INDUCED ATTACK DURING FIXED-RATIO AND MATCHED-TIME SCHEDULES OF FOOD PRESENTATION

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Adjunctive or induced behavior is generated during a variety of schedules of reinforcement. Several theoretical conceptualizations suggest that rate of reinforcement is the primary variable controlling the strength or levels of induced behavior. The operant response requirement within the schedule context has not been extensively studied as a determinant of induced responding. In the present study, levels of induced attack by food-deprived pigeons against restrained conspecifics were compared during response-dependent and response-independent schedules of food presentation equated or yoked interval-by-interval for reinforcement frequency. Experiment 1 compared levels of attack induced by fixed-ratio schedules of key pecking and yoked ''matched-time'' schedules. Experiment 2 similarly compared chained fixed-ratio 1 fixed-ratio 74 and yoked chained matched-time matched-time schedules. In both experiments, the response-dependent schedules generated greater levels (amount and probability) of induced attack than the response-independent time-based schedules. Thus, the ratio response requirement may be an important determinant of levels of induced responding, and the lower levels of attack observed during the response-independent condition may not be due to the absence of stimuli predicting food presentations. It is concluded that rate of reinforcement is not the sole variable determining levels of induced responding and that response-based and time-based schedules differ in their generation of induced responding.

Key words: schedule-induced attack, adjunctive behavior, target pigeons, fixed-ratio schedules, matched-time schedules, key peck, pigeons

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Behavior neither elicited nor directly reinforced is generated and maintained during many intermittent schedules of reinforcement. Adjunctive or schedule-induced behavior includes drinking or polydipsia in rats (e.g., Falk, 1961a,b), pigeons (Magyar & Malagodi, 1980), and monkeys (Porter & Kenshalo, 1974), aggression in rats (Huston & DeSisto, 1971) and pigeons (e.g., Azrin, Hutchinson, & Hake, 1966; Flory, 1969a; Pitts & Malagodi, 1996; Webbe, DeWeese, & Malagodi, 1974); escape (Azrin, 1961; Brown & Flory, 1972; Thompson, 1964); wheel-running (Levitsky & Collier, 1968); hose-biting (DeWeese, 1977; Hutchinson, Azrin, & Hunt, 1968); and a host of other activities (Kelly & Hake, 1970; Killeen, 1975; Lyon & Turner, 1972; Mendelson & Chillag,

1970; Miller & Gollub, 1974; Muller, Crow, & Cheney, 1979; Staddon & Simmelhag, 1971). These topographically dissimilar behaviors display certain functional commonalities when induced during schedules of reinforcement, including: (a) the temporal locus within the interreinforcement interval (induced behavior typically occurs in the immediate postreinforcement period when operant or terminal behavior is low in probability); (b) the gradual development over time of induced behavior with extended exposure to schedule conditions; and (c) the sensitivity of induced behavior (in terms of amount and probability) to schedule parameters (e.g., Allen, Sicignano, Webbe, & Malagodi, 1981; Burks, 1970; Cherek & Heistad, 1971; Cherek & Pickens, 1970; DeWeese, 1973; Dove, Rashotte, & Katz, 1974; Falk, 1961b, 1966; Flory, 1969a,b; Knutson & Kleinknecht, 1970; Webbe et al., 1974). These similarities have led Falk (1971, 1977) and others (Hineline, 1981; Killeen, 1975; Segal, 1972; Staddon, 1977) to suggest that these diverse behaviors exemplify a common behavioral process (induction or arousal) that differs from those at work during operant and respondent procedures. Although the variables that control induced behavior are not fully understood, there has been little analysis

of this class of behavior in recent years. This is unfortunate, as a thorough understanding of the variables controlling the induction process might clarify the relations between motivational operations and the complex aspects of schedules of reinforcement.

