

EFFECTS OF AMOUNT OF FOOD REINFORCEMENT ON  
FIXED-INTERVAL-INDUCED ATTACK IN PIGEONS

By

RAYMOND C. PITTS

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By

RAYMOND C. PITTS

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Chair: Dr. E. F. Malagodi  
Major Department: Psychology

Keypecking by pigeons was maintained on a chained fixed-interval  $\bar{t}$  fixed-ratio one schedule of food presentation. Attacks toward a restrained and protected conspecific were recorded. In the first experiment, the amount of food presented per interval was manipulated across phases by varying the number of repetitions of the fixed-ratio one schedule required in the terminal component of the chain. Levels of attack during the fixed-interval component increased monotonically as a function of amount of food presented in the terminal component. In the second experiment, a multiple schedule was used in which two different food amounts alternated within each session. For both pigeons in this experiment, more attack was observed during the component that delivered the larger amount of

food per interval. The results of these experiments are discussed in terms of a number of different theoretical frameworks, including views that attack is properly considered as "adjunctive behavior," notions that intermittent schedules possess aversive properties, conceptualizations of attack as an example of "interim activities," concepts that suggest that induced attack results from "arousal," and suggestions that induced behaviors can be conceptualized within the context of an "opponent-process" theory of motivation. It is suggested that, although the results of the present study are relevant to each of these views, further analyses are required before an integrated picture of induced attack and other induced behaviors can emerge.

## GENERAL INTRODUCTION

Since Ferster and Skinner's (1957) extensive survey of schedules of reinforcement, numerous empirical studies and theoretical discussions of the effects of various schedules have been published by other investigators (see Zeiler, 1977 for a review). Indeed, it may be said that the study of reinforcement schedules became the dominant research area in the experimental analysis of behavior during the next two or three decades. The primary focus of these empirical and theoretical analyses has been examination of the effects of schedule variables on rates and temporal patterns of ongoing operant behavior maintained by intermittently presented reinforcers.

Some experimenters studying intermittent schedules, however, began to notice that powerful and ubiquitous "schedule-effects" were not restricted to behaviors which produced, or closely preceded, the scheduled reinforcer. Falk (1961), for example, discovered a most interesting and reproducible sequence of behavior in rats when lever pressing was maintained by a variable-interval (VI) schedule of food presentation. Rates and patterns of lever pressing

were typical for VI schedules in that a moderate and steady rate of responding was maintained. In addition to lever pressing, and eating the food pellets as they were delivered, the rats regularly drank from a water bottle that was continuously available in the chamber. While it was not especially surprising that the rats drank from the bottle during lengthy experimental sessions, a number of characteristics of drinking were unexpected, yet were quite orderly. The features of drinking (and of the conditions under which drinking occurred in this experiment) that captured Falk's attention and became the focus of a large number of subsequent experiments were a) while the rats were food-deprived, they were not water-deprived, b) drinking followed each and every delivery of a food pellet, c) the rats consumed excessive amounts of water--approximately four times the amounts normally consumed per twenty-four hour period in the home cages, and d) drinking decreased dramatically or ceased altogether during various "control" procedures during which food was not intermittently scheduled. Subsequent experiments determined that such "adjunctive" or schedule-induced drinking could not be viewed as superstitious behavior controlled by accidental reinforcement of licking by food presentation (see Falk, 1971).

In a related experiment, Gentry (1968) demonstrated that when keypecking by food-deprived pigeons was maintained

on a fixed-ratio (FR) schedule of food presentation, the pigeons reliably attacked a restrained conspecific located at the rear of the experimental chamber. The attacking observed by Gentry (1968) was similar to the drinking observed by Falk (1961) in that attacking a) was typically observed to occur in periods just after food delivery, b) followed a large proportion of food presentations, c) did not occur under conditions when food was not intermittently presented, and d) apparently was not adventitiously reinforced by food presentation. In both Falk's (1961) and Gentry's (1968) experiments, a regular temporal sequence of behavior was observed: following delivery of food, the subjects engaged in a bout of induced activity (pigeons' attacking and rats' drinking) which ceased rather abruptly and was followed by operant behavior (pigeons' keypecking and rats' lever pressing) until the next food delivery.

A rather wide range of other induced behaviors has been found to occur following food presentation during various intermittent schedules of reinforcement. These include pica in rats and monkeys, aggression in monkeys, wheel-running in rats, drinking in pigeons, escaping from stimuli associated with positive reinforcement in pigeons and rats, and air licking in rats (see Falk, 1971; Staddon, 1977; Wetherington, 1982). Investigations over the past 25 years have shown that these schedule-induced behaviors occur in several species, are induced by a variety of intermittent

schedules, and are induced by various events (e.g., food, water, and shock) when scheduled intermittently.

### Literature Review

Much of the research on schedule-induced behavior can be divided into two general categories: a) experiments investigating the effects of schedule variables, such as parameter value of a given schedule or schedule type, and b) experiments investigating the effects of variables associated with the scheduled event itself, or what might be called consequence variables. Included in this class of variables are deprivation of, and amount of the scheduled reinforcer.

#### The effects of schedule variables on induced behavior

Most experiments in this category have focused on examination of induced behavior as a function of schedule parameter, such as the interfood interval on time-based schedules, or the response requirement on ratio schedules. The relationship between induced behavior and interfood interval on time-based schedules depends upon the particular induced behavior and on its measurement. In studies of induced drinking during fixed-interval (FI), variable-interval (VI), and fixed-time (FT) schedules of food presentation, total water consumption is an inverted U-shaped function of the interfood interval (Bond, 1973; Falk, 1966; Flory, 1971; Hawkins, Shrot, Githens, & Everett, 1972;

Wetherington, 1979). This inverted U-shaped, or bitonic, function relating induced drinking to interfood interval has also been reported with the number of licks per session (Flory, 1971; Wetherington, 1979), the amount of time drinking per pellet (Wetherington, 1979), and the percentage of intervals containing drinking (Allen & Kenshalo, 1976; Segal, Oden, & Deadwyler, 1965). However, when drinking induced by an FT schedule of food presentation is measured as the rate of water consumption and as the rate of licking, both are a decreasing function of interfood interval (Wetherington, 1979). These differences in relations between drinking and interfood interval as a function of measurement illustrate the importance of measurement selection, its effects on experimental results, and on theoretical interpretations derived from them. For detailed discussions of measurement issues in schedule-induced behavior, see Allen, Sicignano, Webbe, & Malagodi (1980), Webbe, DeWeese, & Malagodi (1974), and Wetherington (1979, 1982).

Results of experiments examining induced attack as a function of interfood interval are more consistent across measures than those of induced drinking. Attack by pigeons induced by FI, FT, and response-initiated FI schedules of food presentation show a bitonic relation to interfood interval similar to that seen with induced drinking (Cherek, Thompson, & Heistad, 1973; DeWeese, Webbe, & Malagodi, 1972;

Flory, 1969b). This bitonic function was observed with all measures of induced attack employed in these experiments, which included rate of attack, attacks per reinforcement, percent of intervals with attack.

Schedule-induced "escape" by pigeons has also been observed during fixed-interval schedules of food presentation (Brown & Flory, 1972). In this experiment, pecks on one key produced food according to an FI schedule, while pecks on a second key produced an "escape" period with a visual stimulus change. These investigators reported a bitonic relation between measures of escape (escape rate and percent of session during escape stimuli) and interfood interval for most subjects. Note, however, that the fixed-interval timer did not operate during the stimulus change periods and, thus, these periods may not have functioned as true escape periods.

The effects of ratio parameter on schedule-induced behavior most often has been examined in studies of induced attack in pigeons and monkeys, and induced escape in pigeons and rats. As with studies on induced drinking during time-based schedules, the results of experiments on the effect of ratio size on induced attack depend critically upon how attack is measured. When induced attack is examined in fixed-ratio (FR) (Flory, 1969a; Hutchinson, Azrin, & Hunt, 1968; Knutson, 1970; Webbe et al., 1974), variable-ratio (VR) (Webbe et al., 1974), and regressive-ratio (Reg R)

(Allen et al., 1980) schedules of food presentation, most measures tend to increase monotonically as a function of ratio size. These measures include total number of attacks (Hutchinson et al., 1968; Knutson, 1970), total number of attack episodes (Flory, 1969a), time spent attacking (Knutson, 1970), attacks per interval (Webbe et al., 1974), and proportion of intervals containing attack (Flory, 1969a; Webbe et al., 1974). However, when rate of mirror-pecking is measured as a function of ratio size in FR schedules of food presentation, an inverted U-shaped function is observed (Cohen & Looney, 1973).

When keypecking or lever pressing is maintained on ratio schedules of food presentation, pigeons and rats will respond on a second operandum when these responses produce escape, or time-out, periods. During these escape periods, responses usually do not count toward the completion of the ratio requirement. Subjects escape more frequently, following more food presentations, and spend more time in time-out periods as a function of ratio size in FR and progressive-ratio (PR) schedules (Appel, 1963; Azrin, 1961; Dardano, 1973; Thompson, 1964).

Relatively few studies have examined induced polydipsia under ratio schedules of food presentation. Total water intake and total licks are an increasing function of the response requirement on FR schedules (Burks, 1970; Carlisle, 1971). Note that, unlike studies of induced attack and

induced escape, the effects of ratios of over 100 have not been examined in studies of induced drinking.

#### The effects of consequence variables on induced behavior

The literature relating consequence variables to schedule-induced behavior is less extensive than the literature on schedule variables. Data on consequence-variable effects have come nearly exclusively from experiments on schedule-induced polydipsia in rats. Published reports of examinations of these variables on other induced behaviors and in other species are conspicuously lacking.

When studied as a function of food deprivation, induced drinking is usually an inverse function of body weight (e.g., Falk, 1969; Freed & Hymowitz, 1972; Roper & Nieto, 1979; Wayner & Rondeau, 1976). One study examining the effect of this variable on schedule-induced attack in pigeons reported a similar inverse relation (Dove, 1976).

A number of studies have examined the relation between induced drinking and the amount (or magnitude) of food reinforcement. A majority of these experiments have reported increases in measures of induced drinking as a function of food amount (e.g., number of pellets) (Bond, 1973; Couch, 1974; Flory, 1971; Hawkins et al., 1972; Rosellini & Burdette, 1980; Yoburn & Flory, 1977). Some studies, however, have found that induced drinking decreases (Falk, 1967; Freed & Hymowitz, 1972) or does not change

systematically as a function of food amount (Keehn & Colotla, 1971). One set of experiments reported that the effects of amount of food reinforcement on schedule-induced drinking depended upon whether comparisons were made within or between experimental sessions (Reid & Dale, 1983; Reid & Staddon, 1982). Larger amounts of food attenuated drinking when comparisons were made within sessions, but augmented drinking when comparisons were made between sessions.

Issues surrounding measurement of induced behavior are not only important in examinations of schedule variables, but are also important in experiments on food amount. Falk (1967) reported that when lever pressing was maintained on a VI-1 min schedule of food presentation, two pellets per interval resulted in lower total water intakes than did one pellet per interval. However, in this experiment, the number of pellets per session was constant across conditions, resulting in shorter sessions and fewer intervals per session during the two-pellet condition. When these data were recalculated as ingestion rates, drinking was higher during the two-pellet condition in four of six possible comparisons (Hawkins et al., 1972).

The relation between schedule-induced attack and the amount of food has not been extensively studied. One investigation found that the larger of two food magnitudes induced more attack in pigeons when food was presented on FT schedules (Flory, Robinson, & Dunahoo, 1988). Investigations

of induced attack as a function of a range of reinforcement amounts have not been reported.

### Summary and conclusions

As mentioned above, the effects of schedule manipulations depend upon the particular induced response studied and upon how that response is measured. In general, however, most experiments relating induced drinking and induced attack to interfood interval on time-based schedules of food presentation have revealed an inverted U-shaped, or bitonic, function. In contrast, most experiments of induced behavior during ratio schedules have shown monotonically increasing levels of induced responding as a function of ratio parameter. The exceptions to these general findings are usually when rates of induced behavior are used as dependent variables (see section entitled The effects of schedule variables on induced behavior).

The effects of consequence variables have usually been studied on induced polydipsia in rats. In general, levels of behavior induced by intermittent schedules of food presentation increase as a function of deprivation level and as a function of food amount, although a few studies have reported contrasting effects of food amount.

It is tempting to conclude that the data reviewed above on consequence variables imply that operations that increase the reinforcing efficacy of the scheduled event result in increases in levels of induced activity. It is contended

here that such a conclusion would be premature. More systematic and comprehensive analyses of the effects of consequence variable on different induced behaviors, in different species, and in different schedule contexts must be undertaken in order to provide a more complete characterization of the effects of these variables on schedule-induced behavior.

### Theoretical Overview

Several theoretical frameworks have been offered in attempts to clarify the nature of the processes involved in schedule-induced behavior. These include 1) the adjunctive behavior hypothesis proposed by Falk, 2) the view that intermittent schedules possess aversive properties, 3) Staddon's motivational hypothesis, and 4) Killeen's concept of arousal. These views differ markedly in their structure and in specific predictions derivable from them and, therefore, will be discussed separately and in detail.

#### Falk's adjunctive behavior hypothesis

One conceptualization of schedule-induced behavior was proposed by Falk (1969, 1971). When early attempts to reconcile the excessiveness of induced polydipsia with known regulatory mechanisms failed, attention turned toward its environmental determinants. Difficulties in the application of principles of operant or respondent conditioning as explanations of induced behavior led Falk (1971) to propose

the existence of a new class of behavior. Noting a number of similarities among induced activities (discussed above), Falk suggested that schedule-induced drinking, schedule-induced attack, and other schedule-induced activities are properly considered members of a class of "adjunctive" behaviors. These behaviors are adjunctive in that they occur as by-products of a schedule of reinforcement that maintains some other response, and are considered similar to the displacement activities observed and discussed by ethologists. Displacement activities are described as occurring in situations where an animal "under high drive conditions" is engaged in some sort of consummatory behavior and is prevented from continuing this behavior (Falk, 1971). Falk points out that these are the conditions producing adjunctive behavior: a food deprived animal engaged in eating is prevented from continuing this behavior by the imposed intermittent schedule of food presentation.

The bitonic function frequently observed in studies relating induced responding to schedule parameter is central to Falk's interpretation. He proposes that intermittent presentation of food results in adjunctive behavior only when the schedule arranges a rate of food consumption within a certain "effective range." This "consummatory rate hypothesis" suggests that at high rates of food consumption (e.g., short interfood intervals) adjunctive responding is low. As consumption rate decreases (e.g., by lengthening

the interfood interval), adjunctive behavior increases to a maximum until, at still lower consummatory rates, adjunctive behavior decreases (Falk, 1969, 1971). According to this view, the particular type of schedule is important only insofar as it arranges a particular consummatory rate.

Data from those experiments demonstrating a bitonic function between rate of food presentation and measures of induced behavior, coupled with the similarities among induced activities listed earlier provide evidence in favor of Falk's view. In addition, Falk (1967) compared various combinations of interfood intervals and food amounts that programmed equal consummatory rates (e.g., VI 1 min with one food pellet per interval and VI 2 min with 2 pellets per interval), and reported that the most reliable predictor of the total amount of schedule-induced drinking was the number of pellets presented per minute (Falk, 1967). However, different session lengths (and hence, different total interfood intervals per session) were programmed during conditions that delivered two pellets. This feature severely handicaps definitive interpretation of these data (see General Discussion for a more detailed discussion of this study and the consummatory rate hypothesis).

Some studies, however, have reported data that are at odds with Falk's consummatory rate hypothesis. First, FR schedules have been found to induce more attack than response-independent schedules that program equal rates and

temporal distributions of food presentation (i.e., matched-time, or MT schedules) (Malagodi, Sicignano, & Allen, 1979). Second, some studies of induced drinking (Bond, 1973) and induced attacking (Flory et al, 1988), comparing various combinations of interfood intervals and food amounts have failed to replicate Falk's (1967) results. Third, a number of studies have reported direct, monotonic increases in schedule-induced attack, escape, and polydipsia as a function of ratio size (See Literature Review). Falk (1971), has noted that data reported in studies on ratio schedules may represent only the ascending portion of the bitonic function relating adjunctive behavior to interfood interval (the descending portion if food rate is used as the independent variable). However, subsequent data obtained on regressive-ratio (Reg R) schedules have reported a monotonically increasing function between schedule-induced attack and ratio size, even when interfood intervals on the larger ratios (over 100 minutes) far exceeded those previously shown to produce the descending portion of the bitonic function (Allen et al., 1980). The results of the experiments discussed above suggest that factors other than consummatory rate per se are important in the production and maintenance of schedule-induced behavior.

