

SCHEDULE-INDUCED ATTACK: SOME MEASUREMENT
AND METHODOLOGICAL CONSIDERATIONS

By

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When an appropriate target is available, the intermittent presentation of food has been shown to result in intense attack. The attack usually occurs during the period immediately following reinforcement delivery. This schedule-induced attack has been shown to occur as a by-product of most of the basic schedules of positive reinforcement. In the present study, the key pecking of pigeons produced food according to fixed-interval schedules. No-target phases preceded and followed conditions where access to a live target pigeon was provided. Rates and temporal patterns of key pecking were neither disrupted nor systematically affected by target availability. Rates of obtained reinforcement were maximal under all conditions, including interval values which induced high levels of attack. Attack, when it occurred, was usually initiated shortly after food delivery, and the negatively accelerated temporal patterns of attack alternated with the positively accelerated temporal patterns of key pecking. As the inter-

val duration was increased geometrically from 30 sec to 480 or 960 sec, levels of attack for three of the birds increased to a maximum and then decreased. This inverted U-shaped function described these changes in each of the 10 measures of attack for two birds and 5 of the 10 measures for the third bird. For the fourth pigeon, each of the measures decreased as the interval values increased. When this bird was exposed to a 15 sec fixed-interval schedule followed by a second exposure to 30 sec, all attack measures showed increases related to this increase in interval duration. Thus, a bitonic function, peaking at 30 sec, described the relationship between levels of attack and fixed-interval value for this bird as well. For all birds, both key pecking and attack were allowed to stabilize during each with-target condition; the inverted U-shaped relationship shown by all birds between levels of attack and fixed-interval value was based on the last five sessions at each duration employed. When the medians and ranges of each of the measures were compared for the first five and for the second five sessions across interval values, five of the measures consistently revealed an inverted U-shaped function related to interval duration during the second five as well as during the first five sessions. For the other five measures, the second five sessions were no more predictive of this function across birds than were the first five sessions.

Different studies which have manipulated schedule parameters have demonstrated divergent functions relating induced attack to schedule value. These include reports of attack as

a direct function, an inverse function and an inverted U-shaped function of schedule value. Various theoretical frameworks from which to view induced attack have been proposed which suggest that one of these is the "true" relationship. Unfortunately, the measures of attack have varied considerably across individual experiments and no rationale has been provided for selecting any one of these. Neither have previous studies attempted to determine the interrelationships among them. Most of the measures which have been employed previously were also employed in the present experiment. The measures covaried with increases in interval duration, showing an inverted U-shaped function between levels of induced attack and increases in interval value. These results are consonant with the view proposed by Falk that induced attack is neither respondent nor operant in nature, but one of a number of adjunctive behaviors similar to displacement activities. Some aspects of the present results emphasize the difficulties involved in comparing results between experiments which employ different measures of attack and phase duration criteria.

INTRODUCTION

When access to a target is provided, attack behavior has been shown to reliably occur as a by-product of the intermittent delivery of positive reinforcement. No attack-dependent consequences have been scheduled which would account for the attack in these situations, and protective contingencies which prevent the contiguity of attack and food delivery have been usually employed. Subsequent to the initial report of extinction-induced attack (Azrin, Hutchinson and Hake, 1966), schedule-induced attack has been demonstrated to occur during most of the basic types of schedules of positive reinforcement. These include response-dependent ratio schedules which require a certain number of responses such as key pecks or lever presses to produce reinforcement (Cherek and Pickens, 1970; Cohen and Looney, 1973; Cole and Litchfield, 1969; Flory, 1969a; Gentry, 1968; Huston and DeSisto, 1971; Hutchinson, Azrin and Hunt, 1968; Knutson, 1970; Lyon and Turner, 1972; Peterson, 1971; Webbe, DeWeese and Malagodi, 1973) as well as both response-independent (Flory, 1969b) and response-dependent time-based schedules (Cherek and Heistad, 1971; Cherek, Thompson and Heistad, 1973; Dove and Rashotte, 1971; Knutson and Kleinknecht, 1970; Richards and Rilling, 1972).

The present study had four interrelated objectives: first,

to examine the effects that providing access to a live target bird might have on rates and temporal patterns of key pecking maintained by fixed-interval (FI) schedules of food reinforcement; second, to assess the effects of FI duration on induced attack; third, to employ various types of measures of attack in an effort to facilitate both the interpretation of the results of this experiment and comparisons among the measures; and, fourth, to examine the relationships obtained as a function of the number of sessions at the various interval durations employed.

With respect to the first objective, under conditions of response-dependent reinforcement, both schedule-maintained operant responding and schedule-induced attack have been simultaneously recorded in each of the previously cited studies. Although it would appear to be important to determine the effects of induced attack on the rates and temporal patterns of operant responding generated by the various schedules, the only quantitative data in this regard have been provided by Cohen and Looney (1973). In that study, pigeons received food for key pecking according to fixed-ratio (FR) schedules. Obtained reinforcement rates were consistently lowered when the target (a mirror) was introduced to the experimental chamber. Knutson (1970) also has reported that the presence of a target bird resulted in disruption of the key-peck responding after a history of stable key pecking controlled by FR schedules of food reinforcement. Particularly at the higher FR values employed, access to a target produced long periods of neither key pecking nor attacking. The

present study was designed, in part, to assess whether providing the opportunity to attack a live target might similarly disrupt key pecking maintained by FI schedules.

The second purpose was to examine both key pecking and attack as a function of the particular minimum FI duration employed. Flory (1969b) delivered food to pigeons at regular intervals, independently of any operant response requirement. As the interval values were increased, the rates of attack against taxidermically prepared targets increased to a maximum and then decreased with further increases in the inter-food interval. Recent studies by Cherek et al. (1973) and Cohen and Looney (1973) have supported Flory's finding that reinforcement rate is a powerful determinant of the rate of induced attack. The present study was a systematic replication of Flory (1969b), employing comparable minimum interval values of response-dependent rather than response-independent schedules and live rather than taxidermically prepared targets.

With respect to the third objective, technological developments allowing the automatic and direct recording of attack behavior have been implemented in three different ways. These may be classified as individual attacks, attack episodes and attack duration. Switch closures resulting from individual pecks or bites have been counted as the unit of attack by some investigators (Cherek et al., 1973; Cherek and Heistad, 1971; Cherek and Pickens, 1970; Cohen and Looney, 1973; Gentry, 1968; Hutchinson et al., 1968; Knutson, 1970; Knutson and Kleinknecht, 1970; Richards and Rilling, 1972; Webbe

et al., 1973). Others have employed attack episodes (micro-switch closures separated by at least a 1.0-sec interval) as the unit of behavior (Flory, 1969a, 1969b; Webbe et al., 1973). Still others have used attack duration. Duration has been cumulatively recorded from the occurrence of an attack until a 1.0-sec period without a switch closure (Azrin et al., 1966; Knutson, 1970; Webbe et al., 1973). The types of measures derivable from these three direct measures are even more diverse. They include the following: first, absolute number of attacks during sessions terminated after a fixed number of reinforcements (Knutson, 1970; Webbe et al., 1973); second, absolute rate of attacks or absolute attack frequency during sessions of fixed length (Cherek et al., 1973; Cherek and Pickens, 1970; Cohen and Looney, 1973; Gentry, 1968; Knutson and Kleinknecht, 1970; Richards and Rilling, 1972; Webbe et al., 1973); third, absolute frequency of attacks during sessions terminating according to variable criteria (e.g., after a certain number of reinforcements or a certain time, depending on which occurred first) (Hutchinson et al., 1968); fourth, absolute number of attack episodes during sessions ending after a fixed number of reinforcements (Flory, 1969a; Webbe et al., 1973); fifth, absolute episode rate (Flory, 1969b; Webbe et al., 1973); sixth, absolute duration of attack during sessions of fixed length (Azrin et al., 1966); seventh, absolute attack duration during sessions ending after a certain number of reinforcements (Knutson, 1970); and eighth, the mean percent of schedule components during