Various conceptualizations differ with regard to the possible origins and adaptive significance of the inductive processes, but there is general agreement regarding the importance of rate of reinforcement as a fundamental variable governing the strength or probability of induced behavior. One view proposes that induced behavior comprises a functional class of behavior termed ''adjunctive behavior'' which first increases and then decreases in strength and probability as interrinforcement intervals are increased (Falk, 1971, 1977). A second view proposes that induced behavior or ''interim activities'' reflect the operation of principles of behavioral variation and that the strength (rate) of these activities is directly related to rate of reinforcement (Staddon, 1977; Staddon & Simmelhag, 1971). Finally, a third view proposes that schedule-induced activities reflect the general activation or arousal of the organism following food delivery and that arousal, as measured by overall rate of induced behavior, is directly related to the rate of food presentation (Killeen, 1975). These formulations share the view that the inducing properties of intermittent reinforcement schedules may be reduced to two major variables: (a) overall rate of reinforcement or interreinforcement time, and (b) the temporal distribution of reinforcement. Other schedule variables with significant control over operant responding have been relegated to secondary importance.

Other studies suggest that rate of food presentation per se may not be the unitary controlling variable proposed by the formulations summarized above. In studies of induced attack during FR schedules of reinforcement, the amount and probability of attack increased with increasing response requirements that yielded interreinforcement times which ordinarily generate decreases in such measures when time-based schedules are in effect (e.g., Allen et al., 1981; Flory, 1969b). If response-based and time-based schedules of reinforcement generate divergent functions relating induced behavior to schedule parameters, then these schedules may generate different levels of induced responding when the rate of reinforcement is equated. Yet, direct assessment of the role of the response requirement as a controlling variable for levels of induced behavior has not been extensively studied.

Experiments comparing levels of induced behavior under response-dependent and response-independent schedules of reinforcement have employed different methods for equating reinforcement rate between the response-dependent and-independent schedules. These studies have reported decreases (Cherek, Thompson, & Heistad, 1973; Flory & Everist, 1977; Huston & DeSisto, 1971), increases (Burks, 1970; Falk, 1961b; Flory & Everist, 1977; Schaeffer, Diehl, & Salzberg, 1966), or no difference (Azrin et al., 1966; Cherek et al., 1973; Flory & Everist, 1977) in induced responding during response-independent schedules than during comparable response-dependent schedules. The present study examined levels of induced attack during FR schedules, in which food presentation depended upon the completion of a fixed number of key pecks, with those levels generated during response-independent schedules matched for reinforcement frequency, in which the response key was covered and food was presented independent of responding.

EXPERIMENT 1
METHOD

Subjects

Three adult male White Carneau pigeons were maintained at approximately 75% of their free-feeding weight. Pigeons P-3478 and P-3488 were experimentally naïve, and P-4817 had prior history responding under a multiple schedule of food presentation. Each experimental pigeon was paired with a nondeprived ''target'' pigeon. Pairs of experimental and target pigeons remained the same throughout the study. All pigeons were individually housed with water and health grit continuously available.

Apparatus

The experimental chamber was fitted with a BRS-Foringer two-key stimulus panel (BRS-PH-002). The experimental space was approximately 39 cm long by 36 cm wide and 36 cm tall. Only the right key was operative, and

pecks in excess of 0.2 N against the key defined a response and produced a click from a feedback relay behind the stimulus panel. General illumination was provided by two white 1.4-W bulbs located behind a translucent plexiglass strip on the stimulus panel, 20.5 cm apart and 6.5 cm above the response keys. The response key was transilluminated from behind with red light. During the 4-s grain presentations, both the houselights and the keylight were turned off and the raised food hopper was lit with white light.

The apparatus for recording attack was similar to that described by Azrin et al. (1966) and Webbe et al. (1974) and was located at the rear of the chamber, 39 cm from the stimulus panel. The target pigeons were restrained in a clear plexiglass restraint unit that was mounted on a spring-loaded metal plate. A microswitch was located beneath the metal plate such that a force in excess of 100 g (1.0 N) exerted against the front of the unit activated the microswitch and was recorded as a single attack. This force requirement was sufficient to prevent defensive or spontaneous movements of the target pigeon from activating the microswitch.

A target pigeon was confined within the restraint unit by foam cushions above and below its body. An adjustable opening on the top front of the restraint unit allowed the extrusion of the target pigeon's head, neck, and upper breast region. An inverted U-shaped plexiglass shield was mounted 2 cm in front of the target pigeon. This shield, in conjunction with opaque panels located on either side of the unit and a plexiglass panel mounted above the shield, limited access to the target pigeon only to the opening between the downward extensions of the shield. To further protect the target pigeon against injury, the exposed breast area was covered with a white simulated fur bib fastened behind the target pigeon's back. The shield and the fur bib allowed for consistently high levels of attack without the occurrence of a single injury to the target pigeons (cf. Webbe et al., 1974).