Notions that schedules possess aversive properties

A second interpretation of schedule-induced behavior (particularly schedule-induced attack and escape) is offered by Azrin and his associates (Azrin, 1961; Azrin, Hutchinson, & Hake, 1966; Hutchinson et al., 1968), and others (Richards & Rilling, 1972). The results of studies showing a direct relation between attack and response requirement in ratio schedules, in concert with data showing that attack is often generated by conditions that are normally escaped or avoided, such as electric shock presentation (Azrin, Hutchinson, & McLaughlin, 1965; Ulrich & Azrin, 1962), a physical blow (Azrin, Hake, & Hutchinson, 1965), and extinction (Azrin et al., 1966; Kelly & Hake, 1970), suggest that intermittent schedules may possess aversive properties. In this view, periods of zero or low reinforcement probability in intermittent schedules are aversive, and the magnitude of aversiveness is partly determined by the response requirements of ratio schedules (Hutchinson et al., 1968). This interpretation is supported by studies showing that subjects will escape from schedules of positive reinforcement, that likelihood of escape is directly related to ratio size (Azrin, 1961; Appel, 1963; Thompson, 1964) and that more attack is induced by FR schedules than by MT schedules (Malagodi et al., 1979). Further support of this view derives from data that have reported more induced attack under an FR schedule of food presentation than under

an equal valued VR schedule (Webbe et al, 1974). The occasional reinforcements that closely follow previous reinforcement periods on VR schedules might attenuate the aversiveness of the post-reinforcement periods.

Although the notion that intermittent schedules possess aversive properties is compelling, data from some studies suggest that factors other than schedule aversiveness are involved in schedule-induced attack and in other schedule-induced behaviors. The bitonic relation frequently observed with induced behavior during time-based schedules and occasionally observed during ratio schedules is difficult to reconcile with the notion of schedule aversiveness. This relation suggests either an entirely different interpretation, or an amendment that addresses the decreasing portion of the function at longer interfood intervals. For example, it is possible that the ascending portion of the bitonic function on time-based schedules results from an increase in schedule aversiveness, and the decrease in this function at longer intervals reflects competition from other activities that emerge at these longer intervals (e.g., the "facultative activities" proposed by Staddon, 1977).

#### Staddon's motivational hypothesis

A third theoretical approach has been offered by Staddon and his colleagues (Staddon, 1977; Staddon & Ayers, 1975; Staddon & Simmelhag, 1971). According to this

conceptualization, much of the research on schedule-controlled behavior has been governed by the tacit assumption that the effects of response-dependent reinforcement are somehow more fundamental than those of response-independent reinforcement. In Staddon's (1977) view, correlations between reinforcement, and temporal and stimulus variables are most important in determining the final pattern of performance on reinforcement schedules. If the way these variables act is to be understood, the response contingency so ubiquitous in operant conditioning experiments is an unnecessary complication. Therefore, most of the data offered in support of this position are from studies using response-independent food presentation.

Staddon (1977) notes that periodic (and therefore intermittent) presentation of response-independent food results in an organized and stereotyped sequence of behavior (termed "schedule-induced behavior"). In this framework, adjunctive (or schedule-induced) and operant responses are all classified as schedule-induced behavior, with the distinction between them being their temporal location within the interfood interval. For Staddon, induced behaviors that emerge in the presence of, or are directed toward, stimuli that are predictive of food are called "terminal responses" and are what is traditionally studied as operant behavior. Induced behaviors that emerge at times when food is unlikely are called "interim responses" and are

what is traditionally studied as adjunctive or schedule-induced behavior. Thus, when intermittent reinforcement is programmed, observed keypecking by pigeons and lever pressing by rats are considered terminal responses, and schedule-induced attacking in pigeons and drinking in rats are considered interim responses. Each type of activity is seen as serving an adaptive function: terminal responses are related to the procurement and consumption of food, and interim responses serve to remove an animal from food situations at times when food is unlikely. Interim responses include schedule-induced drinking and attacking, and any number of activities observed to occur during the period shortly after food delivery (e.g., grooming, preening, wing flapping) (Staddon & Simmelhag, 1971).

Staddon (1977) suggests that all induced activities are critically dependent upon motivational factors. Two types of motivational variables are said to determine induced behavior: variables related to the scheduled reinforcer (e.g., deprivation, schedule, and amount) and variables related to the particular interim response (e.g., "thirst" if drinking is the interim response). In studies on schedule-induced polydipsia, for example, induced drinking and food related responding (such as lever pressing) are related to food motivation in a similar way: ". . . the 'hungrier' the animal during the terminal period, the 'thirstier' he is during the interim period" (Staddon, 1977,

p. 139). Thus, programming intermittent food presentation to a food-deprived rat is a motivational operation similar to depriving the rat of water and results in drinking at times when food delivery is unlikely. In this view, any operation that increases the reinforcing efficacy of food should similarly increase both terminal and interim responding, until a point is reached where the two activities are in direct competition, at which time the entire interfood interval is dominated by the terminal response.

Staddon (1977) cites examples in which schedule-induced drinking is a direct function of food rate and food amount in support of his motivational hypothesis (see Literature Review). Also presented are data replotted from Falk (1969) and Flory (1971), originally reporting bitonic functions relating total water intake to interfood interval. When these data are plotted as water intake per minute and licks per minute as a function of food rate, both are monotonically increasing. It is not surprising that such a difference is seen when rate is used as a measure of induced activity. When the number of interfood intervals per session are constant (as is frequently the case in studies of induced behavior), then session length is likely to decrease as schedule parameter is decreased (this must occur if interval schedules are used). Thus, when induced behavior is measured as a rate, no change, or even a

decrease in total number of induced responses as schedule parameter is decreased can actually show a rate increase due to a decrease in size of the denominator.

Recall that a number of studies have found that many measures of induced responding are bitonically related to interfood interval and are directly related to ratio size. Neither of these results is predicted from the view proposed by Staddon. Also, recall that Staddon's approach is predicated upon studies employing response-independent food presentation. Indeed, it has been asserted that the presence or absence of a response-requirement makes little difference in the amount or temporal placement of schedule-induced drinking (Burks, 1970; Falk, 1971; Segal et al., 1965; Staddon, 1977). Studies of schedule-induced attack, however, have shown that measures of attack may depend critically upon the number of responses required for food reinforcement (Allen et al., 1980), and that this relation is independent of interfood interval (Malagodi et al., 1979). These results also are not predicted from the theoretical framework offered by Staddon (1977).

#### Killeen's concept of arousal

A fourth approach to schedule-induced behavior has been outlined by Killeen (Killeen, 1975; Killeen, Hanson, & Osborne, 1978) and suggests that these behaviors are a normally occurring part of an organism's repertoire, but "their rate of occurrence is excited to supernormal levels

by a heightened level of arousal" (Killeen et al., 1978, p. 571). This excessive arousal is produced by the periodic delivery of food (or other "incentives"), and each delivery contributes a small amount of arousal. With repeated deliveries, the arousal accumulates to a stable, "equilibrium," level that depends upon the size of the arousal, its rate of decay, and the time interval between arousal impulses.

Killeen's concept of arousal has been operationalized as measurements of "activity" taken by a set of microswitches located under floor panels of a standard pigeon operant-conditioning chamber. When food-deprived pigeons were exposed to fixed-time (FT) schedules of grain presentation at various interfood intervals, a specific pattern of activity within each interval was observed. Low levels of activity occurred immediately following food presentation, increased rather rapidly to a maximum at about one-quarter of the way into the interval, then gradually returned to low levels by the end of the interval (Killeen, 1975; Killeen et al., 1978). The overall amount of activity was an increasing function of food rate, although the general pattern of activity within each interval was similar at all rates.

Killeen et al. (1978) provide a mathematical model of arousal which suggests that the general pattern of activity observed when food is intermittently presented results from

the interaction of three processes: The first process is "arousal," which is maximal immediately after food presentation and decays very gradually throughout the interfood interval. The second process is termed "post-prandial inhibition" (" . . . post-prandial behaviors and quiescence elicited by the offset of the previous incentive or the offset of a conditioned stimulus that indicates the immediate unavailability of other incentives." p. 372). Post-prandial inhibitions are maximal just after food presentation, and decay very rapidly. They compete with arousal and result in the low levels of activity observed just after food delivery; the rapid rise in activity is the result of the rapid decay in these inhibitions coupled with an existing high level of arousal. The third process is competition from terminal behaviors (such as keypecking or approaching the food hopper); competition from these terminal behaviors grows with the passage of time in the interfood interval, and results in an exponential decay of activity across the interval.

Killeen et al. (1978) suggest that if the time between food presentations is short enough, arousal accumulates to such an extent that the "excessive" character of schedule-induced behavior is observed. This model also predicts a proportionality between activity (including schedule-induced behaviors) and rate of food presentation (Killeen et al., 1978). This prediction is confirmed in

some studies of activity (Killeen, 1975; Killeen et al., 1978) and of schedule-induced behavior (Killeen, 1975; Wetherington, 1979). Results of studies that show a bitonic relation between schedule-induced behavior and interfood interval are not predicted from Killeen's model, nor are those that show a direct relation between induced behavior and ratio size. Killeen's model also predicts that other variables which increase arousal should also increase levels of schedule-induced behavior. For example, more arousal is expected to result from increased food deprivation and from presentation of larger amounts of food. With a few exceptions, these predictions are generally confirmed by the data on consequence variables (see Literature Review).

#### Summary and conclusions

It must be noted at this point that the four viewpoints presented above are not offered as an exhaustive list of interpretations of schedule-induced behavior. However, they represent four of the most popular and most cited theoretical conceptualizations in this research area. Other hypotheses, such as notions that induced behaviors are adventitiously reinforced by food presentation, or views of induced drinking as resulting from dry-mouth, have not survived experimental analyses (see Staddon, 1977).

The theoretical positions reviewed above suggest different relationships between induced behavior and schedule and consequence parameters. These viewpoints focus

on different induced activities, emphasize different characteristics of induced behavior, and rely upon different measurement procedures. Each of these conceptualizations are supported by results from some experiments but not by others. Thus, given the differences among these views, and given the disparities in experimental data, it becomes difficult to decide which of these views, or combination of views, is the most effective available account of schedule-induced behavior. The view taken here is that, although an extensive literature exists in schedule-induced behavior, not enough data are available to make conclusions regarding these, or any other, theoretical interpretations. Further analyses along a number of dimensions are required before useful theoretical statements about schedule-induced behavior can be made. For example, a complete picture of the effects of ratio size on induced drinking is lacking. The effects of relatively large ratios must be studied to determine whether the descending portion of the bitonic function so often observed at long interval durations is obtained. Also lacking are data on the effects of consequence variables on induced behaviors other than drinking. The absence of comprehensive analyses of these variables on induced attack and induced escape severely handicaps attempts at theoretical integration.

### The Purpose of the Present Experiment

The relative paucity of data on the effects of consequence variables on induced behaviors other than drinking is surprising, especially in view of a tradition of interspecies and interresponse replication among experiments on schedule variables. Systematic examinations of the relationship between the amount of food reinforcement and schedule-induced attack are noticeably absent. Therefore, the purpose of the present set of experiments is to provide a characterization of the function relating the amount of food reinforcement to schedule-induced attack over a relatively wide range of reinforcement amounts. It is hoped that data from these experiments will fill gaps in the existing literature and help provide an empirical basis for an eventual formulation of an adequate theoretical integration of schedule-induced phenomena.

## EXPERIMENT 1

### Introduction

In Experiment 1, the amount of food was systematically manipulated across phases. Keypecking in pigeons was maintained by a two-component chained schedule of food presentation; the first component was an FI schedule and the second component was an FR 1 x  $\underline{n}$  schedule. In the second component, completion of each FR 1 produced food. The amount of food per interval was examined by manipulating the number of consecutive FR 1's ( $\underline{n}$ ) in the second component.

The particular schedule of food presentation used in this experiment was selected for three reasons. First, an FI schedule was employed in hopes of generating intermediate levels of attack and, thus, providing a sensitive baseline against which to assess the effects of food amount. Ratio schedules of food presentation generally induce greater amounts of attack than do time-based schedules (Malagodi et al., 1979). Employing a ratio schedule in the present experiment may have resulted in near ceiling levels of attack and, therefore, may have masked the effects of food amount. Second, amount of food was varied by programming repeated FR 1's in the terminal component, during which the

food hopper was raised for fixed durations. This procedure was used, rather than simply raising the food hopper for varying durations, partly because of the capacity of the hopper. Because there was no a priori determination of the maximum food amount to be investigated, the possibility existed that, at very long hopper durations, the pigeons would empty the hopper prior to the end of the reinforcement cycle. Programming FR 1's allowed the hopper to refill during the periods it was lowered. Also, the function relating amount of food consumed by pigeons to hopper duration may not be linear, but negatively accelerated, with an asymptote at approximately seven seconds (Epstein, 1981). By arranging FR 1's to produce the food hopper for a fixed duration throughout all conditions, and by varying the number of consecutive FR 1's in the terminal component, it was reasoned that the actual amount of food consumed would more closely correspond to the value of the manipulated variable. Third, a chained schedule was used so that a distinct stimulus would be correlated with the beginning of and, most importantly, the termination of each period of food presentation. If, for example, a tandem rather than a chained schedule had been used, no programmed stimulus change would have accompanied the completion of the final FR 1 in the terminal component. Under such conditions, levels of attack may have been influenced by a tendency to peck the key during the early portions of the fixed-interval.

## Method

### Subjects

Three adult male White Carneau pigeons (Columba livia), P-5626, P-7848, and P-1313 served as experimental subjects. Pigeons P-5626 and P-7848 had previous experience keypecking on concurrent VI schedules of food presentation. Pigeon P-1313 had a history of keypecking under VR and VI schedules of food presentation. Each subject was randomly paired with another bird that served as its target. Each bird was individually housed with water and health grit continuously available. Experimental subjects were maintained at approximately 80% of their free-feeding body weights. Food was continuously available for the target birds.

### Apparatus

A 36 x 40 x 27 cm experimental space was enclosed in a sound-attenuating chamber. One wall was fitted with a standard BRS-Foringer three-key stimulus panel. The right key, located 8 cm from the right wall, could be transilluminated either white or red. Pecks with a force of at least 0.19 N against this key were defined as responses. The other two keys were dark and inoperative during this experiment. Two white houselights, each 10 cm from a side wall and 7 cm apart, were located above the stimulus panel. One white houselight was placed at the center of the back wall. A 4.5 x 5.5 cm aperture, into which a food hopper

could be raised, was located 15 cm below the center key. Reinforcement consisted of 4 s access to mixed grain, during which the houselights and keylight were turned off and a white light illuminated the food hopper.

The apparatus for restraining the target birds and for recording attack was similar to that described by Azrin et al. (1966) and Webbe et al. (1974), and was centered at the rear of the chamber, 40 cm from the stimulus panel. The restraint unit was a rectangular box constructed of clear Plexiglas and was mounted on a spring loaded metal plate. The unit was positioned with one end facing the experimental space. A microswitch was located under the metal plate such that displacements of the unit with a force that exceeded 1.25 N activated the microswitch and were recorded as attacks. Visual inspection of early sessions via a video monitor revealed that at this force requirement, movements of the target did not activate the microswitch, but that most of the contacts by the experimental bird were reliably recorded.

The target bird was restrained within the unit with foam cushions positioned below it and to its rear. An opening on the top of the unit closest to the experimental space allowed for the extrusion of the target bird's head, neck, and upper breast. A bib, constructed of synthetic white fur, was attached to the target so that the exposed breast region was entirely covered. An inverted, U-shaped,

Plexiglas shield was mounted 3 cm in front of the target bird's face and in the same plane as the rear wall of the chamber. This shield was positioned so the fur-covered breast of the target was exposed and the head of the target was protected. This arrangement allowed contacts of sufficient force of either the breast region or of the shield to activate the microswitch, while safeguarding against injury to the target bird. A diagram of the target restraining unit is provided in Figure 1.