which attack occurred (Flory, 1969_a, 1969_b; Webbe et al., 1973). Although theoretical positions often suggest the selection of certain measures of behavior, a number of theoretical and interpretative attempts have concluded that schedule-induced attack is not readily accomodated within the traditional classes of respondent and operant behavior (e.g., Brown and Flory, 1972; Falk, 1971; Richards and Rilling, 1972; Staddon and Simmelhag, 1971). To date, there has been little discussion in the literature related to the orderliness with which a particular attack measure may be shown to respond to the manipulation of various independent variables. The rationale for selecting one of the many measures previously employed has similarly not been provided. Webbe et al. (1973), in studying induced attack under variable-ratio and fixed-ratio schedules, made comparisons among a number of the measures which have been individually employed in prior experiments. They suggested that further studies of schedule-induced attack should incorporate a number of these measures, attending to the interrelationships among them. The extent to which we may directly compare the findings of different studies which have used different measures of induced attack is an important empirical problem. A third objective of this study, then, was to employ a number of measures of attack behavior, including most of those used previously in the study of this phenomenon, in order to examine the relationships among them.

The fourth objective concerned an assessment of changes in attack as a function of the number of experimental sessions at a given value. Since a number of the previous studies were designed to demonstrate the existence of induced attack as a function of a particular type of schedule (e.g., Cherek and Heistad, 1971; Gentry, 1968; Knutson and Kleinknecht, 1970), only a small number of sessions were conducted. Some other studies have reported induced attack to be a transitory phenomenon, gradually declining with continued exposure to a particular schedule (Cherek and Pickens, 1970; Dove and Rashotte, 1971). Still others have reported the long-term maintenance of attack across a large number of sessions (Azrin et al., 1966; Cohen and Looney, 1973; Webbe et al., 1973). Since little is known concerning steady-state induced attack, the fourth purpose of this study was to examine the changes in the relationships among the measures of attack and FI duration which occurred over time.

METHOD

Subjects

Eight experimentally naive male White Carneaux pigeons were used; four served as experimental subjects and four as targets. Each experimental bird was randomly paired with a specific target and the pairs were maintained for the duration of the experiment. Experimental bird P-7123 was paired with target P-814; bird P-7504 with target P-555; bird P-3636 with target P-621; and bird P-8683 with target P-8944. All birds were approximately one year old at the beginning of the study. They were housed in separate cages where water and health grit were continuously available. One of the experimental pigeons (P-3636) was maintained at 75 percent and the other three were maintained at 80 percent of their free-feeding weight. The targets had free access to food in their home cages.

Apparatus

A standard BRS-Foringer two-key stimulus panel (BRS P-002) was situated at one end of the chamber. The left key was covered with a metal plate throughout the experiment. The right key could be transilluminated with a white X superimposed on a red background. Each peck in excess of 20g (0.18N) directed against this key activated the recording circuitry and produced an audible click from a feedback relay mounted behind the stimulus panel. During the 3.5-sec mixed-grain presenta-

tions, the key stimulus and red houselights were off and the raised food magazine was illuminated with white light.

An apparatus for recording attack, similar to that described by Azrin et al. (1966) and Knutson (1970), was located directly opposite and 14 in (35.56 cm) from the stimulus panel. This restraint device was constructed of clear plexiglas and mounted on a spring-loaded metal plate. A microswitch assembly was located beneath this plate, with the plate resting on the switch contacts. Tension- and travel-adjustment screws allowed precise calibration of the force required for microswitch closure. Attacks making contact with the target resulted in displacement of the restraint device, closure of the switch contacts, and automatic recording of the behavior. The force setting employed for each pair of birds was determined by observations of the force at which defensive movements of the target did not effect switch closure. The forces for the four pairs of subjects were: P-7123, 80g (0.80N); P-8683, 115g (1.15N); P-3636, 120g (1.20N); and P-7504, 75g (0.75N). The target was secured within the plexiglas unit with its head, neck and upper breast protruding. A clear plexiglas inverted U-shaped shield was attached to the restraint device in front of the target such that attacks had to be directed over or through it, assuring stabilimeter displacement (Knutson, 1970). In addition to facilitating recording, this shield also served to reduce the probability of serious injury to the targets.

Three direct measures of attack were automatically re-

corded: number of attacks, number of attack episodes and attack duration. The number of attacks was a direct count of individual stabilimeter displacements. One attack episode was counted for each single attack or series of attacks separated by 1.0 sec or more from any other attacks. Timers arranged to record attack duration began operation when one attack occurred and continued timing until a 1.0-sec interval elapsed without a stabilimeter displacement. The various derived measures of attack included both attacks per min and attack episodes per min, the percent session time engaged in attack (total attack duration/session duration), the average attack duration per reinforcement, the average number of attacks and episodes per reinforcement, the average number of attacks per episode, the local rate of attack (total number of attacks/total attack duration) and relative attack rate (attack rate/key-peck rate + attack rate). The percent of interreinforcement intervals containing at least one attack was obtained directly from cumulative recordings.

Sessions were monitored via closed-circuit television. The experimental apparatus was located in a ventilated, sound-attenuating chamber. An exhaust fan and a white-noise generator provided masking sound. Standard electromechanical programming and recording equipment was located in an adjoining room.

Procedure

After the experimental birds had been food-deprived, each was placed in the illuminated experimental chamber for two 1.0-hr adaptation sessions. No target was present during

this condition. During the next seven to eight successive 1.0-hr sessions, any attack behavior that occurred prior to a history of conditioning was recorded. The target was then removed from the chamber, metal doors closed in front of the restraint device, and the experimental birds magazine trained and shaped to peck the key. Two to three sessions were provided during which each key peck produced grain reinforcement (FR 1). An FI 30-sec schedule was then introduced which specified that reinforcement was available dependent upon the first key peck that occurred after 30 sec since the previous reinforcement. Each interval began timing simultaneously with the end of the grain cycle. Key pecking was considered to be stable when the difference between the mean key-peck rate for the last five sessions and that for the previous five sessions was less than five percent of the 10-day mean. When this criterion was met, the target bird was returned to the chamber. Grain continued to be delivered according to the FI 30-sec schedule. A protective contingency was scheduled whenever the target bird was present such that grain reinforcement could not occur less than 15 sec subsequent to an attack (Flory, 1969b). The stability criteria for attack behavior were small daily variations in the average number of episodes per reinforcement and the absence of apparent trends over 10 successive sessions. When the stability criteria for both key pecking and attack were simultaneously satisfied, the FI 30-sec no-target condition was reinstated. This ABA design of FI schedule with no

target (A), FI schedule with target (B), and FI schedule again with no target (A) was employed at each value of a geometrically ascending series of interval durations ranging from 30 sec to 480 sec. Additionally, an FI 960-sec schedule was employed for bird P-3636.

After exposure to the final FI value during the ascending series, recovery points at at least one interval duration were obtained for all birds. The ABA aspect of the design at each FI duration during the ascending series allowed a determination of the effects of access to the target on stable rates and temporal patterns of key pecking. In addition, the with-target conditions at the various FI durations allowed an assessment of the effects of FI schedule value on several measures of attack.

