specific aspect of that schedule directly contributes to that enhancement effect. This approach thus abandons the futile attempt to isolate reinforcer intermittency.

Reinforcer Induction with Respect to a Generically-Defined Reinforcer Schedule

To determine whether a reinforcer schedule as a unit induces responding, it is necessary to view the schedule generically without reference to reinforcer intermittency, behavioral competition, endogenous reactions to the reinforcer, etc. If the frequency of an activity is greater in the reinforcer-schedule condition than in a no-reinforcer baseline, then generically the schedule can be said to induce the behavior.

Reinforcer Induction with Respect to a Specific Aspect of a Reinforcer Schedule

Induction need not be specified exclusively in terms of a generically-defined rein-

forcer schedule. It also can be defined more specifically in terms of any one of several variables such as interreinforcer interval, repetitions of the reinforcer, reinforcer magnitude, etc. To demonstrate induction in this specific fashion, two criteria must be met. First, it must be shown that generically the reinforcer schedule enhances the frequency with which a particular response occurs. Second, it is necessary to show that a change in the schedule variable enhances the frequency of response per reinforcer presentation. If both of these criteria are met, one can conclude that generically the schedule enhanced the behavior and that a particular variable contributed to that enhancement.

Our approach focuses on those aspects of a reinforcer schedule that can be studied in an unconfounded manner. In the section that follows, we illustrate how our criteria can be used for assessing the degree of schedule induction. The behavioral examples that we have chosen to emphasize (i.e., drinking in rats, aggression in pigeons, and distress calling in ducklings) are not the only ones that meet our criteria of schedule induction but simply serve as examples.

Variables Contributing to Schedule Induction

Reinforcer distribution in time. Considerable attention has been given to the behavioral effects of changing the interreinforcer interval. To demonstrate unequivocally that a specific interreinforcer interval contributes to the enhancement of an activity, it would first be necessary to show that the reinforcer schedule as a unit enhances the behavior relative to the no-reinforcer baseline, and, second, that a change in the interreinforcer interval directly enhances the behavior.

Using these criteria, we find ample evidence in the literature that relatively long and intermediate interreinforcer intervals play a significant role in schedule induction. A decrease in interreinforcer interval from approximately 300 to between 30 and 120 s (depending on the situation) can increase drinking in rats (e.g., Falk, 1969; Flory, 1971), attack in pigeons (e.g., Cherek,

Thompson, & Heistad, 1973), and distress calling in ducklings (e.g., Starr, 1978). In addition, responding is higher in the schedule than in the no-schedule condition. Hence, both criteria for schedule induction have been met.

The increased rate of responding cannot be attributed to confounding variables such as differences in the number of reinforcers per session, number of transitions from reinforcement to nonreinforcement, or amount of reinforcement, because in all cases these variables can be held constant. Of course, when these variables are held constant, session length increases with the interreinforcer interval. This increase in the opportunity to respond at longer interreinforcer intervals provides a bias against the finding that the absolute level of responding actually decreases relative to sessions with shorter intervals.

The degree to which relatively short interreinforcer intervals contribute to schedule induction is unknown. With a decrease in interreinforcer interval beyond 30 to 120 s (depending on the condition), the levels of drinking (e.g., Falk, 1969; Flory, 1971) and attack (e.g., Cherek et al., 1973) decrease rather than remaining the same or increasing as they do at longer interreinforcer intervals. This decrease is accompanied by a decreased opportunity to engage in those activities. In addition, at short intervals, "terminal responses" such as feeder-related behavior may occur during much of the interval and thereby successfully compete with drinking or attack (Staddon, 1977).