Continuous white noise was present to mask extraneous sounds, and a ventilation fan provided air circulation within the experimental space. All experimental events were programmed and recorded by electromechanical equipment located in a separate room.

### Procedure

All experimental subjects had prior keypecking experience, so no initial training was necessary. Each subject was initially placed in the chamber for three one-hour sessions with its target bird present, the white houselights on, and no experimental contingencies in effect. The targets were then removed and each experimental pigeon was exposed to a chained fixed-interval  $\underline{t}$  fixed-ratio 1 times  $\underline{n}$  schedule of food presentation (Ch FI  $\underline{t}$  FR 1 x  $\underline{n}$ ). On this schedule, in the presence of a white keylight, the first keypeck after  $\underline{t}$  min had elapsed turned the keylight red, and each of the next  $\underline{n}$  keypecks produced reinforcement.

After  $n$  grain presentations the keylight turned white and the cycle was repeated. The value of  $t$  was 4 min for P-5626 and P-1313, and was 12 min for P-7848.<sup>1</sup> The initial value of  $n$  for each subject was one. After 30 sessions of fifteen intervals each under this schedule, the targets were reintroduced. The targets were present, and attack was recorded, during all remaining sessions of both experiments. Changeover contingencies were programmed such that in the presence of the white keylight keypecks within 5-s after an attack could not change the keylight to red, and in the presence of the red keylight could not produce grain.

After measures (outlined below) of attack had stabilized under the  $n = 1$  condition, the value of  $n$  was manipulated systematically across experimental phases. The values of  $n$  for each subject, the order of exposure to those values, and the number of sessions in all conditions of Experiment 1 are shown in Table 1. Pigeons P-7848 and P-

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<sup>1</sup>The FI value for P-7848 was initially 4 min. Manipulation of  $n$  from 1 to 24 under this schedule had little effect on measures of attack. Attack levels at all  $n$  values were relatively high for this subject. Because many studies have shown that attack induced by time-based schedules is bitonically related to inter-food interval, with peak levels often seen at intervals between 2 and 4 min (e.g. Cherek et al., 1973; DeWeese et al., 1972; Flory, 1969b), it was thought that attack in this subject may have been at ceiling levels at all  $n$  values. The fixed-interval duration for this subject was therefore increased to 12 min in hopes of producing a more intermediate attack level, and hence a more sensitive baseline against which to assess the effects of  $n$ . When the interval value was increased to 12 min at an  $n$  of 1, mean attacks per interval with attack for the last 15 sessions decreased from 118.7 to 64.2.

5626 were exposed to an ascending series of  $n$  values from 1 to 24, in increments of 8. The effects of  $n = 8$  and  $n = 16$  were redetermined once for P-7848 and P-5626, respectively. The effects of  $n = 1$  were redetermined twice for each bird. Pigeon P-1313 was exposed to  $n$  values of 1, 8, and 16. After 92 sessions under the  $n = 16$  condition this subject was removed from the experiment because of illness.

Sessions were usually conducted 5 days per week, except at larger values of  $n$ , when sessions were conducted every other day to insure that the body weights of the subjects at the beginning of each session were comparable across experimental conditions. Sessions were also conducted every other day during one of the exposures to  $n = 1$  for both birds and during the second exposure to  $n = 8$  for P-7848. These conditions are noted by a <sup>1</sup> in Table 1. Phases in which sessions occurred every other day at lower  $n$  values were conducted to assess the effects of  $n$  when a manipulation in this variable was not accompanied by a change in the schedule of sessions. Sessions terminated following completion of the fifteenth cycle, except at large  $n$  values, when the number of intervals per session for P-5626 was reduced to 10 (noted by a <sup>2</sup> in Table 1).

Two measures of attacking served as dependent variables in the present experiment: the number of attacks per interval with attack and the proportion of intervals with at least one attack. These measures capture two different

characteristics of induced attack, the former depicts the average level of attack within an interval once attack has been initiated, and the latter estimates the tendency to initiate attack within a given interval. Measures such as these have been shown to be quite sensitive to manipulations of schedule parameter in both interval and ratio schedules (e.g., Allen et al., 1980; Wetherington, 1979).

Experimental conditions were changed only when at least 15 sessions had occurred with no systematic trends in both measures of attack, as determined by visual inspection of daily plots and cumulative records.

### Results and Discussion

All birds attacked at low levels during the first two sessions during which no contingencies were programmed. Zero levels of attack were observed for all birds during the third session of this condition. Typical, positively accelerated temporal patterns of keypecking were seen for all birds during the FI component prior to the introduction of the target birds. When the target birds were introduced, each subject began to attack within the first session. Topographical characteristics of attack were similar to those reported in other studies (e.g. Dove, 1976), primarily consisting of forceful pecking against the protective shield and the exposed bib.

Representative cumulative records of responding are presented in Figure 2 for P-7848, Figure 3 for P-5626, and Figure 4 for P-1313. For P-7848 and P-1313, records are shown from conditions when  $\underline{n}$  was 1, 8, and 16; for P-5626 records shown are from conditions when  $\underline{n}$  was 1 and 16. There are two records for each bird from each condition. In each set, keypecks stepped the response pen in the upper record, and attacks stepped the response pen in the lower record. These records illustrate several characteristics of responding that occurred in all birds. First, keypecking was generally characterized by a pause following reinforcement, followed by a transition to a moderately high rate. This transition was positively accelerated for P-7848, but more abrupt for P-5626 and P-1313. Both positively accelerated and "break and run" patterns of responding have been maintained under FI schedules of food presentation (e.g., Branch & Gollub, 1974; Ferster & Skinner, 1957). Second, more attacks occurred when larger amounts of food were delivered per interval. Third, attacking usually occurred in bursts shortly after the last food presentation of an interval (i.e., upon illumination of the white keylight) and terminated abruptly sometime before the onset of keypecking. None of the birds attacked in the presence of the red keylight. Note that P-5626 occasionally attacked well into the fixed-interval (indicated by arrows in Figure 3). Although this was not a consistent within-

session characteristic of attack, it did occur intermittently throughout the experiment with this subject. While most theorists reject the notion that induced behavior is an early response in a chain (Staddon, 1977), it is possible that attacks occurring in later portions of the interval were part of a heterogeneous chain that terminated in keypecking. If such were the case, however, alternations between attacking and keypecking might have been expected to occur more frequently.

Figures 5, 6, and 7 relate the number of attacks per interval with attack and the proportion of intervals containing attack for P-7848, P-5626, and P-1313, respectively, to the amount of food per interval, or  $\underline{n}$ . Values shown are means from the last 15 sessions of each condition. For each subject, these measures of attack generally increased monotonically as a function of  $\underline{n}$ . These functions can be characterized as increasing to a maximum at some intermediate  $\underline{n}$  value, and remaining at or near that maximum with further increases. (Note that for P-1313 the function for attacks per interval with attack increased with each increase in  $\underline{n}$ , up to 16 - the last value examined with this bird).

With subject P-7848, increasing  $\underline{n}$  from 1 to 8 more than doubled mean attacks per interval with attack and increased the mean proportion of intervals with attack from 0.77 to 0.98. When  $\underline{n}$  was changed from 8 to 16, mean attacks per

interval with attack again increased, from 132.5 to 176.2, while the proportion of intervals with attack remained near the maximum value. Both measures of attack were essentially unchanged when  $\underline{n}$  was increased to 24. Reexposure to various  $\underline{n}$  values produced the same general function, although both measures were generally lower than those observed during the initial exposures. This may have resulted from the intervening exposure to larger food amounts or from a general decrease in attack levels across sessions. Such a decrease has been previously reported with induced attack (Cherek & Pickens, 1970). It is likely, however, that the former variable is responsible because no general decline in attack was seen across sessions within any phase of the experiment.

Both functions for P-5626 resembled those seen with P-7848, except that attacks per interval with attack reached a maximum at  $\underline{n} = 8$  (see Figure 6). Further increases in  $\underline{n}$  produced comparable levels of attacks per interval and the same maximum proportion levels. The means of these measures during the second (and third, for  $\underline{n} = 1$ ) exposure to various  $\underline{n}$  values were comparable, but slightly lower, to those observed during initial exposures.

The data from the phases at lower  $\underline{n}$  values under conditions in which sessions were conducted every other day (P-5626 and P-7848) and when sessions ended after 10 intervals (P-5626) suggest that the increases in attack were

indeed a function of increases in  $n$ , rather than a function of some characteristic of the different conditions required at larger  $n$  values. For example, it cannot be argued that the higher levels of attack observed at large  $n$  values were due simply to deprivation of the opportunity to attack that resulted from conducting sessions every other day.

Although P-1313 had to be removed from the experiment before being exposed to all conditions, the data for this bird warrant examination. After attacking at relatively low levels during the early sessions of the  $n = 1$  condition, this bird ceased attacking, and failed to do so for the final 22 sessions under this phase. When  $n$  was increased to eight, attacking occurred in the first session, and persisted for the remainder of this phase. The mean levels of attacks per interval with attack and proportion of intervals with attack for the last 15 sessions were 43.6 and 0.97, respectively. When  $n$  was increased to 16, mean attacks per interval with attack increased to 84.7 and the proportion measure increased to 0.99 (see Figure 7). After 92 sessions under this condition, both keypecking and attacking began to decrease until this subject failed to engage in either activity. Probe sessions at other  $n$  values failed to produce keypecking or attacking. This bird was removed from the experiment and perished shortly thereafter. The results presented in Figure 7 include only those

sessions prior to the sudden decrease and subsequent cessation of keypecking and attacking.

The development of attack in P-1313 as a result of changing  $\underline{n}$  from one to eight is shown in Figure 8. This figure shows daily levels of attack per interval with attack for the last 15 sessions of the  $\underline{n} = 1$  condition and the first 15 sessions of the  $\underline{n} = 8$  condition. This figure reveals that the zero levels of attack observed when  $\underline{n}$  equaled one were substantially increased by the first session when  $\underline{n}$  was increased to eight. Attack continued to occur at similar levels throughout this phase.

Note that for all birds, when conditions arranged for intervals terminating in multiple grain cycle presentations--when  $\underline{n}$  was greater than one--attack occurred in nearly every interval (i.e., proportion values were usually near 1.0). In contrast, when  $\underline{n}$  was one, attack occurred in fewer intervals per session. Thus, one major effect of programming multiple grain cycle presentations was to increase the likelihood of initiating attack, as well as to increase the amount of attack per interval once it was initiated.

A summary of keypecking data for each bird for all conditions is provided in Table 2. For both P-5626 and P-7848, response rates generally decreased and pause times generally increased as a function of  $\underline{n}$ . For P-1313, no

systematic trend can be seen over the range of parameter values studied.

Decreases in operant response rates and increases in pauses similar to those seen with P-7848 and P-5626 have been reported on FI schedules as a function of feeder cycle duration (Staddon, 1970), or milk concentration (Lowe, Davey, & Harzem, 1974). These results have been attributed to the "inhibitory" effects of food presentation (Lowe et al., 1974). Other studies, however, have reported a positive relation between operant response rates and reinforcement magnitude, and are generally attributed to the "motivational" or "strengthening" effects of food reinforcement (see Bonem & Crossman, 1988, for a review). The effects of reinforcement magnitude are quite inconsistent across studies and appear to depend upon a number of procedural characteristics. A more detailed discussion of the effects of this variable on operant behavior and the relevance to the present experiments will appear in the General Discussion.

In summary, Experiment 1 revealed two major effects of increasing the amount of food per interval on schedule-induced attack: a) the amount of attack (as measured by attacks per interval with attack) is a direct function of the amount of food per interval, with this measure increasing to a maximum at some  $\underline{n}$  value and remaining at high levels with further increases in  $\underline{n}$ , and b) the

probability of initiating attack is higher when conditions arrange for the delivery of multiple grain cycles rather than a single cycle. These data extend those reporting that the larger of two amounts of food induced more attack on FT schedules (Flory, et al., 1988) by providing a characterization of the function over a greater range of parameter values.

Figure 1. Diagram of experimental apparatus used to secure the target pigeon and measure attacks. This diagram is copied from Azrin, Hutchinson, & Hake (1966).

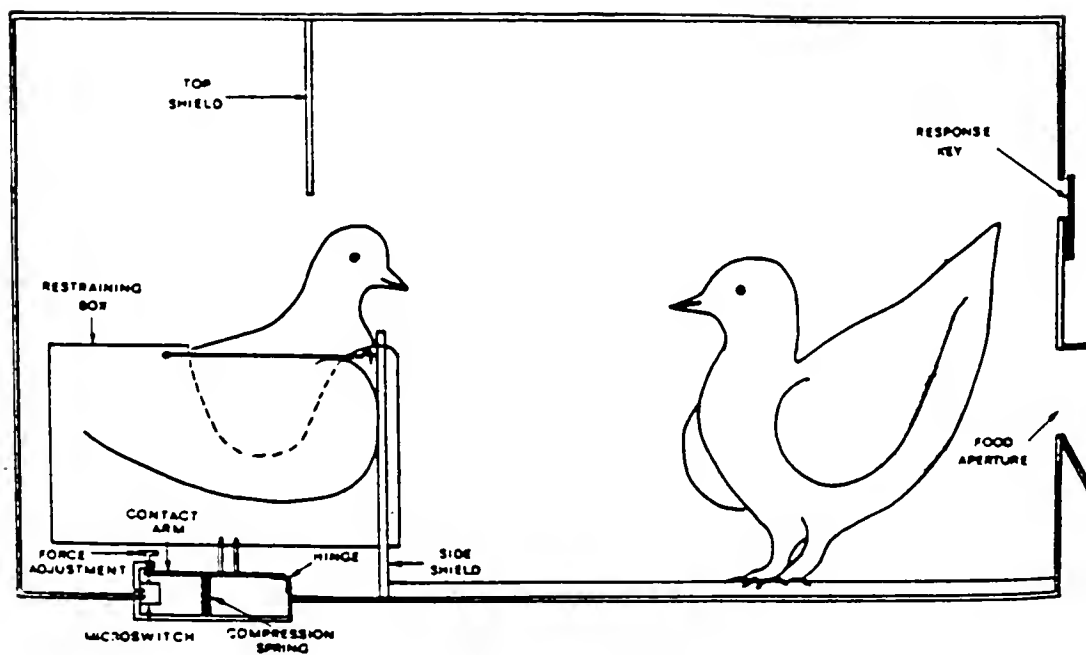


Figure 2. Sample cumulative records from portions of sessions from  $\underline{n} = 1$ ,  $\underline{n} = 8$ , and  $\underline{n} = 16$  conditions for P-7848 during Experiment 1. In the upper record of each condition, each keypeck stepped the response pen, the response pen deflected with each food presentation and reset after the last food presentation of an interval, and each attack deflected the event pen. In the lower record of each condition, each attack stepped the response pen, the response pen reset after the last food presentation of an interval, and each food presentation deflected the event pen. Records are taken from sessions in which the attacks per interval with attack measure closely approximated the mean for the last 15 sessions.