Experimental sessions were conducted six days a week. Sessions terminated following the first reinforcement after 30 min at FI 15 sec, after 60 min at FI 30 sec to FI 120 sec, and after 120 min at FI 240 sec to FI 960 sec. Table 1 contains a summary of the order of experimental conditions and the number of sessions under each for all birds.

Table 1
The Order of Experimental Conditions

Condition	Number of Sessions for Birds			
	P-7123	P-3636	P-7504	P-8683
Chamber Adaptation (No Target)	2	2	2	2
Pre-Training (With Target)	8	7	7	7
FI 30 sec (No Target)	16	24	24	16
FI 30 sec (With Target)	71	17	43	62
FI 30 sec (No Target)	5	5	37	23
FI 60 sec (No Target)	49	41	25	22
FI 60 sec (With Target)	17	18	17	27
FI 60 sec (No Target)	7	13	18	6
FI 120 sec (No Target)	49	25	20	35
FI 120 sec (With Target)	69	10	10	21
FI 120 sec (No Target)	19	5	39	46
FI 240 sec (No Target)	20	48	66	38
FI 240 sec (With Target)	35	37	14	20
FI 240 sec (No Target)	5	16	16	16
FI 480 sec (No Target)	32	15	11	18
FI 480 sec (With Target)	83	26	27	51
FI 480 sec (No Target)	12	24	11	19
FI 960 sec (No Target)	-	14	-	-
FI 960 sec (With Target)	-	51	-	-
FI 960 sec (No Target)	-	13	-	-
FI 15 sec (No Target)	-	-	-	19

Table 1 (continued)

Condition	Number of Sessions for Birds			
	P-7123	P-3636	P-7504	P-8683
FI 15 sec (With Target)	-	-	-	83
FI 30 sec (No Target)	-	-	-	11
FI 30 sec (With Target)	-	-	-	71
FI 60 sec (No Target)	17	-	23	-
FI 60 sec (With Target)	42	-	14	-
FI 60 sec (With Empty Restraint Device)	11	-	-	-
FI 240 sec (No Target)	-	63	-	-
FI 240 sec (With Target)	-	49	-	-
FI 120 sec (No Target)	-	20	-	-
FI 120 sec (With Target)	-	10	-	-

RESULTS

Figure 1 summarizes rates of key pecking and key-peck quarter-life values (Gollub, 1964; Herrnstein and Morse, 1957) during both with- and no-target conditions at each of the interval values employed. For all birds, comparison of the filled and open symbols indicates that, when stable rates and temporal patterns of key pecking were maintained under FI schedules, providing access to an attackable target produced no systematic changes in key-peck responding. Bird P-8683 showed decreases in key-peck rates and increases in quarter-life values during the with-target conditions compared to those obtained during the initial no-target phases at each interval duration. The changes in key-peck responding produced by the subsequent removal of P-8683's target were non-systematic, however. Positively accelerated patterns of key pecking were maintained in all birds during both conditions at each interval value. Patterns of key pecking were never discernibly disrupted by the presence of the target or the intense attack that occurred at some FI durations. Table 2 shows that maximal rates of reinforcement were achieved by all pigeons at each FI value during both with- and no-target conditions.

Comparisons among the groups of connected circles which represent key-peck rates in Figure 1 indicate no systematic changes in rates among birds as a function of increases in

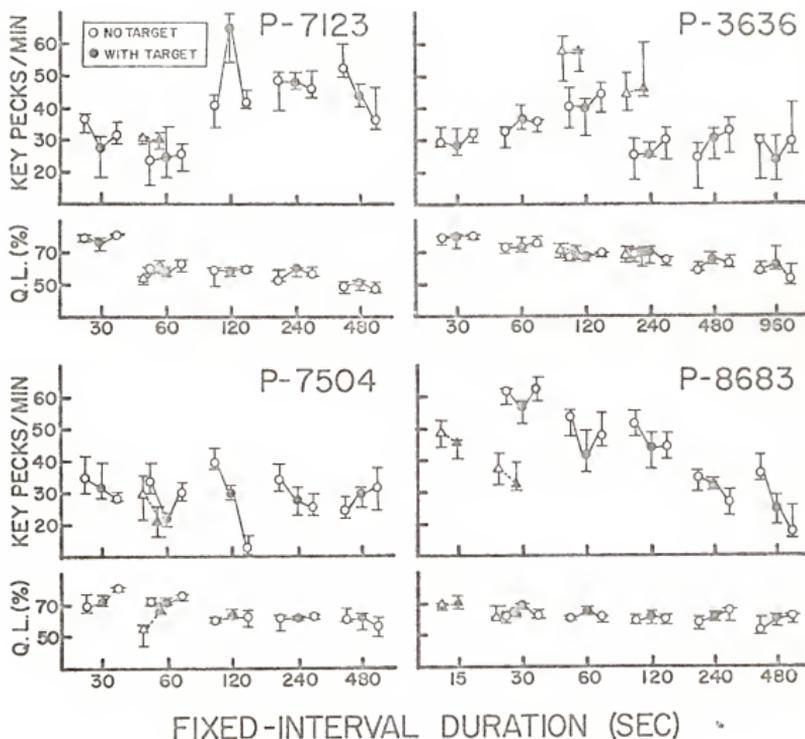


Fig. 1. The medians and ranges of key-peck rates and key-peck quarter-life values for the last five sessions at each FI schedule in the order of exposure. The horizontal axes are logarithmic to allow compact presentation. Open circles represent the no-target conditions and filled circles denote the with-target condition at each schedule value in the ascending series. Open triangles represent no-target recovery points and filled triangles represent with-target recovery conditions.

Table 2

Mean Inter-food Intervals (sec) During Last Five Sessions
at Each Fixed-Interval Value in the Order of Exposure

Minimum FI Duration (sec)	Subject	No Target	With Target	No Target	
30	P-7123	30.27	30.54	30.19	
60		61.21	60.99	60.84	
120		120.95	120.55	121.03	
240		240.87	240.93	240.91	
480		480.44	481.72	480.16	
60		61.32	61.34	61.51	
30	P-3636	30.65	30.77	30.52	
60		60.74	60.70	60.52	
120		121.09	121.09	120.78	
240		241.29	241.73	241.20	
480		483.76	482.68	481.16	
960		960.93	962.80	960.08	
240		240.80	240.43		
120		120.70	120.57		
30	P-7504	30.49	30.57	30.68	
60		60.50	60.74	60.54	
120		120.66	120.79	121.32	
240		240.99	241.39	241.18	
480		482.12	482.63	482.57	
60		61.30	60.93		
30	P-8683	30.46	30.49	30.31	
60		60.72	60.80	60.60	
120		120.68	120.73	120.86	
240		241.01	240.41	240.81	
480		482.39	483.08	482.92	
15			15.39	15.92	
30			31.07	31.23	

FI duration. Rates of key pecking first increased and then decreased for both P-7123 and P-3636, showed little change for P-7504, and decreased with increases in interval value for P-8683. Key-peck quarter-life values for all of the birds consistently decreased as the FI duration was increased, however.