Variables related to reinforcer potency. From the current perspective, reinforcer-related variables such as reinforcer magnitude, quality, and deprivation might also be schedule factors that contribute to reinforcer induction. Several studies have investigated the effects of such variables on the level of drinking in rats, aggression in pigeons, and distress calling in ducklings. In general, it appears that factors increasing a reinforcer's potency tend to increase the number of responses per reinforcer presentation. This increased level of responding, again, exceeds

that of the no-reinforcer baseline. As we will see, it is often difficult to assess the contribution of such variables to the induction of drinking. Drinking studies typically use food as the reinforcer, which means that changes in drinking could be both schedule-induced and prandial.

The number and scope of studies that have explored the effect of reinforcement magnitude on aggression in pigeons and distress calling in ducklings are quite limited. It appears that an increase in reinforcer magnitude increases the level of both these activities. In their study of aggression in pigeons, Azrin et al. (1966) found that an increase in the number of reinforcers scheduled between 5-min no-reinforcer periods resulted in an increase in the level of attack. Starr (1978) examined distress calling in ducklings and found that the duration of a single stimulus presentation to a duckling affected the level of distress calling when that stimulus was terminated. A 360-s presentation of the stimulus resulted in approximately ten times as much calling as did a stimulus of 30-s duration.

Studies that have explored how reinforcer magnitude contributes to induction of drinking in rats are more extensive but also more difficult to interpret. Increasing reinforcer magnitude either across groups or subjects (Rosellini & Burdette, 1980) or across test sessions for a particular subject (Flory, 1971) increases the amount of water ingested per reinforcer presentation (see Reid & Dale, 1983, for complications associated with changing reinforcement magnitude within a session). In general, this effect is most evident at intermediate and long interreinforcer intervals and is most likely to occur at the beginning rather than at the end of a session. This is presumably due to satiation effects produced by large reinforcers. Although it is likely that increased amount (and palatability, Rosellini & Lashley, 1982) of food contributes to the enhanced level of drinking to some degree, it is unclear how much of this is due to reinforcer potency and how much is related to metabolic changes and dry mouth resulting from eating large amounts of dry food. Schedule-induced and prandial

drinking are, in this case, unavoidably confounded, making it impossible to experimentally determine the relative contribution of each.

Several studies have examined the effects of chronic food deprivation on drinking (e.g., Falk, 1971), airlicking (e.g., Chillag & Mendelson, 1971), and aggression (e.g., Dove, 1976) in subjects exposed to schedules of food reinforcement. In general, the frequency of such activities is directly related to the degree of chronic food deprivation.

The increased levels of attack that accompany an increase in food deprivation can be attributed to the increased reinforcing properties of food and not to other factors such as an increase in overall level of activity (Dove, 1976). The degree to which reinforcer deprivation directly contributes to reinforcer-induced drinking is less certain because of the possible confounding effects of prandial drinking discussed earlier.

Reinforcer repetition. Several recent studies of distress calling, drinking, and attack indicate that maximum levels of those activities are not seen without repeated presentations of a reinforcer. This enhanced effect, again, exceeds that observed in the no-reinforcer baseline.

Several studies illustrate how reinforcer repetition contributes to reinforcer induction. Starr (1978), for example, reported that distress calling in ducklings increases with repetition of the scheduled reinforcer, and also found that the rate of this increase is inversely related to the interval between reinforcer presentations. If the interreinforcer interval was longer than a critical value, distress calling did not increase, thus providing, by our second criterion, no evidence of schedule induction. Studying drinking in rats, Rosellini and Lashley (1982) reported that the amount of water ingested per reinforcer increased with repetition of the scheduled reinforcer, and that the rate of increase was proportional to the reinforcing properties of the food. It is unlikely that these increased levels of drinking reflect the development of prandial drinking, for prandial drinking should be fully developed

in food-deprived rats prior to exposure to a food reinforcement schedule. Studying aggression in pigeons, Looney and Dove (1978) likewise have found that the probability of aggression is an increasing function of the number of food-reinforcer presentations. In their study, the number of subjects that exhibited attack against a conspecific target increased with extended exposure to a fixed-time 90-s schedule. This growth effect occurred even though, for some subjects, the target was not available during the initial presentations of the reinforcer. It appears, therefore, that under some conditions, the repeated presentations of a reinforcer can contribute to schedule induction.