White noise was continuously present in the room where the experimental chamber was located. An exhaust fan on the side of the chamber provided ventilation. Standard electromechanical scheduling and recording equipment and cumulative recorders were located in an adjoining room.

Procedure

To assess baseline levels of attack, each experimental pigeon was placed in the chamber in the presence of the restrained target pigeon for daily 30-min sessions. During these preexperimental sessions, the response key and food hopper were inoperative. Some attack occurred upon initial exposure to the target pigeons, but dropped to zero by the second (P-3478 and P-3488) or third (P-4817) session where it remained for three additional sessions.

Target pigeons were then removed and, in the presence of a red keylight, key pecking was shaped for P-3478 and P-3488, and P-4817 was exposed to a fixed-ratio 1 (FR 1) schedule of food presentation. The response requirement was increased gradually for all 3 pigeons to FR 75 for P-3478, FR 65 for P-3488, and FR 100 for P-4817. These ratio values were chosen to allow roughly comparable interreinforcement times for the 3 pigeons. Once rate and patterning of responding stabilized at these FR values, target pigeons were re-introduced and attack was recorded. Attack measures during all phases included: number of attacks per reinforcement, duration of attack per reinforcement, and conditional probability of attack per reinforcement. The number of attacks was a direct count of each microswitch closure, and attack duration was the cumulative time spent attacking, recorded as time from the initiation of an attack until a 1-s interval occurred without an attack. Thus, an attack episode was defined as any attack or series of attacks separated by at least 1 s from other attacks. The conditional probability of attack was obtained directly from cumulative records and was defined as the proportion of food presentations followed by at least one attack. The FR schedules remained in effect until no systematic trends in rate of key pecking and attack measures were observed for 15 consecutive sessions.

Daily sequences of the interreinforcement times during each of the last 20 sessions of the initial FR phase were used to generate 20 matched-time (MT) schedule sessions yoked interval-by-interval to the interreinforcement times in the preceding FR sessions. For example, the 30 interreinforcement intervals occurring in the first of the last 20 sessions of the FR phase constituted the 30 interreinforcement intervals of the first session of the MT

Table 1

Summary of conditions and number of sessions under each for Experiment 1.

P-3478		P-4817		P-3488	
Condition	Sessions	Condition	Sessions	Condition	Sessions
FR 75	164	FR 100	57	FR 65	59
MT	43	MT	22	MT	91
FR 75	47	FR 100	30	FR 65	32
				MT	31
				FR 65	32

phase. During the MT phase, the response key was covered with a metal plate and food was presented independently of responding. The 20 yoked-MT sessions were repeated until the 15-session stability criterion was met. During the final phase, the key was uncovered and the initial FR values were reinstated. Table 1 summarizes the order of experimental conditions and the number of sessions under each condition for all pigeons.

To ensure that attacks were never followed immediately by food presentation, a 5-s change-over-delay (COD) was in effect. During the FR phase, a key peck could not produce food for at least 5 s following an attack. During the MT phase, food could not be presented for 5 s following an attack. Sessions were terminated following the 30th food presentation and were conducted on the average six days per week.

RESULTS

Characteristic patterns of key pecking were obtained with all pigeons under the FR schedules of reinforcement. Responding consisted of a postreinforcement pause followed by an abrupt transition to high constant rates terminating with food presentation. Attack typically occurred in the immediate postfood period, and attack bouts were evenly distributed throughout the session. Representative cumulative records selected from the last 15 sessions for each pigeon under its respective FR schedules and yoked MT schedule are shown in Figures 1 through 3 for P-3478, P-4817, and P-3488, respectively. A greater number of attacks was generated under the FR schedules than during the yoked MT schedules for each pigeon. For example, in the session shown for P-3478, 350 attacks were recorded during the FR schedule, whereas 160 attacks were recorded during the yoked MT schedule.