Figure 2 shows the various measures of attack as a function of FI duration for Bird P-7123. Overall rate measures are shown in Frame A. Both discrete attacks and bouts of attack (episodes) are treated as units of behavior. Although high attack and episode rates occurred during the first two of the eight pre-training sessions, both of these measures were near zero during the last five sessions of the pre-training condition. Introduction of the target after key pecking had stabilized at FI 30 sec resulted in increases in both the attack rate and episode rate. As the FI duration was increased, attack and episode rates both increased to a maximum at FI 60 sec and decreased with further increases in interval value. At FI 480 sec, these measures of attack showed levels comparable to those obtained prior to a history of intermittent food reinforcement. When the schedule was decreased to FI 60 sec subsequent to the FI 480 sec condition, both attack and episode rates increased to peak values comparable to those obtained during the initial condition at FI 60 sec. Frame B of Figure 2 shows the percent time spent attacking (duration of attack/total session time x 100) as a function of FI duration. As the interval value was increased, the percent of the session engaged in attack increased to a

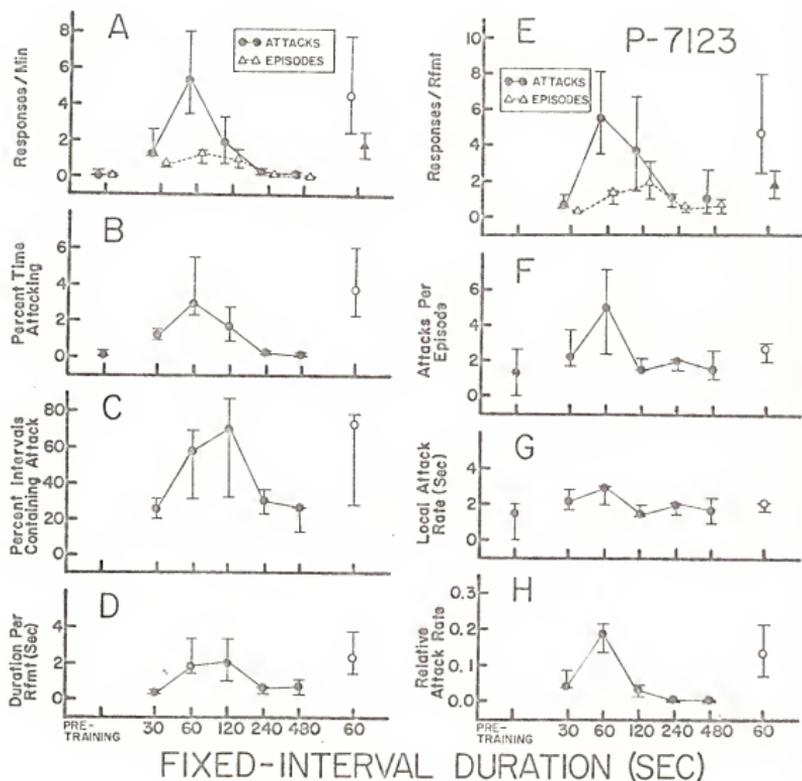


Fig. 2. The medians and ranges of the measures of attack behavior for bird P-7123. Data are from the last five sessions at each FI value in the order of exposure. Recovery points are offset to the right of each frame and are the negative image of the symbols representing the ascending series. The horizontal axes are logarithmic to allow compact presentation.

maximum at FI 60 sec, where a median of three percent of the session was spent attacking. Further increases in FI duration produced decreases in this measure. The percent of inter-reinforcement intervals in each session during which at least one attack occurred are shown in Frame C. Similar to the functions previously described, there was an inverted U-shaped relationship between the percent of intervals containing attack and increases in FI value. The peak of the function occurred at FI 120 sec, where a median of 70 percent of the intervals contained attack. A median of 26 percent of the intervals contained attack at both the shortest (FI 30 sec) and longest (FI 480 sec) interval durations employed with this bird.

Frames D and E depict each of the three units of attack behavior which were divided by the number of food reinforcements obtained within sessions. Each of these measures similarly shows a bitonic function related to increasing interval values. Attack duration per reinforcement (Frame D) and episodes per reinforcement (Frame E) reached their maximum levels at FI 120 sec. Attacks per reinforcement (Frame E) peaked with a median of 5.5 attacks per reinforcement at FI 60 sec. The two local measures of attack that were computed are shown in Frames F and G. As interval durations were increased, both the number of attacks within a bout of attack (Frame F) and the local attack rate (attacks/attack duration) (Frame G) increased to a maximum at FI 60 sec and then decreased. In order to examine the relationship between changes in attack rates and concurrent changes in key-peck rates, the relative rate of attack was computed and is shown in Frame H. Key-

peck rates for Bird P-7123, like attack rates, showed an inverted U-shaped curve related to increases in FI duration (see Figure 1). The absolute increases in attack rate were sufficiently greater than the concurrent absolute increases in key-peck rate, however, resulting in a bitonic function relating relative attack rate to increases in interval value; this function peaked at FI 60 sec at a relative rate of 0.20. To summarize these results for P-7123, the several measures of attack behavior employed (overall time-dependent measures, Frames A and B; overall time-independent measures, Frames C, D and E; local time-independent and time-dependent measures, Frames F and G respectively ; relative measure, Frame H) all showed inverted U-shaped curves related to increases in FI duration. Peak values for these various measures occurred at either FI 60 sec or FI 120 sec. A recapitulation at FI 60 sec, subsequent to the FI 480 sec phase, produced increases in each of these measures of attack. During the final condition, food continued to be delivered according to the FI 60-sec schedule and the target bird was removed from the exposed restraint device; only one attack was recorded during 11 1.0-hr sessions.

The various measures of attack for Bird P-3636 are shown in Figure 3. This bird emitted only three attacks during the pre-training phase. These attacks occurred during the second of the seven sessions under this condition. The scale on the ordinates for each of the measures (except for Frames C and F) are different for P-3636 than those for the other birds due to the extremely low levels of attack displayed. Despite

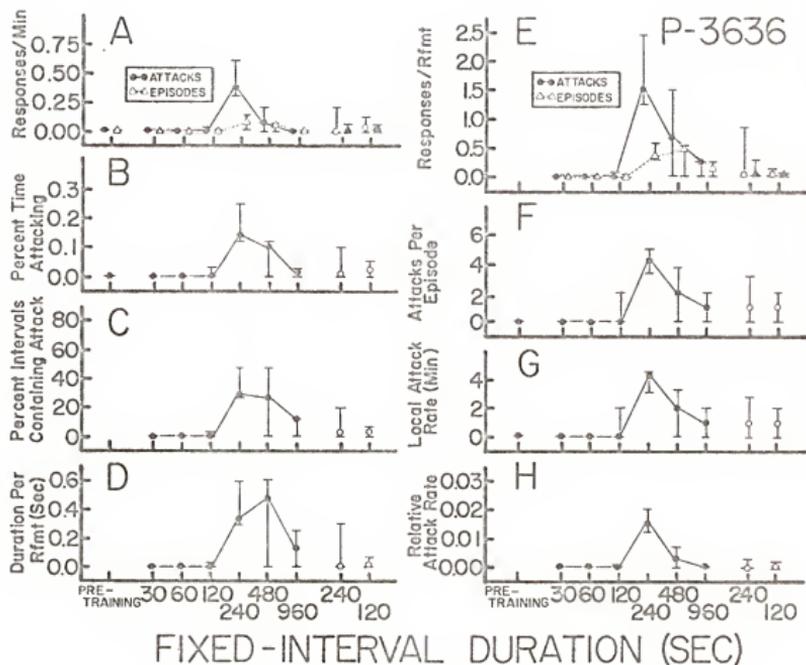


Fig. 3. The medians and ranges of the measures of attack behavior for bird P-3636. Data are from the last five sessions at each FI value in the order of exposure. Recovery points are offset to the right of each section and are the negative image of the symbols representing the ascending series. The horizontal axes are logarithmic to allow compact presentation.

the large differences in absolute levels of attack between Birds P-7123 and P-3636, the general shape of the relations between the various measures of attack and increases in FI duration was the same for the two birds. An inverted U-shaped function, peaking at FI 240 sec, was found with eight of the ten attack measures shown in Figure 3. Both duration per reinforcement (Frame D) and episodes per reinforcement (Frame E) showed a bitonic function peaking at FI 480 sec. Although each of the measures of attack showed increases when the interval duration was decreased from FI 960 sec to FI 240 sec, the levels obtained were below those observed at FI 240 sec during the ascending series. A further decrease to FI 120 sec produced decreases in all measures of the attack behavior.