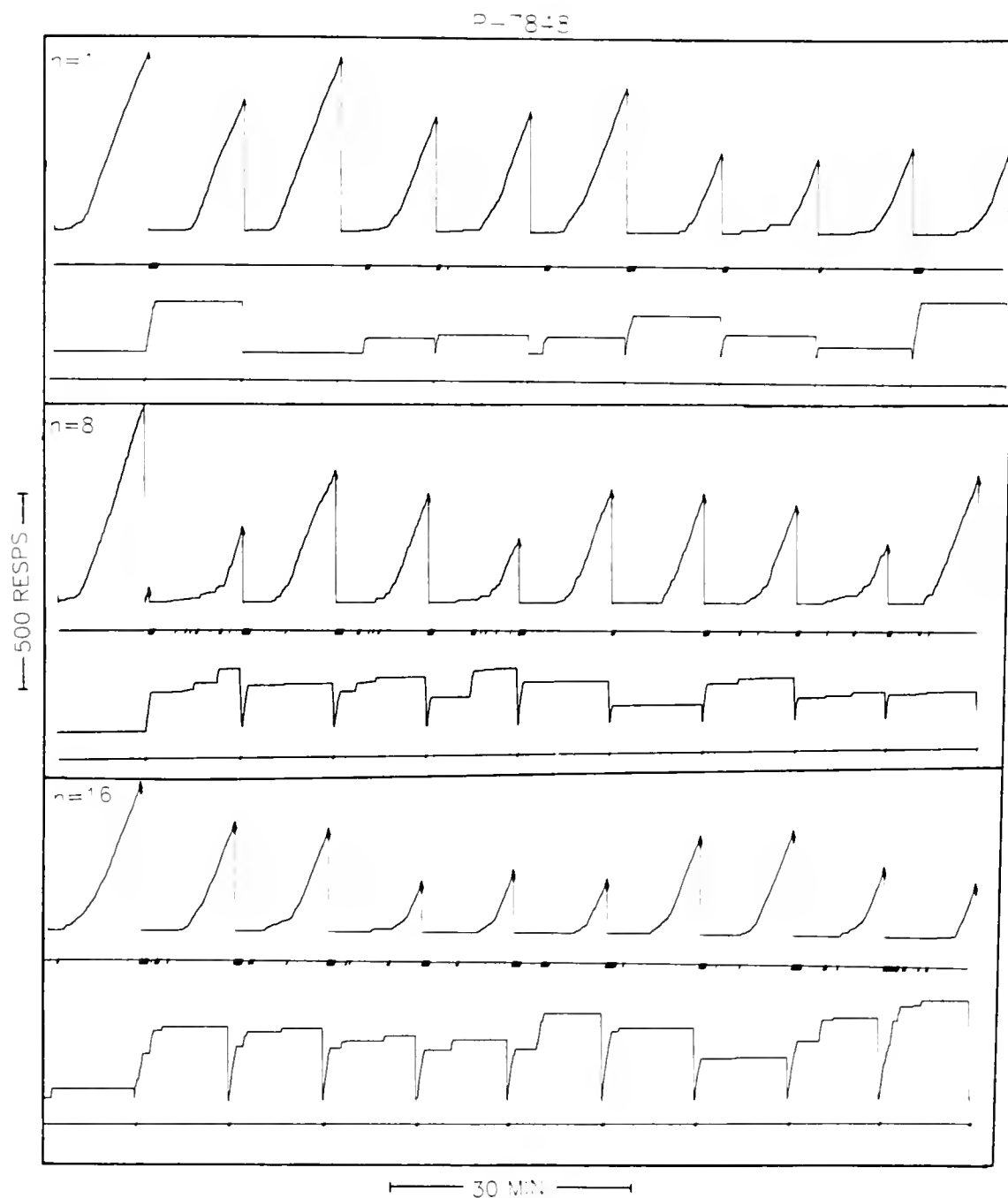


Figure 3. Sample cumulative records from entire sessions  $\underline{n} = 1$  and  $\underline{n} = 16$  conditions for P-5626 during Experiment 1. All conventions are as in Figure 2.

P-5626

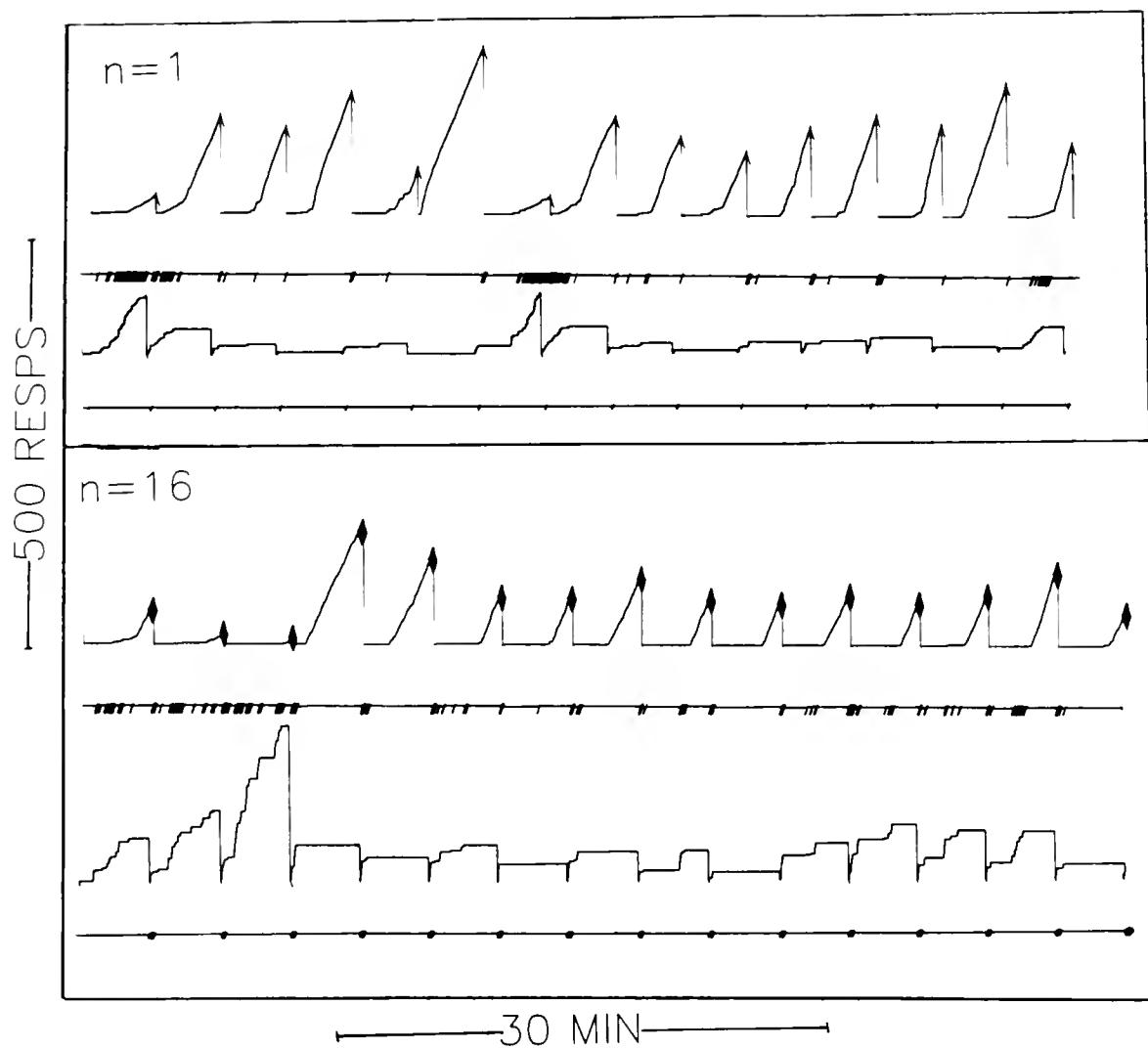
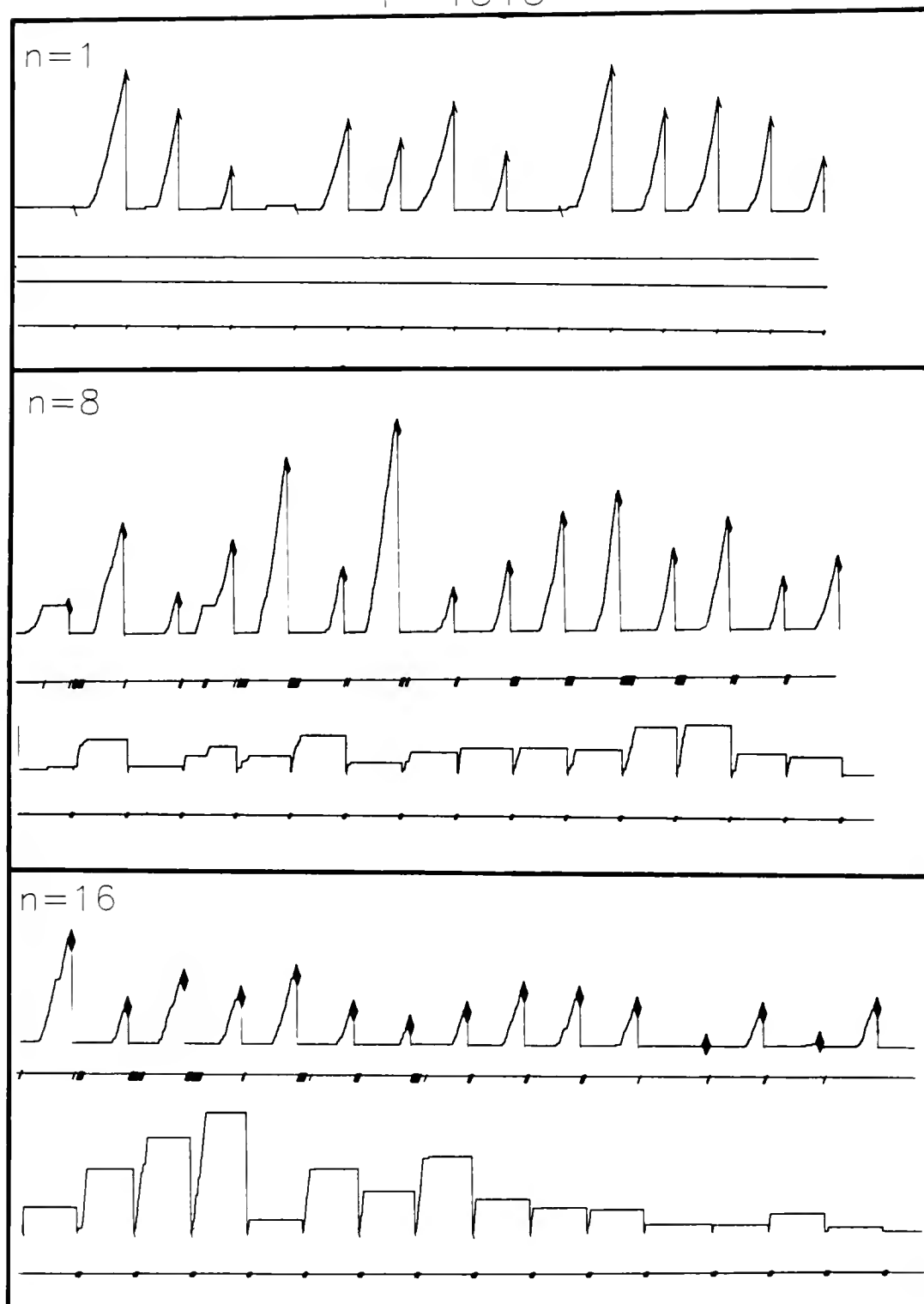


Figure 4. Sample cumulative records from  $\underline{n} = 1$ ,  $\underline{n} = 8$ , and  $\underline{n} = 16$  conditions for P-1313 during Experiment 1. All conventions are as in Figure 2.

P-1313

— 500 RESPS —



— 30 MIN —

Figure 5. Attacks per interval with attack and the proportion of intervals with attack as a function of the amount of food per interval ( $\underline{n}$ ) for P-7848 from Experiment 1. Closed circles are from the initial exposure to each  $\underline{n}$  value, open circles are from the second exposure to  $\underline{n} = 1$  and  $\underline{n} = 16$  conditions, and open triangles are from the third exposure to the  $\underline{n} = 1$  condition. See text for specific characteristics of each condition. Values are means taken from the last 15 sessions. Vertical bars indicate ranges.

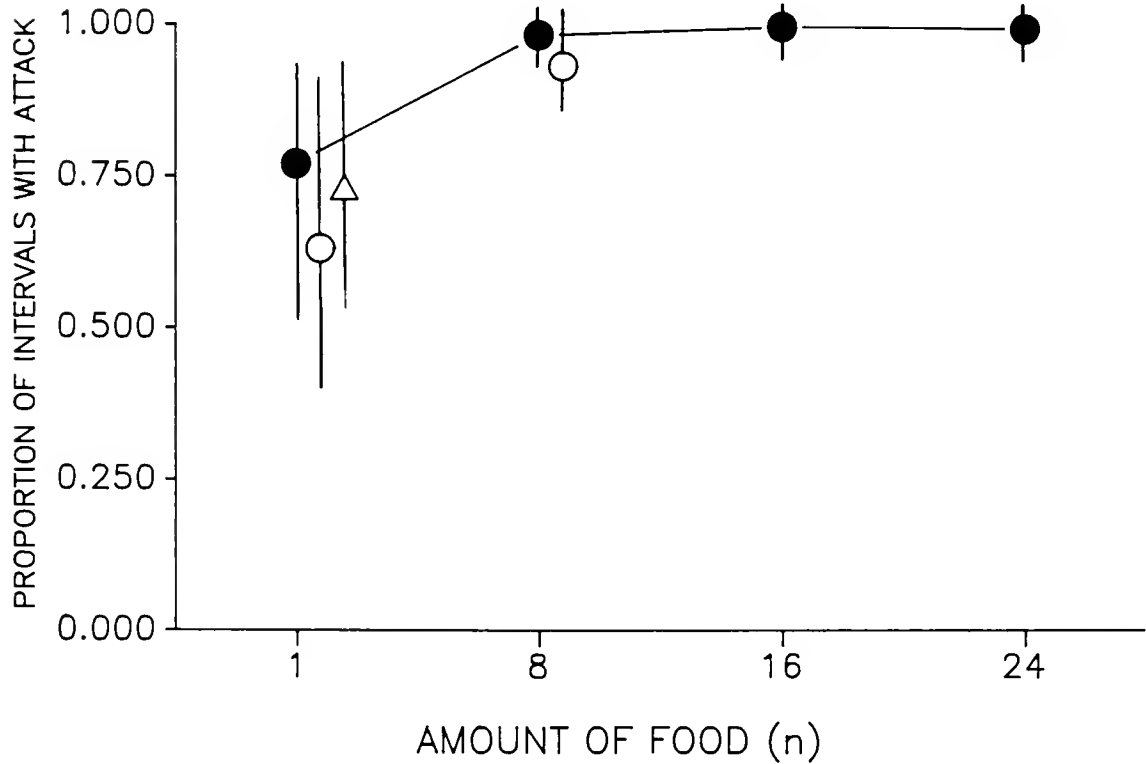
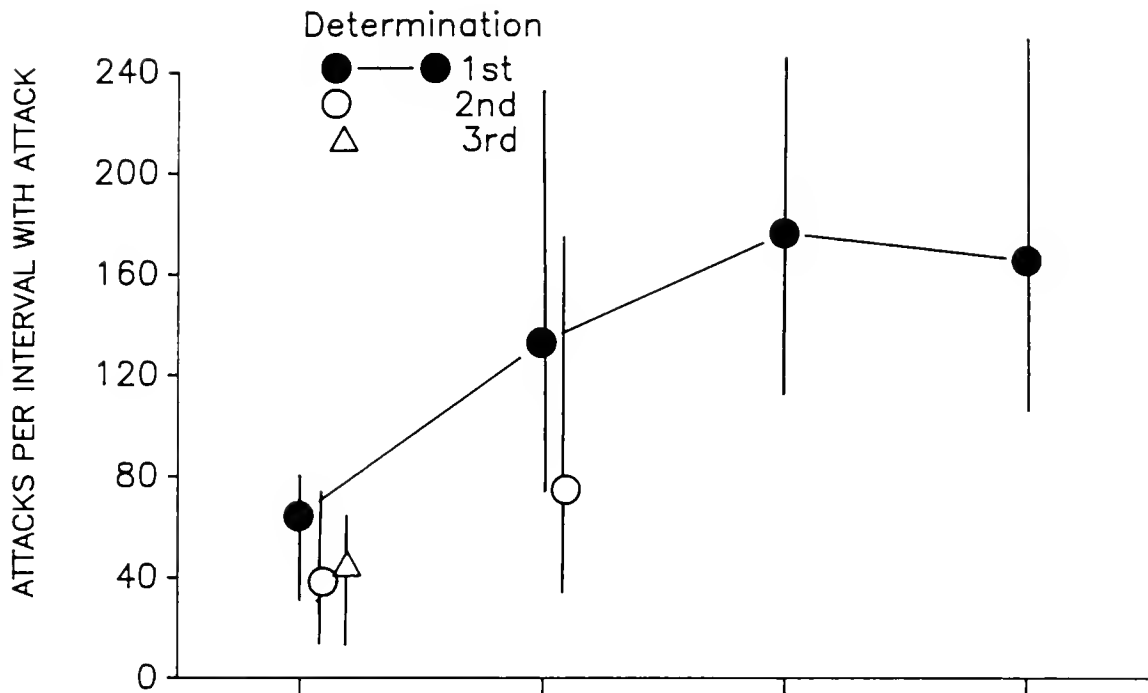


Figure 6. Attacks per interval with attack and the proportion of intervals with attack as a function of the amount of food per interval ( $\underline{n}$ ) for P-5626 from Experiment 1. All conventions are as in Figure 5.