Programmed-reinforcement contingencies. Relatively little is known about the extent to which a programmed contingency contributes to reinforcer induction. Although induction of attack (e.g., Flory, 1969) and drinking (e.g., Falk, 1971) can definitely occur without a programmed contingency between a response and a reinforcer, there is some evidence that a programmed contingency directly increases the level of induced attack. Specifically, Huston and Desisto (1971) compared interspecific attack of rats exposed to FR schedules of hypothalamic stimulation with a condition in which the reinforcer was given freely at the same mean intervals. Rats showed more attack under the FR condition, suggesting that the response contingency was important and that attack was not simply a result of the stimulation. Other studies of schedule-induced attack (Cherek et al., 1973; Flory & Everist, 1977) have shown similar although less clear-cut effects of FR and FI contingencies. Perhaps other reinforcer-schedule contingencies (e.g., differential reinforcement of low rates) will be found to provide more clear-cut results.

SUMMARY AND CONCLUDING COMMENTS

In this paper, we have outlined a strategy for determining whether a reinforcer schedule enhances the frequency of an activity. In

reviewing this strategy, it is useful to contrast it with alternative approaches.

Roper (1981) has suggested that in order to determine whether an activity is enhanced in frequency by a reinforcer schedule, it is necessary to compare the level of that activity during a schedule condition with that of levels seen with the no-reinforcer and the massed-reinforcer baselines. In a reply to Roper's proposal, Timberlake (1982) argued in favor of the massed-reinforcer control. We suggest that neither approach is viable for assessing the level of schedule induction because both are based on a faulty assumption. They incorrectly assume that it is possible to eliminate reinforcer intermittency by the use of a massed-reinforcer baseline and, consequently, to determine the extent to which reinforcer intermittency alone enhances the level of an activity. We contend that this assumption is unjustified and that the massed-reinforcer baseline has no special empirical or logical status as a control for determining whether a reinforcer schedule enhances the level of an activity.

In light of these considerations, we propose an alternative strategy. Specifically, we suggest that a first step in determining whether a reinforcer schedule enhances the level of an activity is to examine whether the reinforcer schedule, when considered as a unit, increases the frequency with which the behavior occurs relative to its occurrence on the no-reinforcer baseline. If so, schedule induction has been demonstrated. This could be particularly useful in clinical or applied settings in which it may be sufficient to know whether a reinforcer schedule induces a particular pattern of behavior without necessarily identifying which aspect(s) of the schedule contributed to that effect.

The no-reinforcer baseline is also important because it is a prerequisite condition for determining whether a particular aspect of a reinforcer schedule contributes to schedule induction. In this paper we have argued that reinforcer induction can be defined not only generically, but also more specifically in terms of particular schedule variables such as interreinforcer interval, repetition of the

reinforcer, reinforcer magnitude, etc. To demonstrate reinforcer induction in this more specific fashion, a second criterion must be met: One must show that a particular schedule variable directly enhances the frequency with which the behavior occurs.

Using our criteria, we find that, generically, reinforcer schedules induce several different activities. We have identified, in each case, variables that contribute to that induction effect. On the basis of these observations, we conclude that schedule induction is a general phenomenon and is not restricted, as Roper (1981) has suggested, to drinking in rats.

The types of behavior discussed in this paper usually occur following reinforcer termination and develop without a contingent relationship between the activity and the scheduled reinforcer. In keeping with the traditional use of the term *schedule induction*, we prefer to use the term in this restrictive sense. On the other hand, it is important to realize that the criteria that we have outlined for specifying behavioral excess are not of necessity linked to a particular classification or theoretical system. Our approach to assessing schedule enhancement could also be used to determine whether reinforcer schedules enhance activities that have been classified and conceptualized in other ways (e.g., Pavlovian conditioned responses, terminal activities).

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