Figure 4 summarizes the various measures of attack for Bird P-7504. This pigeon attacked at extremely low rates (Frame A) throughout the pre-training period. Similar to Birds P-7123 and P-3636, Bird P-7504 showed inverted U-shaped functions relating five of the ten measures of attack to increases in FI duration. These include attack and episode rates (Frame A), percent time spent attacking (Frame B), percent intervals containing attack (Frame C), and relative attack rate (Frame H). Each of the three unit measurements per reinforcement (Frames D and E) showed bi-modal relations with peaks at FI 60 sec and FI 240 sec. The two local measures of attack (Frames F and G) decreased with increases in the interval value. When P-7504 was exposed to FI 60 sec subsequent to the FI 480 sec condition, increases in each of the

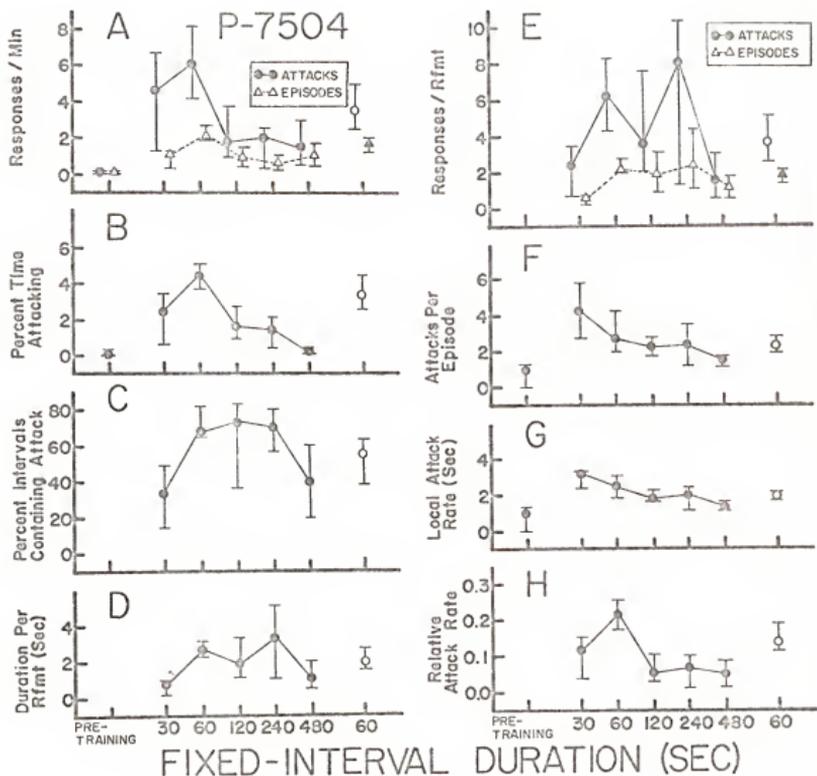


Fig. 4. The medians and ranges of the measures of attack behavior for bird P-7504. Data are from the last five sessions at each FI value in the order of exposure. Recovery points are offset to the right of each frame and are the negative image of the symbols representing the ascending series. The horizontal axes are logarithmic to allow compact presentation.

measures of attack were recorded.

The several measures of attack for Bird P-8683 are shown in Figure 5. Decreases in each of these measures were obtained as the FI duration was increased from FI 30 sec to FI 480 sec. In order to determine whether the functions obtained represented decreasing limbs of inverted U-shaped curves, this bird was exposed to an FI 15 sec condition following the exposure to FI 480 sec. The minimum time possible between an attack and the delivery of food was changed from 15 sec to 5 sec during this phase. Figure 4 shows that levels of each of the measures of attack at FI 15 sec were intermediate between those recorded at FI 480 sec and FI 30 sec during the ascending series. When the interval value was increased from FI 15 sec to FI 30 sec, all of the measures of attack increased. Thus the various measures of attack for P-8683 showed an inverted U-shaped curve, peaking at FI 30 sec, related to increases in FI duration. This bitonic relation is comparable to those obtained with each of the ten attack measures for both P-7123 and P-3636 and five of the ten measures for P-7504.

Figure 6 summarizes the distribution of attacks within the inter-food interval for each of the pigeons. Both the percent of total attacks and the absolute number of attacks occurring during each successive fifth of the interval are shown for the last five sessions and in the order of exposure to the various FI durations. Although the relative segment lengths were comparable, the absolute lengths varied with the

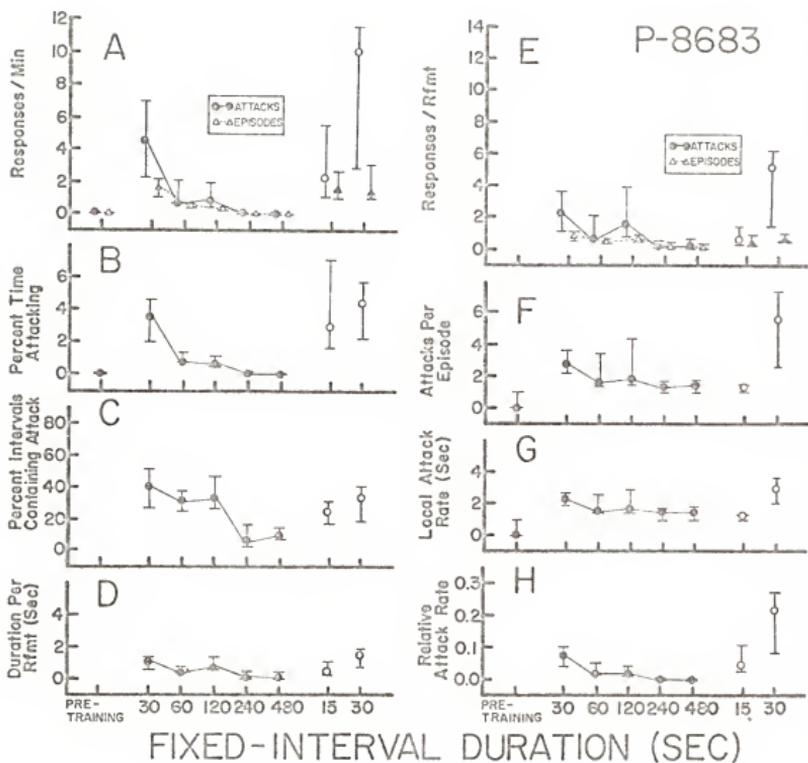


Fig. 5. The medians and ranges of the measures of attack behavior for bird P-8683. Data are from the last five sessions at each FI value in the order of exposure. Recovery points are offset to the right of each section and are the negative image of the symbols representing the ascending series. The horizontal axes are logarithmic to allow compact presentation.