P-5626

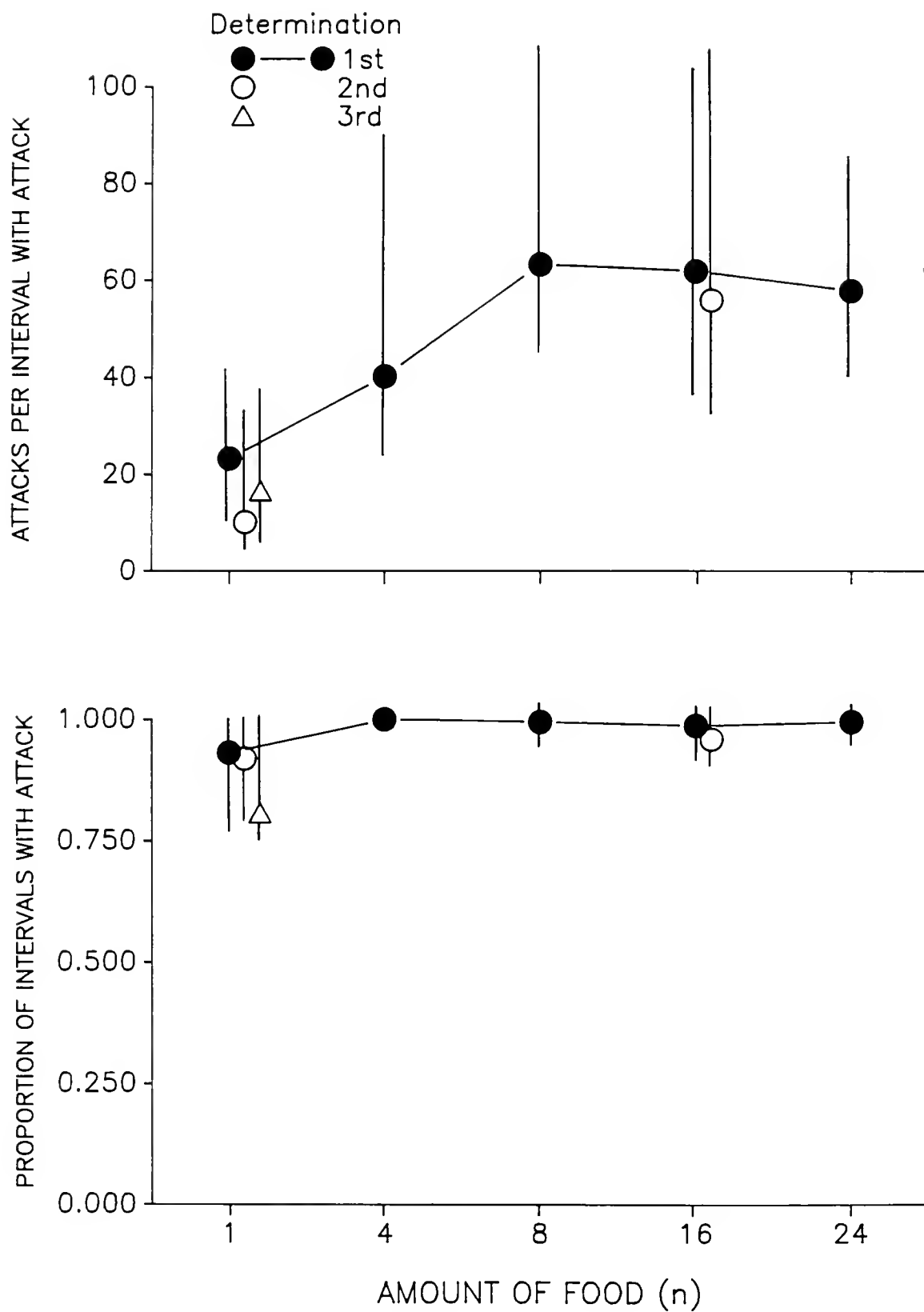


Figure 7. Attacks per interval with attack and the proportion of intervals with attack as a function of the amount of food per interval (n) for P-1313 during Experiment 1. All conventions are as in Figure 5.

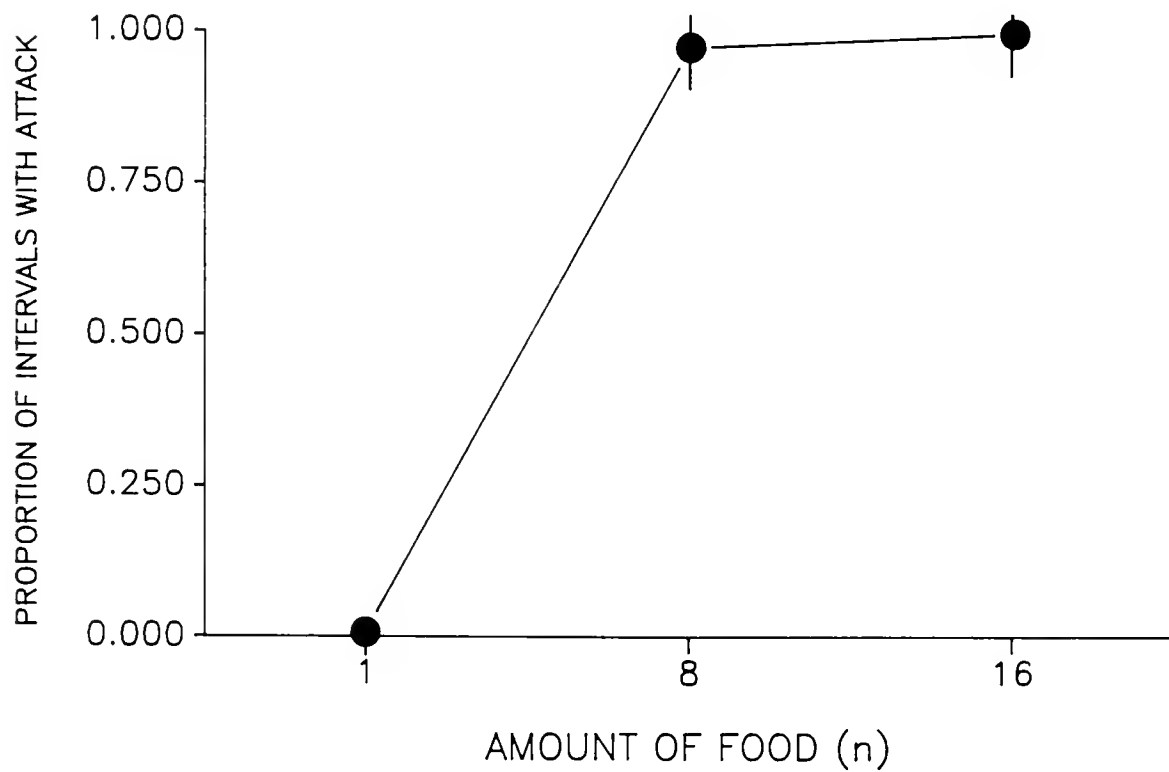
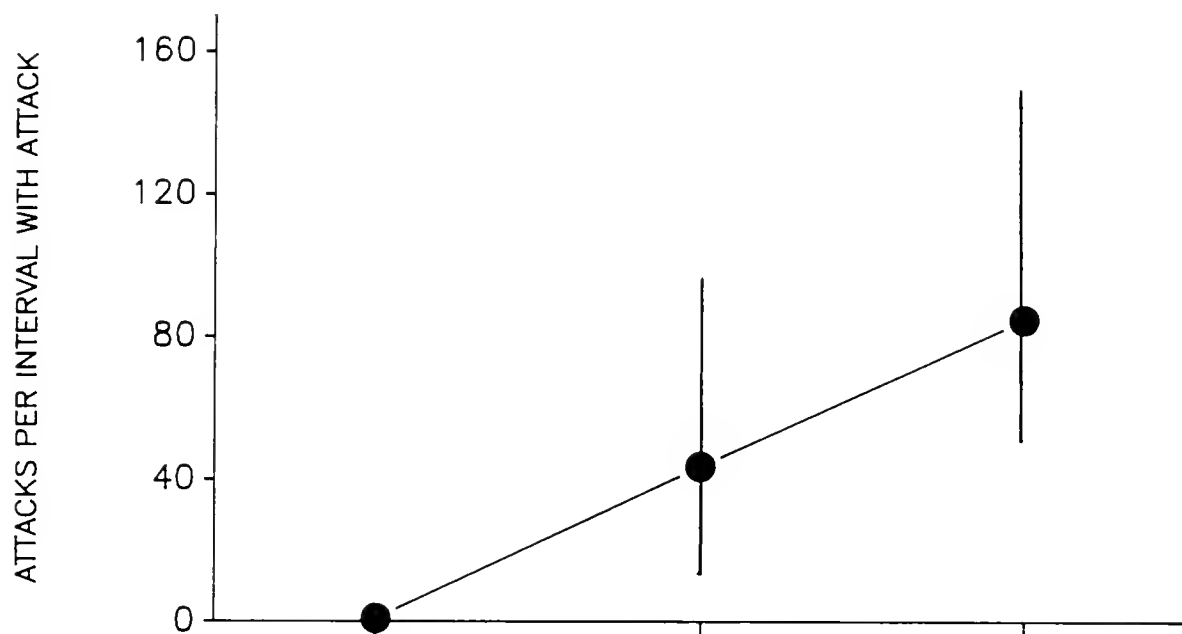


Figure 8. Daily plots of attacks per interval with attack for P-1313 for the last 15 sessions of the  $\bar{n} = 1$  and the first 15 sessions of the  $\bar{n} = 8$  condition from Experiment 1.

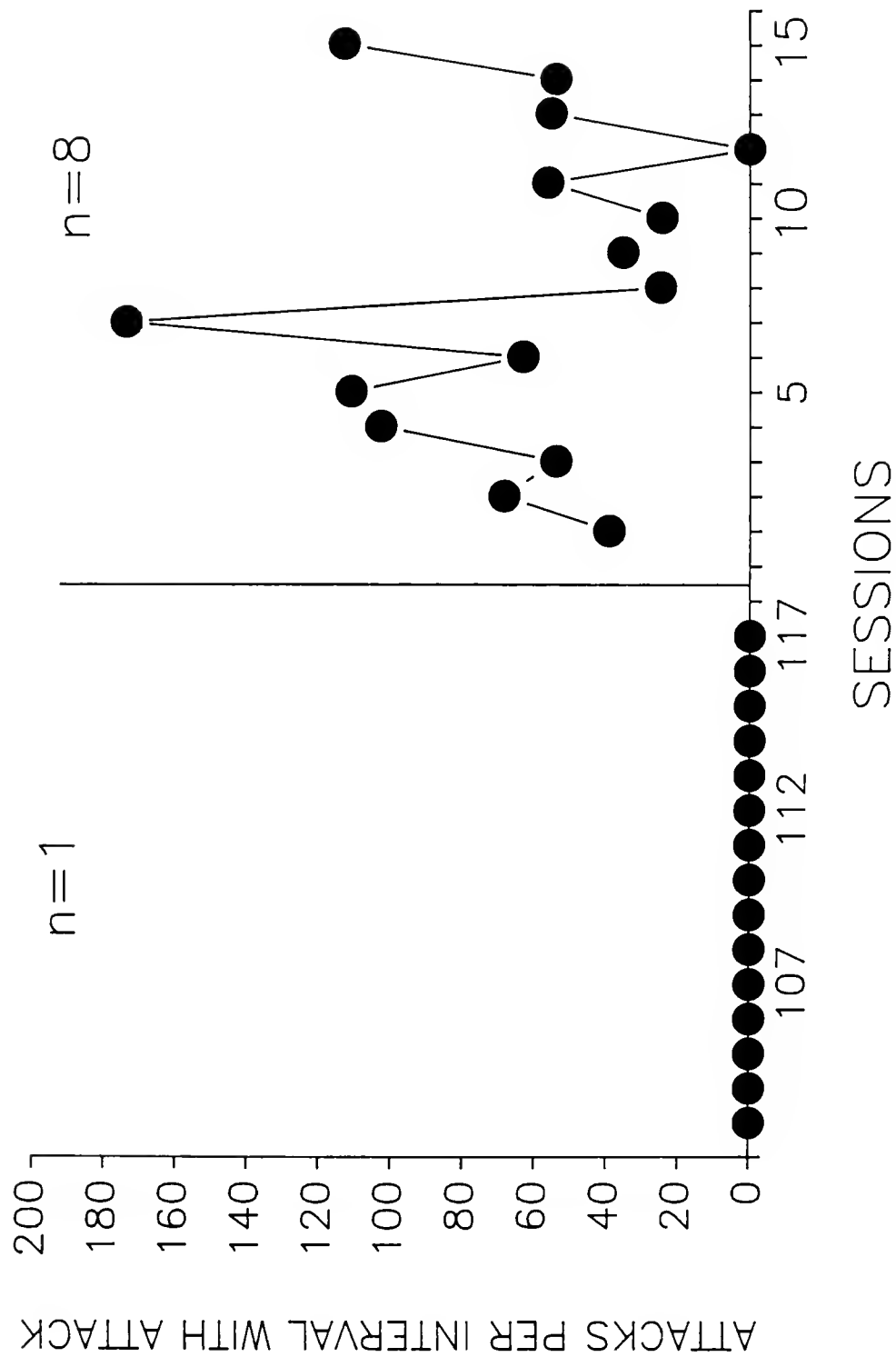


TABLE 1

The order of conditions and number of sessions in each for all subjects in Experiment 1. Each subject responded on a Ch FI  $\bar{t}$  FR 1 x  $\bar{n}$  schedule of food presentation. Sessions ended after 15 intervals and run 5 days per week unless otherwise noted.

	$\bar{n}$ value	sessions
<u>P-7848</u>		
$\bar{t}$ = 12 min		
	1	120
	8	61
	16 <sup>1</sup>	32
	24 <sup>1</sup>	27
	1	32
	8 <sup>1</sup>	52
	1 <sup>1</sup>	34
<u>P-5626</u>		
$\bar{t}$ = 4 min		
	1	138
	8	83
	16 <sup>2</sup>	78
	24 <sup>1,2</sup>	44
	1	120
	16 <sup>1</sup>	47
	1 <sup>1,2</sup>	51
<u>P-1313</u>		
$\bar{t}$ = 4 min		
	1	117
	8	58
	16 <sup>1</sup>	98

<sup>1</sup>Sessions conducted every other day

<sup>2</sup>Sessions ended after 10 intervals

TABLE 2

Overall keypeck rates and average pause times during the FI for each subject for every condition of Experiment 1. Values are means for the last 15 sessions. Values in parentheses are ranges. Each subject responded on a Ch FI  $\underline{t}$  FR 1 x  $\underline{n}$  schedule.