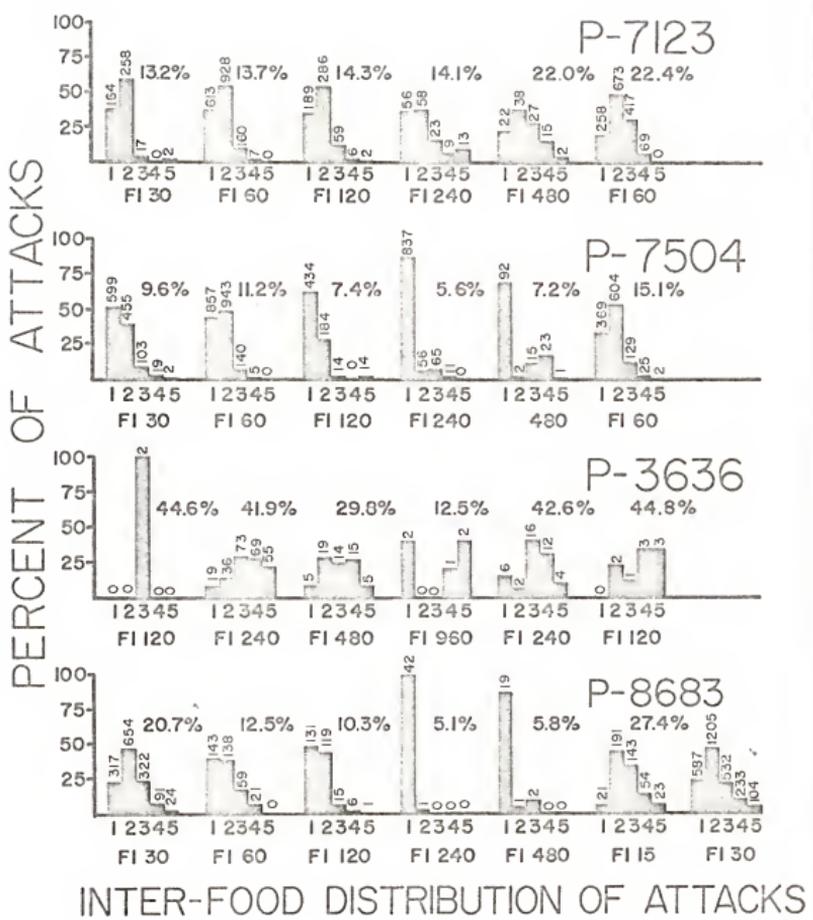


Fig. 6. Percent of total attacks that occurred in each fifth of the interval at each FI duration. These data were pooled over the last five sessions and are presented only for those FI values for which at least one attack occurred during this period. The absolute number of attacks occurring during each segment are shown at the top of each histogram, parallel to the vertical axes. The mean attack quarter-life values for the last five sessions are shown above each set of histograms, parallel to the horizontal axes.

interval in effect. Mean quarter-life values for attack during these five sessions are shown as the percentages above each set of histograms and horizontal to the abscissa. Most of the attacks for Birds P-7123, P-7504 and P-8683 occurred during the first two segments of each interval duration. The percent of attacks then decreased over the remaining three segments within the interval. These negatively accelerated patterns of attack most often occurred prior to the initiation of the positively accelerated patterns of key pecking within each interval. The small absolute number of attacks by P-3636 were fairly evenly distributed throughout the segments of the various intervals employed. The highest absolute number of attacks for P-3636 occurred during the initial exposure at FI 240 sec. As the segment lengths were 48 sec long at this interval value, the 55 attacks that occurred during segment five neither came in contact with the 15 sec protective contingency nor significantly affected the mean rate of food reinforcement during these five sessions (see Table 2). Although the attacks by P-3636 usually occurred prior to the initiation of key pecking within a given interval, this was not as consistently the case as with the other three birds.

In an effort to examine the changes in attack occurring at each interval value and across interval values as a function of the number of sessions, the medians and ranges for each of the ten measures of attack were compared during blocks composed of the first five, second five and last five sessions at each FI value. For all birds, five of the measures (over-

all attack rate, overall episode rate, relative attack rate, percent of the session time engaged in attack, and percent of intervals containing attack) revealed inverted U-shaped functions related to increases in interval value for the first five, second five and last five sessions. The only exception occurred for Bird P-7504, who showed increases in the percent of intervals containing attack with increases in FI value when the first five sessions at each duration were compared. Although the overall shape of the function (inverted U) shown by each of these measures was consistent, changes in both absolute levels of attack and in the FI value at which the peak levels occurred were often observed to change across blocks of sessions. In contrast to these five measures, the three overall time-independent measures (attacks, episodes and duration per reinforcement) and two local attacks measures (attacks/episodes and local attack rate) all showed inverted U-shaped functions relating levels of attack to increases in FI value for only three of the four birds during the last five sessions (see Figures 2, 3, 4, and 5). For Birds P-3636, P-7504 and P-8683, these five measures were also less consistent than the other five in showing similar functions for a single bird between blocks of sessions or across birds after an arbitrarily fixed number of sessions. Figure 7 shows the medians and ranges of attacks per reinforcement for the first five sessions (triangles), second five sessions (circles) and last five sessions (squares) at each interval duration for the four birds. For P-7123 and P-3636,

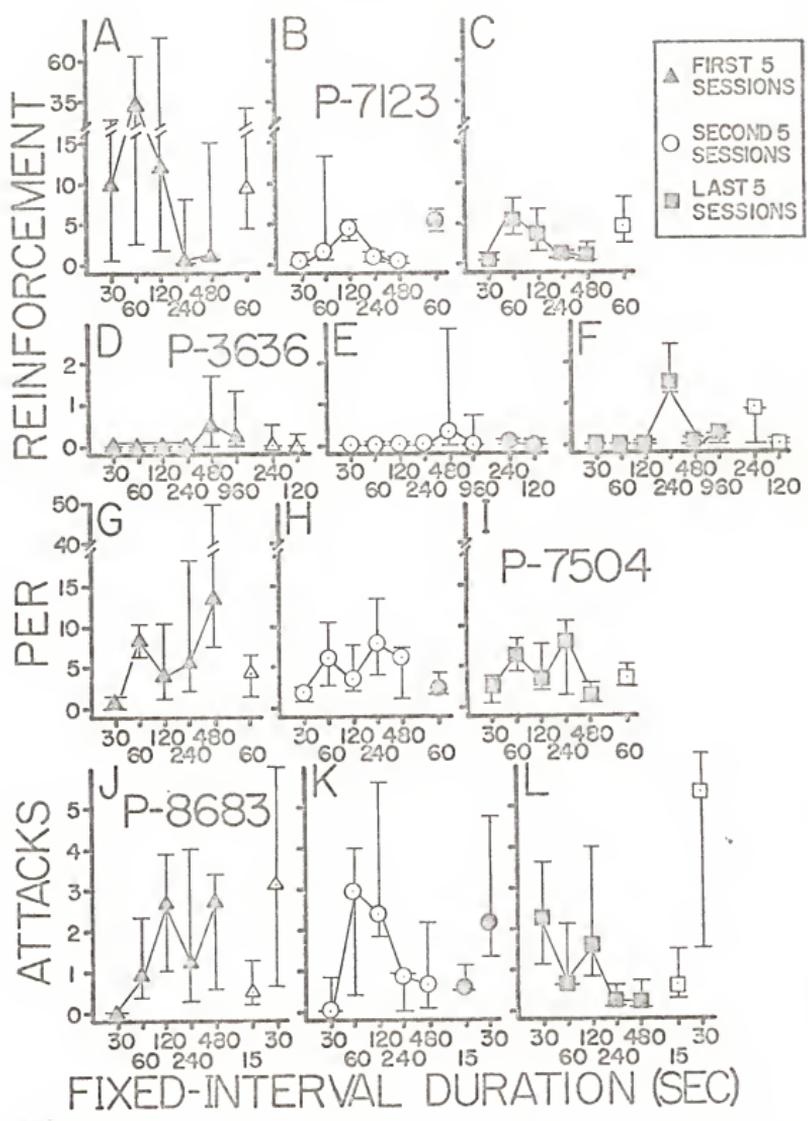


Fig. 7. The medians and ranges of attacks per reinforcement for the first five (triangles), second five (circles), and last five (squares) sessions at each FI schedule in the order of exposure. The horizontal axes are logarithmic to allow compact presentation. Recovery points are offset slightly to the right of each frame and are denoted by the negative image of the symbol representing the ascending series.