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<u>n</u>	<u>keypecks/min</u>	<u>pause/interval(min)</u>
<u>P-7848</u>		
<u>t</u> = 12min		
1	24.5 (20.1-29.9)	2.9 (1.7-4.0)
8	24.0 (20.5-33.5)	3.2 (1.7-4.3)
16	18.0 (15.3-25.1)	4.3 (3.2-5.5)
24	14.2 (11.3-17.2)	4.5 (3.5-6.1)
8	30.8 (25.0-41.7)	2.9 (1.6-4.0)
1	27.8 (24.2-30.5)	3.0 (1.6-5.2)
<u>P-5626</u>		
<u>t</u> = 4min		
1	27.4 (21.7-30.8)	1.5 (1.3-2.1)
8	25.6 (17.5-45.0)	1.7 (1.3-2.4)
16	20.8 (18.3-32.8)	2.0 (1.1-2.5)
24	17.4 (10.6-23.9)	2.2 (2.0-3.0)
1	27.7 (23.1-37.8)	1.5 (0.9-1.9)
16	19.7 (6.5-24.5)	2.1 (1.6-2.6)
1	30.1 (21.9-33.3)	1.5 (1.2-2.1)
4	29.0 (22.4-37.8)	1.8 (1.4-2.3)
<u>P-1313</u>		
<u>t</u> = 4min		
1	32.6 (0.5-56.9)	2.3 (1.1-8.7)
8	37.3 (23.8-46.5)	2.1 (1.5-2.7)
16	25.2 (9.9-40.8)	1.9 (0.9-2.6)

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## EXPERIMENT 2

### Introduction

The results from Experiment 1 indicated that induced attack was a monotonic, increasing function of the amount of food presented dependent upon keypecking. Data from studies of induced polydipsia with rats, however, suggest that relations obtained from manipulations of amount of food across sessions may change when comparisons of different food amounts are made within sessions. When presented food pellets according to an FT schedule, rats drank slightly more when multiple pellets (four or six) were delivered than when one pellet was delivered each interval per session (Reid & Dale, 1983; Reid & Staddon, 1982). However, when intervals ending in multiple pellets were interspersed with intervals ending in one pellet within experimental sessions, rats drank more in those intervals that followed one pellet and during those intervals that ended in one pellet, if those intervals were signalled (Reid & Dale, 1983; Reid & Staddon, 1982). While the determinants of the differences in across- and within-session comparisons are not clear, these data suggest that the function relating induced

polydipsia to amount of food may depend critically upon the context in which the amount of food is manipulated.

Experiment 2 was conducted to determine if the relationship revealed in Experiment 1, when the amount of food was varied across experimental phases, would hold when varied within sessions. If a comparable relation is obtained, then the generality of the results of the first experiment would be demonstrated. However, if differences similar to those discussed above with polydipsia are seen, further analysis would be required to determine the factors responsible.

### Method

#### Subjects

P-5626 and P-7848 served as experimental subjects. Each was maintained at 80% of its free-feeding body weight. Each subject was paired with a target pigeon. For P-5626, the target was the same as in Experiment 1; for P-7848, the target was different than in Experiment 1. The target for P-5626 became ill midway through this experiment and was replaced. Each target was given free access to food and all birds were individually housed with water and health grit continuously available.

## Apparatus

The apparatus used in this experiment was the same as in Experiment 1.

## Procedure

After completion of the sequence of conditions listed in Table 1, P-5626 and P-7848 were exposed to a two-component multiple schedule in which  $\underline{n} = 1$  and  $\underline{n} = 16$  conditions alternated irregularly within experimental sessions. For P-5626 the schedule was a Mult [Ch FI 4 FR 1 x 1] [Ch FI 4 FR 1 x 16]; the schedule for P-7848 was a Mult [Ch FI 12 FR 1 x 1] [Ch FI 12 FR 1 x 16]. The component that began the session was determined randomly. Components alternated irregularly and lasted either 2, 3, or 4 intervals. For P-5626, a clicking sound accompanied the  $\underline{n} = 16$  component. For P-7848 the clicker accompanied the  $\underline{n} = 1$  component. Sessions were terminated after 9 intervals had occurred in each component. Components were separated by 30-s time-outs (TOs) during which the chamber was dark, no experimental events were programmed, and attacks were recorded (but had no effect on TO duration). Changeover contingencies in Experiment 2 were identical to those in Experiment 1.

After 51 sessions for P-5626 and 47 sessions for P-7848, the TOs were lengthened to 60-s. This condition lasted 33 sessions for P-5626 and 30 sessions for P-7848.

The target for P-5626 was replaced on the ninth session of this condition.

### Results and Discussion

Figures 9 and 10 show representative cumulative records of responding under the multiple schedule for P-5626 and P-7848, respectively. Several general characteristics of responding are illustrated in these records. First, keypeck patterns for both birds resembled those seen in Experiment 1. Second, attacks usually occurred during the periods immediately after the last grain presentation of an interval. (Note that P-7848 often continued to attack well into the interval). Third, more attack was induced in the  $n = 16$  component.

The third characteristic listed above is quantitatively summarized in Figures 11 and 12. Figure 11 presents attacks per interval with attack and proportion of intervals with attack in each component for P-5626; Figure 12 shows these data for P-7848. For P-5626, both measures of attack were higher during the  $n = 16$  component, but the differences in attack were not as great as seen in Experiment 1. In Experiment 1, this bird attacked in virtually every interval when  $n$  was 16, while during the multiple schedule, attack usually occurred in all but one interval. This interval was

usually the first interval after a component change or the first interval of the session.

The data for P-7848 were similar to those for P-5626 in that, although more attack was observed under the  $\underline{n} = 16$  condition than when  $\underline{n}$  was 1, the differences were not as great as in Experiment 1. This was primarily the result of elevated levels of attack (in both measures) under the  $\underline{n} = 1$  condition. Attacks per interval under the  $\underline{n} = 16$  condition were similar in both Experiments. As with P-5626, this bird did not attack in every interval when  $\underline{n}$  was 16, and intervals that lacked attack in this component were usually the first interval following a component change or the first interval of the session.

Keypecking data from Experiment 2 are shown in Table 3. As in Experiment 1, rates were lower and pause times were longer when  $\underline{n}$  was 16.

One advantage of employing a multiple schedule for the present comparison is that, because both experimental conditions ( $\underline{n} = 1$  and  $\underline{n} = 16$ ) occur within the same session, attacks during both conditions are similarly exposed to effects of extraneous, uncontrolled variables. Although not necessarily the case, it is quite possible that those variables do not operate differentially on attack in the two components of the multiple schedule. If this is indeed the case, then it might be illustrative to compare the number of sessions in which attack was higher under the  $\underline{n} = 1$  and  $\underline{n} =$

16 conditions. For both birds, attacks per interval with attack were higher during the  $\underline{n} = 16$  component in each of the last 15 sessions. For the proportion measure, attack was higher during the  $\underline{n} = 16$  component in 6 of these sessions for P-5626 and in 5 of these sessions for P-7848. This measure was never higher during the  $\underline{n} = 1$  component for P-5626 and was higher in only 1 session for P-7848.

Employing a multiple schedule to compare conditions within experimental sessions is not without its disadvantages. Interactions between components is frequently observed in studies using multiple schedules (e.g. Bloomfield, 1966; Pear & Wilkie, 1971; Reynolds, 1961). It is possible that such interactions occurred in the present experiment. Inspection of the cumulative records in Figures 9 and 10 reveals that for both birds elevated levels of attack were sometimes seen in the first interval of  $\underline{n} = 1$  components and reduced levels were sometimes seen in the first interval of  $\underline{n} = 16$  components. It is quite possible that attacking in the first interval of a component is at least partially controlled by the amount of food delivered in the final interval of the preceding component rather than by the stimulus correlated with the current component, despite the 30-s TO's between components. When the TO durations were increased to 60-s, no change in this characteristic of attack, or in overall levels of attack was observed. The smaller differences in levels of

attack between  $\underline{n} = 1$  and  $\underline{n} = 16$  conditions in Experiment 2 (compared with those seen in Experiment 1), also may have resulted from interaction between the two components. Perhaps attacking was partially controlled by some overall session average of food amount, and this source of control attenuated the differences seen in Experiment 1. Despite these limitations, the data presented in Figures 9, 10, 11, and 12 and the proportion of sessions in which attack during the  $\underline{n} = 16$  component was greater provide substantial evidence that attack is more likely when larger amounts of food are delivered, even when large and small amounts alternate within experimental sessions.

Figure 9. A sample cumulative record for P-5626 from Experiment 2. All conventions are as in Figure 2. See text for details of procedure.

P-5626

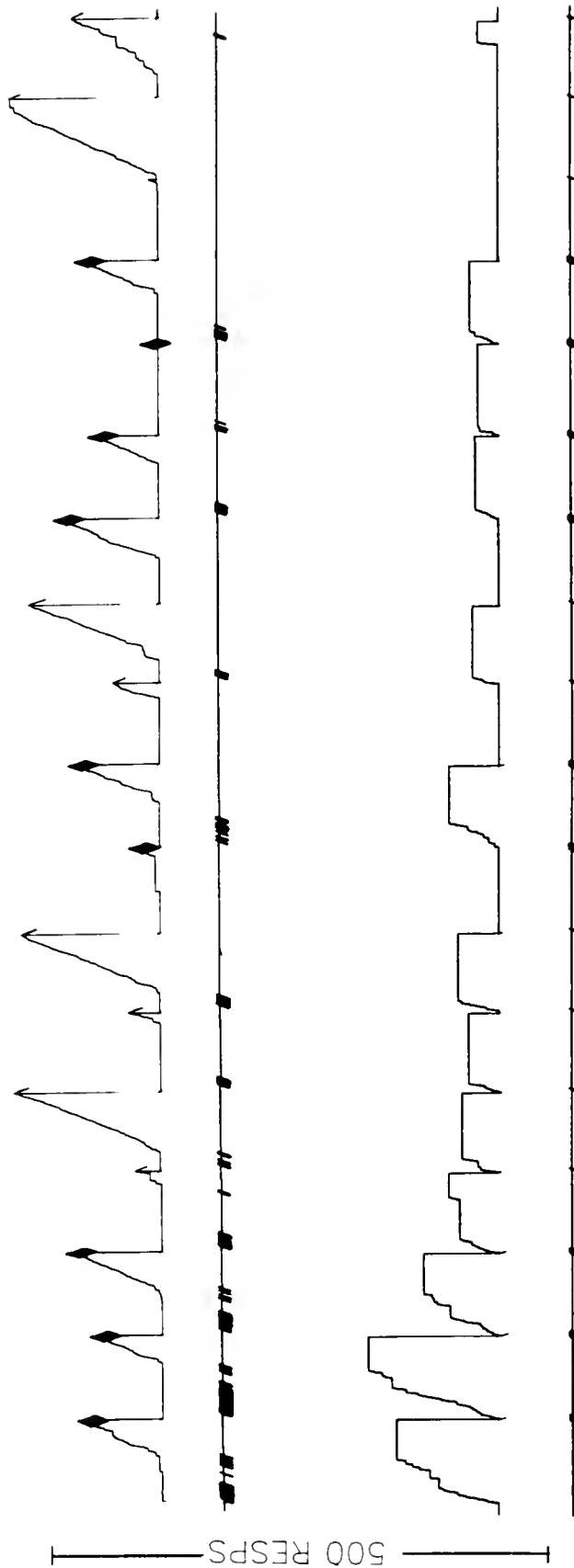
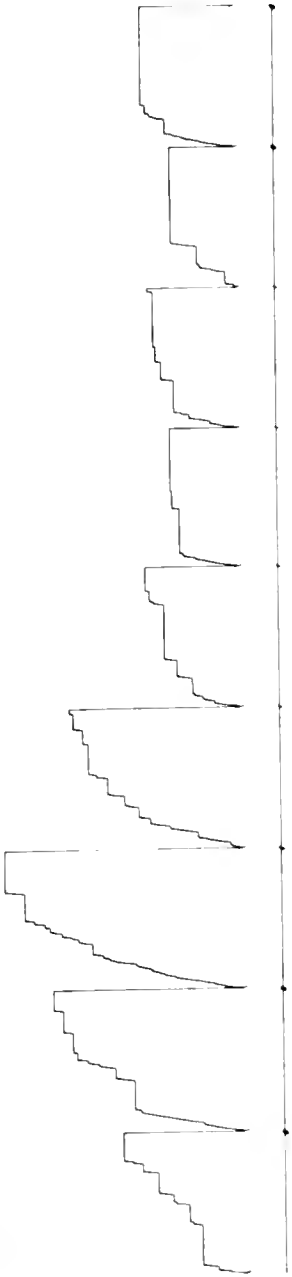
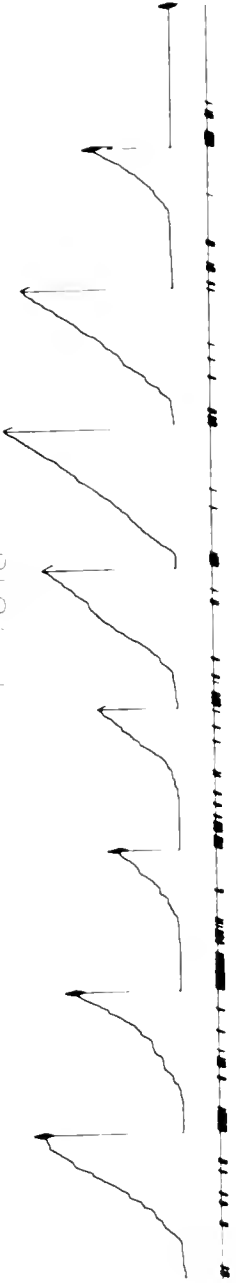
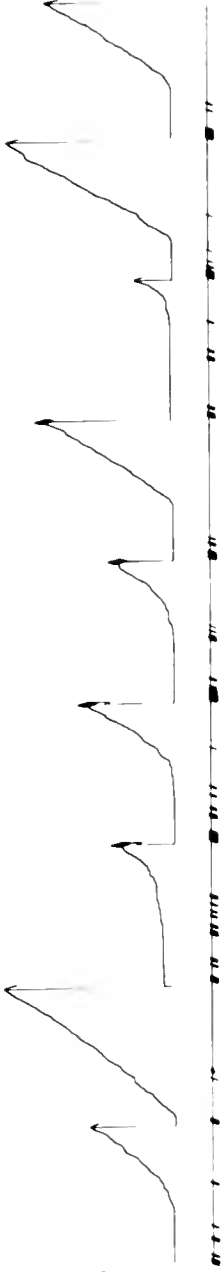


Figure 10. A sample cumulative record for P-7848 from Experiment 2. All conventions are as in Figure 2. See text for details of procedure.

P-7818



500 PPS



500 PPS

Figure 11. Mean levels of attacks per interval with attack and proportion of intervals with attack for P-5626 for  $\underline{n} = 1$  and  $\underline{n} = 16$  components during Experiment 2. Striped bars are from the  $\underline{n} = 16$  components. Values are from the last 15 sessions. Vertical bars indicate ranges.