attacks per reinforcement showed a bitonic function related to interval value when viewed in terms of the first five (Frames A and D), second five (Frames B and E) and last five (Frames C and F) sessions. For Bird P-7504, the median number of attacks per reinforcement during the first five sessions (Frame G) generally increased as the FI duration increased, but showed bimodal distributions for the second five (Frame H) and last five (Frame I) sessions. During the ascending series for P-8683, the median attacks per reinforcement increased during the first five sessions (filled triangles, Frame J), showed an inverted U-shaped function which peaked at FI 60 sec during the second five sessions (open circles, Frame K) and decreased during the last five sessions (filled squares, Frame L). Attacks per reinforcement for P-8683 during subsequent exposures to FI 15 and FI 30 sec were supportive of the ascending function during the first five sessions (open triangles, Frame J) and the bitonic function in the second five sessions (filled circles, Frame K) which were observed during the initial series. For the last five sessions, however, these additional determinations (open squares, Frame L) in combination with those obtained during the ascending series (filled squares) indicated an inverted U-shaped function, with a peak at FI 30. Without regard to the general functions obtained, Figure 7 also is representative of the range of changes in the various measures of attack that occurred as a function of session number. For Bird P-7123, a wider range and higher absolute levels of attack were usually observed in the first five (Frame A) than those occurring dur-

ing the second five (Frame B) sessions at each interval value. By the second five sessions (Frame B), the absolute levels were generally comparable to those maintained for the duration of each condition. For example, the median number of attacks per reinforcement for Bird P-7123 during the second five sessions at FI 120 (open circles) and the recovery point at FI 60 (filled circle) were similar to the medians at these FI values for the last five sessions, even though the phase lengths were 69 and 42 sessions respectively. No consistent changes in absolute levels of attack as a function of number of sessions at a given FI value were observed for Birds P-3636, P8683 and P-7504.

DISCUSSION

Stable rates and temporal patterns of key pecking maintained by fixed-interval schedules of food reinforcement were not systematically affected by providing access to a live target. The presence of the target and the intense attack that occurred at several interval values neither disrupted the key-peck behavior nor affected the obtained rates of food reinforcement. Both Knutson (1970) and Cohen and Looney (1973) have reported reductions in the rate of reinforcement obtained under fixed-ratio schedules when access to live and mirror targets were respectively provided. Differences inherent between FI and FR schedules may account for these differences between the present and previous results. With fixed-interval schedules, even though moderate rates of operant responding are usually maintained, only one response after a certain interval has elapsed is required to produce food; the post-reinforcement pause may vary widely without affecting reinforcement rate. The length of the post-reinforcement pause directly affects the reinforcement rate obtained with ratio schedules, since reinforcement depends only on the occurrence of a certain number of responses. Additionally, the degree of schedule control achieved prior to introducing the target may have contributed to these different findings. Although Knutson (1970) did not describe the cri-

terion employed, he reported that stable rates and patterns of key pecking were maintained prior to target introduction. The number of sessions during the initial no-target phase in the Knutson (1970) study ranged from 3-7, while 11-66 sessions were provided during the comparable condition in the present study.

Attack occurred primarily during the post-reinforcement pause, prior to a resumption of key pecking. This is consistent with the distribution of attack responses that has been observed under fixed-time (Flory, 1969b), response-initiated fixed-interval (Richards and Rilling, 1972), fixed-ratio (Cohen and Looney, 1973; Flory, 1969a; Gentry, 1968; Hutchinson *et al.*, 1968; Knutson, 1970; Lyon and Turner, 1972; Webbe *et al.*, 1973), and variable-ratio (Webbe *et al.*, 1973) schedules.

There were large individual differences among birds in the absolute levels of attack at a particular interval value, and in the FI duration inducing the highest rates of attack (FI 30 sec, P-8683; FI 60 sec, P-7123 and P-7504; FI 480 sec, P-3636). Large individual differences between subjects in the levels of attack have been similarly reported in many previous studies (e.g., Azrin *et al.*, 1966; Cohen and Looney, 1973; Gentry, 1968; Knutson, 1970; Knutson and Kleinknecht, 1970; Lyon and Turner, 1972; Webbe *et al.*, 1973). Despite these individual differences, when the data were analyzed for the last five sessions at each FI value, three of the

birds showed an inverted U-shaped function between each of 10 measures of attack and increases in FI duration. The fourth bird showed a similar bitonic function for five of the 10 measures.

A controversy currently prevails concerning the shape of the function relating induced behaviors such as attack to schedule parameters (Brown and Flory, 1972; Hutchinson et al., 1968; Falk, 1971; Staddon and Simmelhag, 1971; Webbe et al., 1973). A number of studies in which ratio size was varied reported that increases in ratio size resulted in increased levels of induced attack (Cole and Litchfield, 1969; Flory, 1969a; Hutchinson et al., 1968; Knutson, 1970; Lyon and Turner, 1972; Webbe et al., 1973). These results support one of the basic positions, which posits a direct relationship between the response requirements of ratio schedules and the magnitude of aversiveness (of which attack has been considered to be an index) (Azrin et al., 1966; Hutchinson et al., 1968). A second position has been elaborated by Falk (1971). Induced attack was included among a number of "adjunctive" behaviors which resemble displacement activities. One of the commonalities shared by these behaviors was suggested to be an inverted U-shaped function relating various magnitude or frequency measures of induced behaviors (e.g. attack) to parameter values of schedules of reinforcement. Falk (1971) emphasized the rate of consummatory behavior as a major variable controlling this bitonic function. The first experiment measuring attack behavior to provide

support for this position was reported by Flory (1969b). Food was presented to pigeons independently of any response requirement. As these fixed-time durations were increased, several measures of attack increased to a maximum and then decreased with further increases in the inter-food intervals. These data were interpreted as showing that a response requirement is not necessary for a schedule to induce attack; changes in the inter-food interval (reinforcement rate) were considered to control the bitonic function produced. Still a third suggestion, an inverse relationship between the overall rate of induced behavior and reinforcement rate has been proposed by Staddon and Simmelhag (1971). Although several studies of induced drinking (polydipsia) were cited as supporting this position, such an inverse function has not been reported in studies of induced attack. When the data are analyzed for the last five sessions of the present experiment across the entire range of FI durations employed, they similarly fail to support this proposal. Instead, and in support of Falk (1971), a number of measures of attack for each subject revealed an inverted U-shaped function related to the FI values tested (range: 15 sec to 960 sec). In addition to the experiment by Flory (1969b), these results support and extend the findings of Cherek *et al.* (1973) and Cohen and Looney (1973). Flory (1969b) used taxidermically prepared targets that remained continuously available while inter-food intervals were manipulated, employing response-independent schedules, with an unknown phase length or criterion for