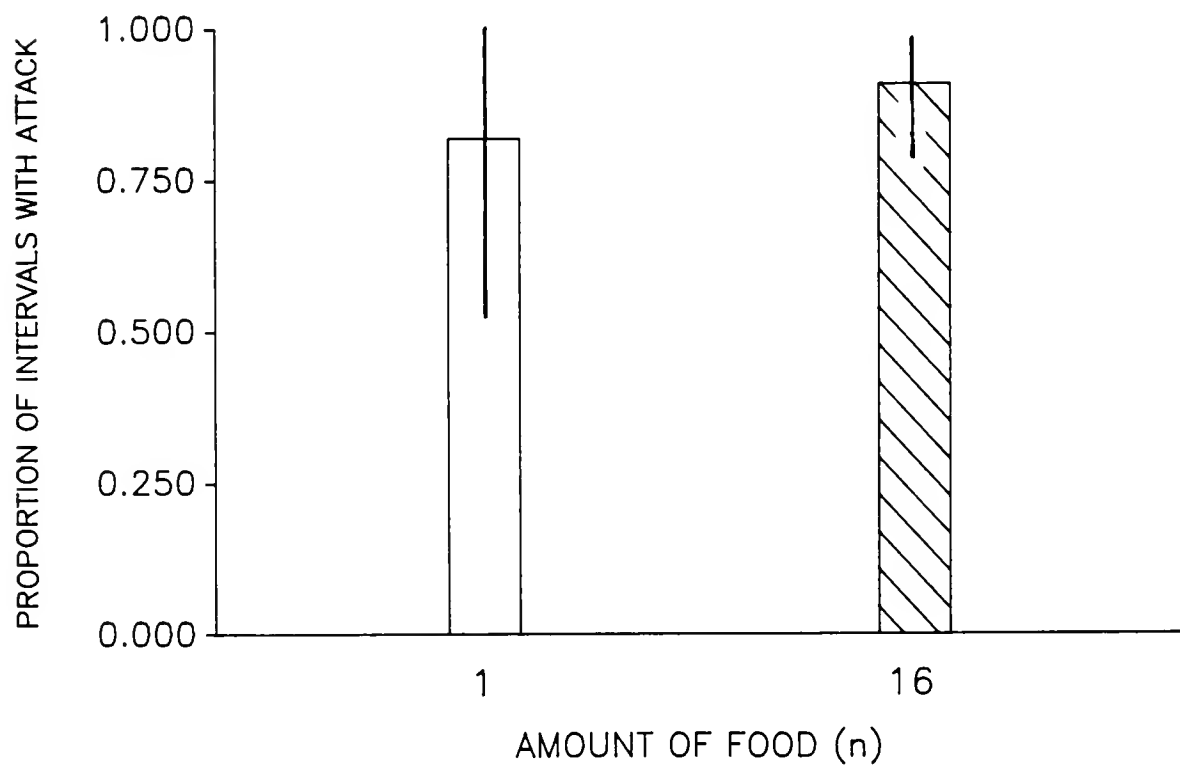
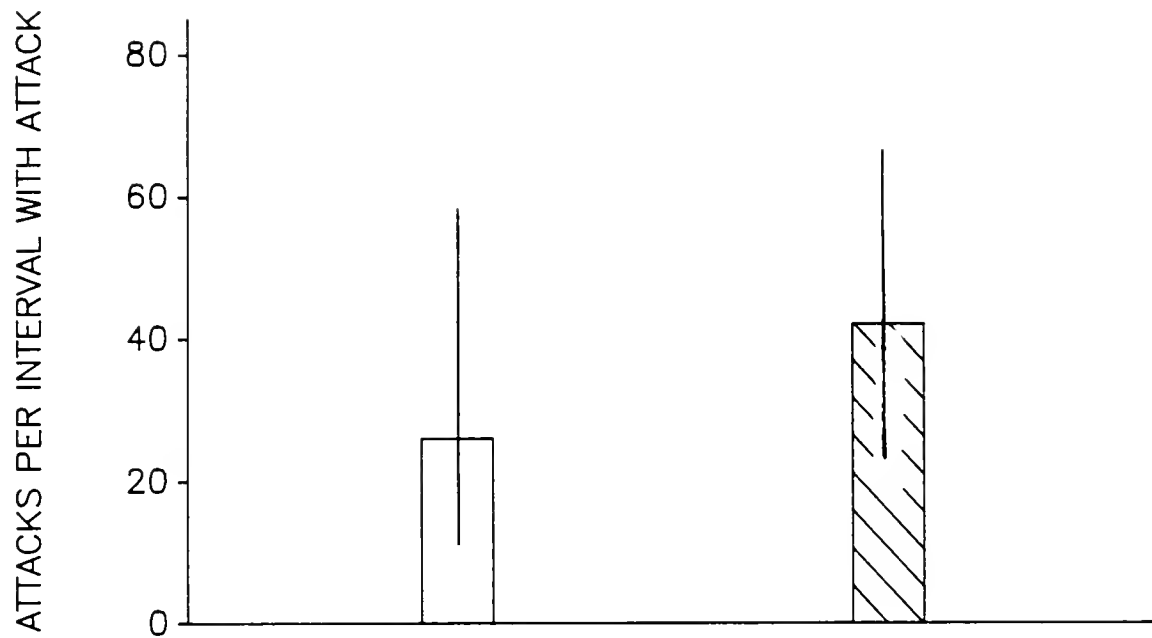


Figure 12. Mean levels of attacks per interval with attack and proportion of intervals with attack for P-7848 for  $\underline{n} = 1$  and  $\underline{n} = 16$  components during Experiment 2. All conventions are as in Figure 11.

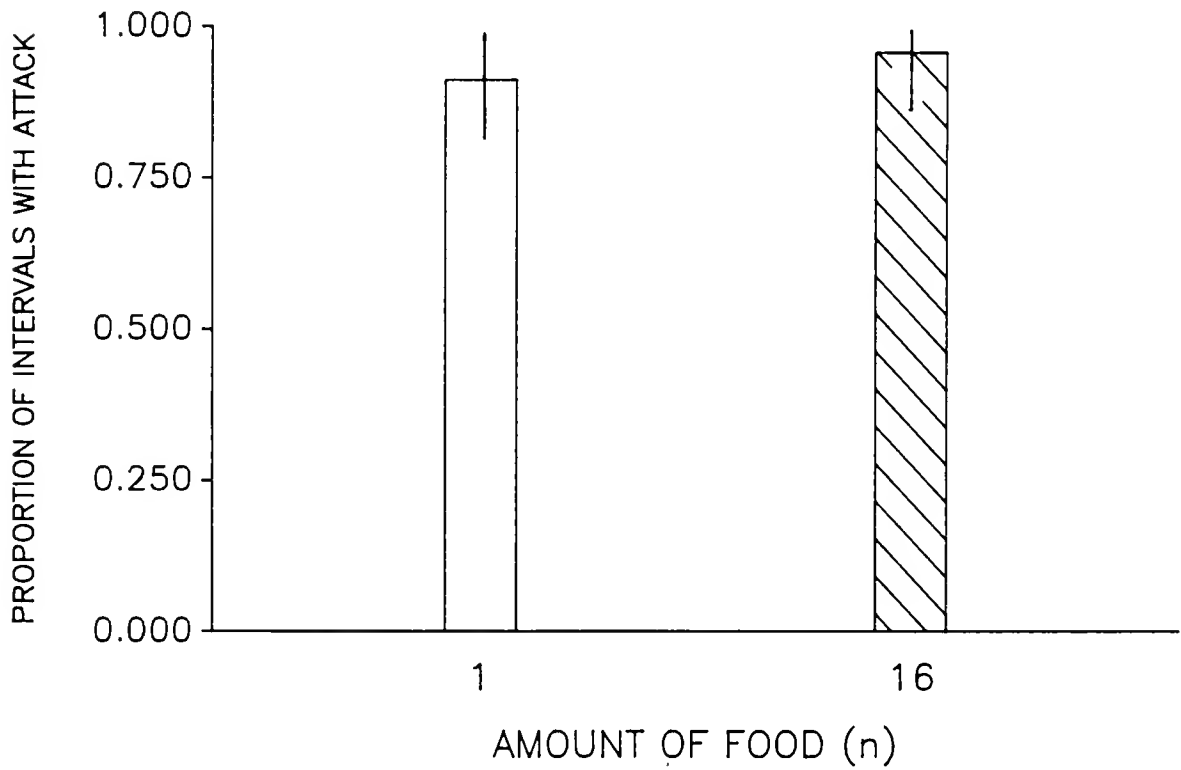
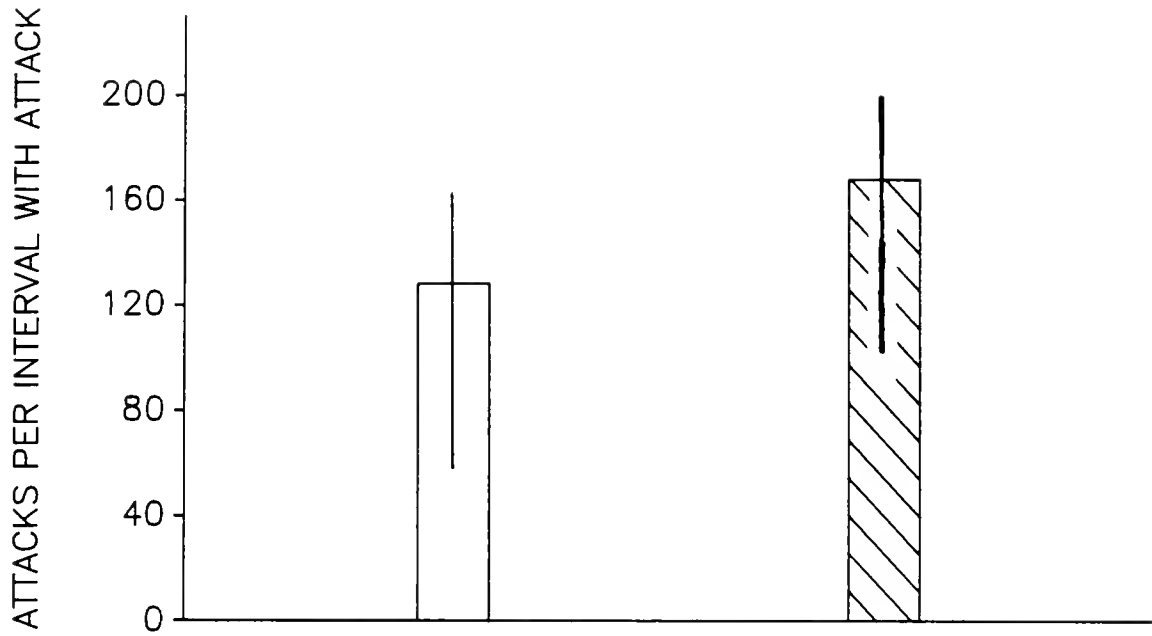


TABLE 3

Overall keypeck rates and average pause times for both subjects during the FI in each component of the mult [ch FI  $\bar{t}$  FR 1 x 1] [ch FI  $\bar{t}$  FR 1 x 16] schedule of food presentation used in Experiment 2. Data are from conditions when the time-out duration was 30 s. Values shown are means for the last 15 sessions. Ranges are indicated in parentheses.

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<u>P-5626</u>	<u>n</u>	<u>keypecks/min</u>	<u>pause(min)</u>
<u><math>\bar{t}</math> = 4 min</u>			
	1	22.0 (19.4-26.1)	1.1 (0.7-1.6)
	16	14.7 (10.0-22.2)	1.9 (1.4-2.7)
<u>P-7848</u>			
<u><math>\bar{t}</math> = 12 min</u>			
	1	24.7 (17.2-33.6)	1.7 (1.0-2.6)
	16	18.0 (9.5-24.8)	3.2 (1.9-5.0)

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## GENERAL DISCUSSION

In both experiments, induced attack by pigeons was positively related to the amount of food delivered on an FI schedule. In Experiment 1, when the amount of food per interval was examined across phases, attacking increased to a maximum and remained at high levels with further increases in food amount. In Experiment 2, when two different amounts alternated within the context of a multiple schedule, attack was higher in the component that programmed more food, with the differences slightly less than those observed in Experiment 1.

Considerations of the results of the present study can conveniently be made within the context of the theoretical frameworks presented in the General Introduction. The frameworks discussed were the classification of induced attack as a member of a class of "adjunctive behaviors" (Falk, 1969, 1971), the view of induced attack as arising from aversive properties of intermittent schedules of food presentation (Azrin, 1961; Azrin et al., 1966; Hutchinson et al., 1968), an analysis of induced attack as a form of "interim activities" (Staddon, 1977; Staddon & Simmelhag, 1971), and the view that induced attack results from

"arousal" generated by presentation of food (Killeen, 1975; Killeen et al., 1978). In addition, two other interpretations of the present results will be considered, one in terms of principles of reflexive behavior, and another in terms of "an opponent-process theory of motivation" (Solomon & Corbit, 1974).

The results of the present experiments are, for the most part, incompatible with Falk's view. Although attack observed in these studies shares a number of characteristics with other induced activities classified as adjunctive (e.g., attack was induced by intermittent food presentation, and occurred in the post-reinforcement period), a monotonically increasing function relating attack to amount of food is not predicted from Falk's "consummatory rate hypothesis." Recall that in Falk's view, adjunctive activities are bitonically related to the rate of food presentation, with high levels induced at intermediate food rates, and low levels induced both at high and at low food rates (Falk, 1969, 1971). Thus, according to this view, levels of attack in Experiment 1 should have decreased substantially at the larger food amounts ( $\bar{n} = 16$  and  $\bar{n} = 24$ ). While it might be argued that such a decrease would have occurred had larger amounts of food been examined, previous experiments on induced drinking and induced attack have shown that, when fixed food amounts were intermittently presented (e.g., one food pellet or one grain cycle), levels

of these behaviors began to decline as food rates were increased to greater than one unit per 2.5 min (0.4 units per min) (Falk, 1966). Other data indicate that induced behaviors begin to decline as food rates are increased to greater than one unit per minute (e.g., DeWeese et al., 1972; Falk, 1966; Flory, 1969). These results suggest that the highest food rates in Experiment 1 were sufficient to produce a decrease predicted by Falk's hypothesis. During the present experiment, attack levels continued at maximum levels at food rates of six units per minute (P-5626 at  $\bar{n} = 24$ ) and of two units per minute (P-7848 at  $\bar{n} = 24$ ). Also, as mentioned earlier, other studies examining induced attack (Flory et al., 1988) and induced drinking (Bond, 1973) under different combinations of food amounts and interfood intervals have reported data at odds with the consummatory rate hypothesis. Those results, as well as those reported here, suggest that it may be useful to consider manipulations of food amount and interfood interval as separate variables.

The data from the present study at first seem incompatible with the view that induced attack is produced by aversive properties of intermittent schedules of food presentation. If aversive aspects of conditions arranged in the present experiments were responsible for the production of attack, it seems likely that smaller amounts of food would have resulted in more attack. In the sense that

conditions arranging for lower frequencies or amounts of reinforcement are less preferred (see de Villiers, 1977), they could be considered as relatively more aversive, and might be expected to induce higher levels of attack. Such is certainly the case when the extremes are programmed, as when periods of FR 1 alternate with periods of extinction (Azrin et al., 1966).

An interpretation of the present results in terms of schedule aversiveness is<sup>2</sup> still possible, however, by considering FI schedules as suggested by Schneider (1968). In this view, FI schedules are similar to programming alternating periods of extinction and periods in which a VI schedule is in effect (with the value of a given interval determined by the post-reinforcement pause). Thus, the period just after food presentation functions as an  $S^{\Delta}$ , and the period towards the end of the interval functions as an  $S^0$ . Indeed, with respect to induced behavior, it has been suggested that the periods of zero reinforcement probability just after food presentation on intermittent schedules function similarly to programmed periods of extinction (e.g., Azrin, 1961; Hutchinson et al, 1968; Richards &

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<sup>2</sup>The term aversiveness is used here only as a reference to certain effects upon behavior. A set of conditions is called aversive only to the extent that these conditions are escaped and avoided, or to the extent that aggressive behavior is produced. Use of the term is not meant to imply that the property of aversiveness exists independent of any measurable dimension of behavior, and is measured, if at all, in some separate dimension.

Rilling, 1972). In viewing FI schedules of food presentation in this fashion, the increase in attack as a function of increasing the amount of food may have resulted from an increase in the relative aversiveness of post-food stimuli. Such an effect might be expected on the basis of data showing negative behavioral contrast in multiple schedules. That is, when the rate of food presentation is increased in one component of a multiple schedule, the rate of responding in the other (unchanged) component often decreases (e.g., Reynolds, 1961). Thus, the "strength" of operant behavior maintained in a given set of stimulus conditions is dependent upon context. It is possible that the aversive characteristics of  $S^A$  periods are also dependent upon context. Indeed, the aversiveness of the post-reinforcement period during ratio schedules (as indicated by the likelihood of escape) is dependent upon the size of the ratio (e.g., Appel, 1963; Azrin, 1961; Thompson, 1964). Thus, the aversiveness of the early portions of the FI in the present experiment may have increased as a result of increases in the amount of food presented in the terminal component, resulting more attack and less keypecking. Such an interpretation is supported by data demonstrating higher levels of attack during extinction components of a multiple schedule as a function of the number of food reinforcements delivered according to an FR 1 schedule in the other component (Azrin et al., 1966).

An important test of the behavioral contrast view presented above might be to compare the effects of reinforcement amount on schedule-induced escape. This view predicts that larger amounts of reinforcement would induce more escape. Also, it might be informative to evaluate the effects of a type of "errorless" discrimination training (Terrace, 1963, 1964). In errorless discrimination training,  $S^A$  is gradually introduced so that its behavioral function is acquired with very few "errors" (i.e., responses during  $S^A$ ). Terrace (1963, 1964) reported that the usual "emotional" responses (e.g., aggression) often observed during  $S^A$  periods were lower in experimental subjects trained errorlessly. Terrace also reported that manipulations usually resulting in behavioral contrast failed to do so in subjects trained in this fashion. If the effects of the amount of food reinforcement on attack in the present experiments are an example of behavioral contrast, then subjects with a training history in which the FI schedule parameter was increased very gradually (i.e., a gradual introduction of  $S^A$ ) might be expected to attack less than subjects for which the FI schedule parameter was abruptly increased.