change. Episode rates, episodes per reinforcement, duration per reinforcement and percent time engaged in attack increased to a maximum and then decreased with increases in inter-food intervals. The present study found similar changes in each of these measures across the same values and range of reinforcement rates, even though there were a number of differences between the two studies. In contrast to Flory (1969b), live targets were introduced subsequent to a change in interval value only after key pecking had stabilized; stability criteria for attack were adhered to and response-dependent schedules were employed. Cherek *et al.* (1973) on the other hand used live targets, changed the response-initiated FI values by increments of one min (range: 1 min to 5 min) every five sessions, kept the target available across all sessions, and provided access to the target for 15-sec periods dependent upon two pecks on a second key. A bitonic function was reported relating attack rate to changes in interval value of the response-initiated FI schedule. Cohen and Looney (1973) used a mirror target and FR schedules ranging from FR 25 to FR 150. The mirror was continuously available both within and across all sessions. The FR values were changed every 11 to 14 sessions, according to unspecified criteria. Attack rates showed an inverted U-shaped function related to FR value as well as reinforcement rate. Cohen and Looney (1973) summarized these results, in combination with those of Flory (1969b), as suggesting that the rate of reinforcement exerts more powerful control over induced attack

than do other schedule contingencies such as response requirements. An example of this reasoning is their suggestion that further increases in FR values, in experiments reporting a direct function, would result in the decreased reinforcement rates necessary to produce the descending limb of a bitonic function. It is important to note, however, that Cohen and Looney (1973) also reported an inverted U-shaped relationship between the rate of attack and FR size, independently of inter-food intervals. Thus, the changes in the rates of attack occurring in the Cohen and Looney (1973) study could as easily be attributed to the probability of reinforcement (the reciprocal of the mean number of responses per reinforcement) as to rate of reinforcement. The confounding of rate of reinforcement and probability of reinforcement provides little basis for assessing the relative importance of each in the determination of the attack rate changes. Reinforcement rate and reinforcement probability have similarly been confounded in every previous study of attack induced by response-dependent schedules, including the present one (e.g., the number of key pecks per reinforcement changed as a function of changes in FI value). The probability of reinforcement for key-peck responses at each schedule value may be roughly computed from Figure 1 by taking the reciprocal of key pecks per min divided by the FI duration in minutes. These calculations show that probability of reinforcement for key pecking decreased as the interval value increased with each of the four birds. Thus, the obtained bitonic functions

shown by the various measures of attack could be related to changes in the probability of reinforcement as easily to changes in rate of reinforcement. Unfortunately, the use of fixed-time schedules (Flory, 1969b) offers little to resolve this question, even though no response is required for food delivery. Reinforcement does not have to be dependent upon behavior to exert control over temporal patterns of "terminal" responding such as keypecking (Staddon and Simmelhag, 1971). The fact that such behaviors are not recorded does not preclude their changing in an orderly fashion as a function of changes in the rate of food delivery (Staddon and Simmelhag, 1971). It would appear to be important, therefore, to investigate the effects of probability of reinforcement on induced attack while holding the reinforcement rate constant as well as to perform the converse of this operation. An experiment reported by Webbe et al. (1973) provides data to further suggest the importance of such a determination. When the response requirements of both fixed-ratio and variable-ratio schedules were varied from 50 to 125, comparable reinforcement rates within a component resulted in different levels of attack when the probabilities of reinforcement were different (e.g., VR 75 to VR 125). The resolution of questions concerning the form of the relation between levels of induced attack and schedule parameters may well depend upon the suggested determination of the precise variables which control these relations.

A number of different types of measures of induced attack were employed in the present study. As FI values were changed, five of the measures revealed the same function relating attack to FI duration for all four birds; the other five measures showed a similar relation for three of the four birds. Thus, under conditions of the present study, the choice of only one of these measures would not have significantly affected the resultant function reported. In contrast to this finding, however, Webbe et al. (1973) reported that different measures of attack showed dissimilar functions related to manipulations in variable-ratio size. Previous studies of induced attack have most often reported a single measure or two related measures, and the selection of measures has varied widely among the different experiments. Although the present study found similar changes in a number of these measures as a function of changes in FI value, the Webbe et al. (1973) study emphasizes that such covariation is not inherent to the measures themselves. As a hypothetical example, consider that an animal makes three attack responses after each food delivery during an experimental condition in which food is presented every 2.0 min for a total of 20 food deliveries. During the next session, the schedule is then changed such that food is now delivered every 4.0 min for 20 reinforcements. Under this condition, the animal makes four attack responses after each food delivery. An experimenter employing the percent of intervals containing attack as the dependent variable

measure ($20/20 = 1$; $20/20 = 1$) would report no change in "attack" as a function of this manipulation. If the number of attacks per reinforcement were employed ($60/20 = 3$; $80/20 = 4$), then an increase in the "amount of attack" resulted from the increase in the inter-food interval. The investigator employing rate as the datum ($60/40 = 1.5$; $80/80 = 1$), however, reports that "attack" decreased as a function of this manipulation. These considerations also relate to the problem of phase-change criteria. Five of the measures of attack revealed functions related to FI value during the first five and second five sessions that were similar to those shown in the last five sessions, when stability criteria had been met. Support for any of the three theoretical positions concerning the relationships between attack and schedule values could, however, have been indicated with some measures of attack if the criteria for phase termination had been different (e.g., after five or after 10 sessions, without regard to stability). As an example, if attacks per reinforcement had been used as the single measure of attack and five sessions run at each interval value in the ascending series, bird P-8683 would have shown a direct relationship between attack and FI value (see Figure 7). A 10-day criterion would have shown an inverted U-shaped function; an analysis in terms of the last five days at each interval using the stability criteria employed in this study showed an inverse relationship between attacks per reinforcement and the interval durations in the ascending series.

Cumulative progress in the study of induced attack may, therefore, depend upon the extent to which the effects of variables manipulated are reported in the form of a variety of measures of attack, particularly until the efficacy of the various measures, the relationships among them, and information concerning both transition- and steady-state induced attack may be determined.

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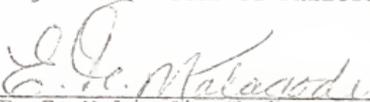
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BIOGRAPHICAL SKETCH

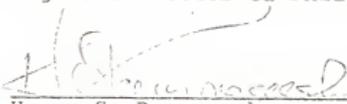
Jo DeWeese was born December 21, 1945, at Bowling Green, Kentucky. She was graduated from Bowling Green High School in June, 1963. In December, 1969, she received the Bachelor of Arts degree with a major in psychology from the University of Florida. In January, 1970, she enrolled in the Graduate School of the University of Florida and received the Master of Science degree in 1971. From August, 1971, until the present time she has pursued her work toward the degree of Doctor of Philosophy.

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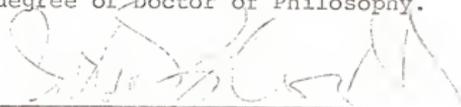
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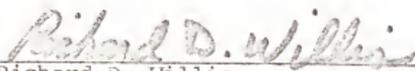
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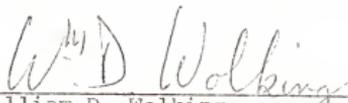
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This dissertation was submitted to the Department of Psychology in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1973

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