The relationship of the present data to the theoretical position offered by Staddon and his colleagues (Staddon, 1977; Staddon & Ayers, 1975; Staddon & Simmelhag, 1971) is not straightforward. Recall that, in this framework,

because motivational variables governing interim responses depend upon those governing terminal responses, operations that increase the reinforcing efficacy of the terminal event should produce increases in levels of both interim and terminal activities. Indeed, the principal findings of the present studies provide support for Staddon's conceptualization. The monotonic increasing function relating induced attack to food amount is consistent with predictions based upon this view. However, rather than increasing as predicted, terminal responding (keypecking) decreased as a function of food amount. Thus, while it seems that this view is useful with respect to predictions of the effects of food amount on schedule-induced attack, keypeck data from the present studies make it difficult to assess the utility of this view as a general conception of behavior.

Recent studies seem to have occasioned a slight restructuring of Staddon's view (Reid & Dale, 1983; Reid & Staddon, 1982). In these studies, induced drinking (an interim activity) and "head-in-feeder" (a terminal activity) in rats were examined during FT 60-s schedules of food presentation. In the experiment by Reid & Staddon (1982), occasional intervals ending in six pellets were interspersed with intervals that usually ended in one pellet. In the Reid & Dale (1983) study, intervals ending in four pellets randomly alternated with intervals ending in one pellet. In

both of these experiments, levels of interim drinking were lower and levels of terminal responding were higher during intervals that followed presentation of the larger food amount. When different stimuli were present during intervals ending in different food amounts, levels of drinking were lower and levels of terminal responding were higher in intervals beginning and ending in the larger food amount. These results led the investigators to suggest that terminal activities are both elicited by food and occur in "anticipation" of food, and that terminal activities and interim activities are "reciprocally, linearly related" (Reid & Dale, 1983). In this view, then, interim activities are only indirectly controlled by food presentation, and the amount of interim responding observed under intermittent schedules is primarily determined by the amount of terminal responding generated by that schedule. The results of the present experiments suggest that induced attack and operant behavior are reciprocally related: as attack increased, keypecking decreased. However, the functions relating each of these responses to food amount are directly opposite of those predicted on the basis of data reported by Reid & Dale (1983) and Reid & Staddon (1982).

The data from studies by Reid & Dale (1983) and Reid & Staddon (1982) discussed above were obtained when manipulations of food amount made within experimental sessions. However, as noted in the Introduction to

Experiment 2, the effects of food amount in those studies were entirely different from comparisons that were made across sessions (Reid & Staddon, 1982), or across phases (Reid & Dale, 1983). In those cases, the larger of two food amounts induced more drinking, but had no systematic effect on terminal responding. In contrast, in the present studies, induced attack was positively related and keypecking was inversely related to food amount, both when comparisons were made within sessions and across phases. The reasons for the disparity in these findings are not clear. Perhaps some of the differences in results were due to differences in species used, responses measured, inducing schedules, apparatus used, or measures of induced responding. In the studies by Reid & Staddon (1982) and Reid & Dale (1983), the mean percent of 1-s bins containing drinking and head-in-feeder were measured as a function of time in the interfood interval. This measure provided an estimate of the probability of these two activities at various points within the interfood interval. It is possible that such partial-interval recording resulted in different estimates of responding than if more conventional measures had been used (e.g, rate, response per interval, total amount). This seems unlikely, however, given that the correspondence between interval recording methods and continuous measures (such as response rate) is greatest when short intervals are used (Powell, Martindale, & Kulp, 1975),

and that rather short intervals were used in those experiments (1-s). Thus, it seems as though the differences in data obtained in those experiments and in the experiments presented here result from features other than measurement procedures.

The present results also relate to the theoretical framework proposed by Killeen (1975) and Killeen et al., (1978). This conceptualization suggests that a variety of induced behaviors result from "arousal" generated by food presentation. Repeated presentation of food produces an accumulation of arousal such that the excessive character of induced behavior is observed. This model predicts that larger amounts of reinforcement ("incentive") should produce more arousal, and thus, more induced behavior (Killeen et al., 1978). The direct relation between induced attack and amount of food presented here are in accord with this view. Killeen et al., (1978), however, go on to suggest that as food amount is increased, it is possible that arousal will be diminished through satiation. Thus, at very large food amounts, induced attack, for example, might be expected to decrease. Such a decrease was not seen in the present results. Satiation, however, did not appear to be a factor in the present experiment. Inspection of the cumulative records presented in Figures 2, 3, and 4 reveals little evidence of a decline in keypecking as session progressed for any subject during any phase of Experiment 1.

While the increase in attack as a function of food amount is predicted by Killeen's model, other features of the present results differ from predictions based upon this model. For example, Killeen et al., (1978) reported peak rates of activity at about one-quarter into the interfood interval, regardless of interval duration. In the present study, highest attack rates were observed during the period immediately following food presentation. Indeed, inspection of cumulative record figures reveal that, for the most part, attacking occurred at rather constant rates in the early portion of the interval (rather than positively accelerated rates, as predicted by Killeen). Note, that there were occasional exceptions to both of these general characteristics (see Figures 3 and 10). However, these were not consistent across conditions or across birds. Thus, the differences in temporal characteristics between attack seen here and activity measured by Killeen et al. (1978), suggest that these behaviors may result from different processes.

A alternative interpretation of the present results is derived from relations obtained from studies of reflexes. Although attack occurs closely following food presentation, as might be expected if it was elicited, some investigators reject the possibility that attack and other induced activities are respondent in nature (e.g., Falk, 1971). Certain characteristics are often cited that seem to preclude classification of induced activities as

unconditional respondents elicited by food or by eating. For example, induced behaviors usually take several sessions to develop (e.g., Falk, 1971; Magyar & Malagodi, 1981), they can be modified by consequences (Bond, Blackman, & Scruton, 1973; Dunham, 1971), and certain operations will produce a shift in their temporal locus within the interfood interval (Gilbert, 1974). However, it has been argued that the tendency to reject interpretations of induced behavior as respondent is premature (Wetherington, 1982). Wetherington reviews data from studies on the effects of repeated elicitations, such as sensitization, habituation, temporal conditioning, temporal summation, and emergence of new unconditional responses. These data suggest that many respondents may actually possess characteristics that have been cited as evidence against a view that schedule-induced behavior is elicited. The results from the present experiments are in accord with predictions that are likely to emerge from a view of induced attack as an unconditional response to food presentation. Increases in attack as a function of increases in the amount of food can be considered an example of the Law of Intensity/Magnitude (Sherrington, 1906).

A final interpretation of the function relating attack to food amount can be made on the basis of an "opponent-process theory of motivation" (Solomon & Corbit, 1974). These theorists argue that presentation of an emotion-

arousing stimulus (e.g., food or electric shock) produces two important effects. The initial effect is called the "primary affective reaction," or "a process," and is what is generally expected in the presence of that stimulus (e.g., "happiness" if it is a positive reinforcer). The a process is assumed to elicit, in turn, an "affective after-reaction," called the "opponent" or "b process," that generates an opposite emotional reaction (e.g., "unhappiness"). The overall emotional change that occurs when a stimulus is presented and then withdrawn is the net result of the primary and opponent processes. The a process ceases immediately when the stimulus is withdrawn, while the b process lingers unopposed after the stimulus is terminated. This model can be described as homeostatic in that it is assumed that physiological mechanisms underlie these processes and act to control emotional behavior by minimizing deviations from emotional neutrality.

The following example may help to clarify the nature of the opponent processes. Solomon & Corbit (1974) describe behavior changes in a dog subjected to "intense" aversive stimulation (electric shock). The dog was placed in a Pavlov harness and was given periodic 4-mA, 10-s electric shocks. The initial effect of shock presentation was described as "terror and panic," which included expulsive defecation and urination, pupil dilation, piloerection, and heart rate increase. After shock was terminated, this "a

state" gave way to a state of "stealth," during which the animal was subdued and relatively inactive, and during which heart rate decreased to levels below those observed prior to shock delivery. After a minute or so, this "b state" was replaced by normal behavior patterns and heart rate. After a number of repeated presentations of shock, the characteristics of the a state were diminished (e.g., behavior patterns were described as "annoyed and anxious," and heart rate increase was attenuated), and b state characteristics were augmented (e.g., behavior patterns were described as "euphoric and active," and heart rate decreases were greater) compared to those seen during initial shock presentations. In this framework, the a process is unchanged, and the b process is strengthened, by repeated stimulus presentation. This presumably explains the changes observed in the dog's behavioral patterns and heart rate in the above example. Solomon & Corbit (1974), interpret a number of behavior phenomena in terms of this theory, such as drug addition and certain characteristics of escape and avoidance.

The opponent-process theory of motivation seems relevant to schedule-induced behavior, particularly induced attack. Schedule-induced attack generally occurs at high probability just after food presentation (i.e., during the period in which the effects of the b process are strongest). In addition, according to Solomon & Corbit, (1974),

activities generally observed during aversive conditions should occur during post-food periods. Attack is often observed under conditions in which aversive stimuli are presented (Azrin et al., 1965; Azrin et al., 1964; Ulrich & Azrin, 1962). Also, several food presentations are often required before attack and other schedule-induced activities develop (Dove, Rashotte, & Katz, 1974; Magyar & Malagodi, 1980). This characteristic of induced behavior is predicted by the opponent-process theory, due to strengthening of the b process by repeated stimulus presentations. Finally, the opponent-process theory suggests that increases in the intensity of the stimulus (e.g., food amount) should result in an increase in both the a process and the b process. In example above in which a dog was presented periodic 10-s electric shock, when shock intensity was increased from 4-mA to 8-mA, a moderate increase in the magnitude of the heart rate elevation was observed during shock, and a dramatic increase in the magnitude of the heart rate decline was observed following termination of shock (Church, LoLordo, Overmier, Solomon, & Turner, 1966). These data are compatible with the relation between food amount and attack observed in the present study: as the amount of food was increased, the magnitude of the b process is increased, resulting in more attack.

Finally, the effects of food amount on keypecking in the present experiment must be considered. A number of

studies have indicated that the function relating operant responding to reinforcement magnitude is positive, especially when VI schedules are concurrently or multiply arranged (Catania, 1963; Fantino, Squires, Delbruck, & Peterson, 1972; Merigan, Miller, & Gollub, 1975). This relation has also been observed under simple FI schedules (Guttman, 1953), and under FI second-order schedules of token reinforcement (Malagodi, Webbe, & Waddell, 1975). The data reported here and elsewhere, however, seem to suggest that the relation between reinforcement magnitude and operant responding is negative. For example, when five different feeder cycle durations (Staddon, 1970), and when four different milk concentrations (Lowe et al., 1974) were randomly presented on FI schedules, operant response rates decreased and pause times increased as a function of the preceding reinforcement magnitude. Indeed, there is considerable disagreement about the effects of reinforcement magnitude on operant behavior. The effects of this variable depend critically upon the procedures used, and upon the baseline schedules under which reinforcement is presented. For a review of the literature in this area, and a discussion of methodological and theoretical issues relevant to these studies, see Bonem & Crossman, (1988).

Presentation of reinforcing stimuli often have multiple behavioral effects. In addition to rate increasing, or strengthening effects, reinforcement can also have

discriminative properties (e.g., Zimmerman, 1971). Perhaps inconsistencies in the effects of reinforcement magnitude on operant behavior result, in part, from differences in the degree to which certain schedules establish reinforcement presentation as discriminative. For example, post-reinforcement pauses typical of behavior maintained by FR and FI schedules of have been interpreted as resulting from  $S^A$  properties of reinforcement presentation, in that reinforcement never closely follows a previous reinforcement (e.g., Ferster & Skinner, 1957). It is quite possible that the increases in pause duration as a function of reinforcement magnitude observed in the present study, and in other studies (Lowe, et al., 1974, Staddon, 1970), result from an increase the  $S^A$  function of reinforcement delivery. The increase in attack observed in the present experiments is also consistent with this interpretation. Thus, under conditions in which reinforcement presentation is less likely to serve an  $S^A$  function (e.g., VR and VI schedules), increasing reinforcement magnitude might not produce an increase in pausing and induced attacking.

It is also possible that the increase in pausing by P-7848 and P-5626 was an indirect function of the increase in attacking. That is, keypecking began later in the interfood interval under larger food amounts simply because attacking continued later into the interval. This did not appear to be the case as causal observation and inspection of the

cumulative records (Figures 2, 3, 9, and 10) indicated that, in most cases, post-reinforcement pauses were not entirely subsumed by attacking, even at large food amounts. Precise statements regarding the interaction of keypecking and attacking, however, require more extensive data analysis than possible here.

In conclusion, the data presented in these experiments are important for a number of reasons. For example, while relevant to each of the theoretical positions discussed above, the relationship between attack and food amount observed here does not provide conclusive evidence for the selection of one position over the others. Indeed, in view of the literature on schedule-induced behavior as a whole, such a selection is extremely difficult. Each of these theoretical frameworks is supported by data from some studies but not others. It is contended here that a number of schedule and consequence variables have not been studied extensively enough to permit adequate theoretical integration (See General Introduction). Thus, the results of the present experiments are important in that a functional relation between attack and food amount is demonstrated over a range of parameter values not previously reported, and the generality of that relation is extended by showing comparable effects during a multiple schedule. Only after further analyses of this sort, can questions pertaining to the utility of these, or other, theoretical

views be answered. In addition, the data presented here are relevant to issues regarding classification of various schedule-induced activities. It appears that induced attack and induced polydipsia are not always related to amount of food reinforcement in the same way. Although many of the theoretical positions presented above tend to classify induced activities together, the data from the present experiments suggest that these activities may result from different properties of intermittent reinforcement schedules and, thus, may be more profitably considered as functionally distinct.

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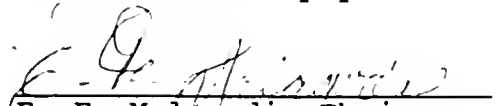
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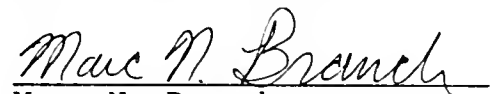
## BIOGRAPHICAL SKETCH

Raymond C. Pitts was born in Jacksonville, FL on July 10, 1957 to R. C. and Nita Pitts. After graduation from Jacksonville's Terry Parker High School in 1975, he moved to Gainesville, FL and enrolled in the University of Florida. Ray graduated with a B.A. in 1980, and an M.S. in 1986, both in psychology and both from the University of Florida. He plans to receive his Ph.D. in December of 1989.

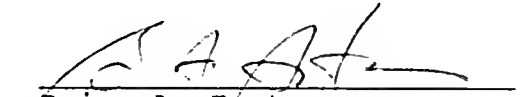
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E. F. Malagodi, Chairman  
Professor of Psychology

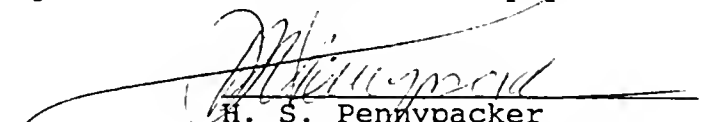
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Marc N. Branch  
Professor of Psychology

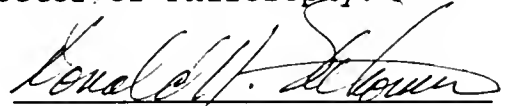
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Brian A. Iwata  
Professor of Psychology

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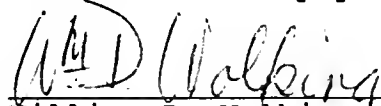
  
H. S. Pennypacker  
Professor of Psychology

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Donald J. Stehouwer  
Associate Professor of  
Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



William D. Wolking  
Professor of Education

This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Liberal Arts and Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1989

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Dean, Graduate School

UNIVERSITY OF FLORIDA



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