Figure 4 shows per-session summaries of attacks-per-reinforcement during the last 15 sessions of each phase for the 3 pigeons. With the transition to the MT phase, attacks per reinforcement decreased abruptly for each

Fig. 1. Representative cumulative records of key pecking and attacking for P-3478 under a fixed-ratio (FR) and yoked matched-time (MT) session. The response pen steps up with the occurrence of each key peck or attack. All pips indicate food deliveries. The key peck and attack records reset together after approximately 500 key pecks.
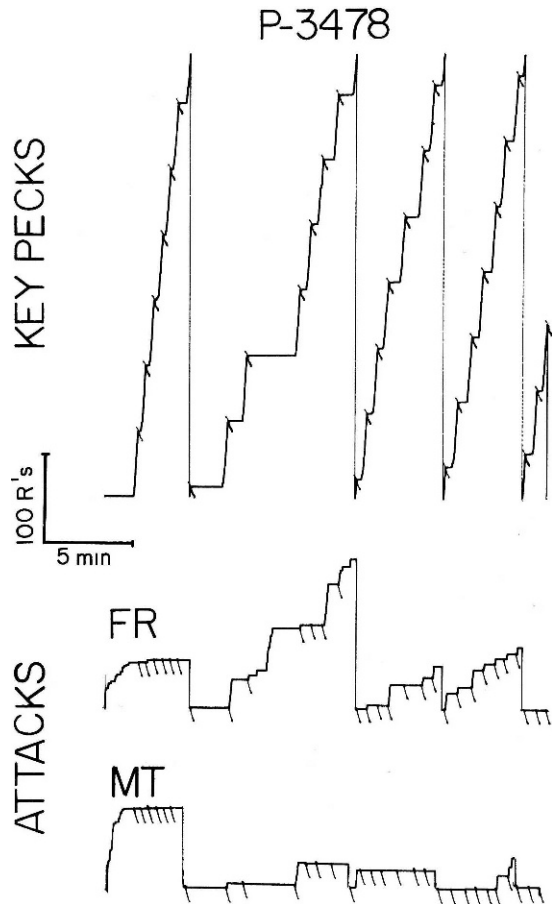
Fig. 2.   Representative cumulative records of key pecking and attacking for P-4817 under a fixed-ratio (FR) and yoked matched-time (MT) session. The response pen steps up with the occurrence of each key peck or attack. All pips indicate food deliveries. The key peck and attack records reset together after approximately 500 key pecks.
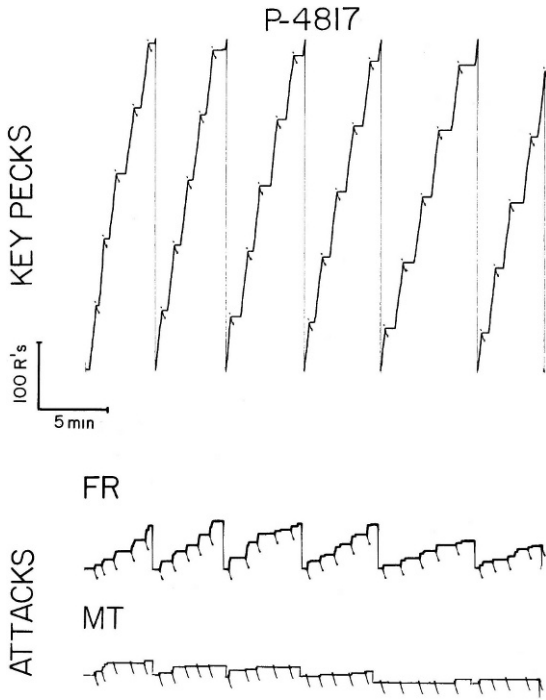
pigeon to 50% of that during the FR phase. Duration of attacks per reinforcement varied directly with the number of attacks per reinforcement for each pigeon and thus is not shown.

The conditional probability of attack or the proportion of interfood interval with at least one attack similarly decreased during the MT phase for P-3478 and P-4817. Figure 5 shows per-session summaries of conditional probability of attack for each pigeon in each phase. For example, conditional probability of attack for P-3478 decreased from an average of approximately 0.6 during the FR phase to an average of approximately 0.2 during the MT phase. As with attacks per reinforcement and duration of attack per reinforcement, conditional probability of attack for P-3478 and P-4817 decreased precipitously upon transition to the MT schedule to a stable level well below that obtained during the FR schedule condition.

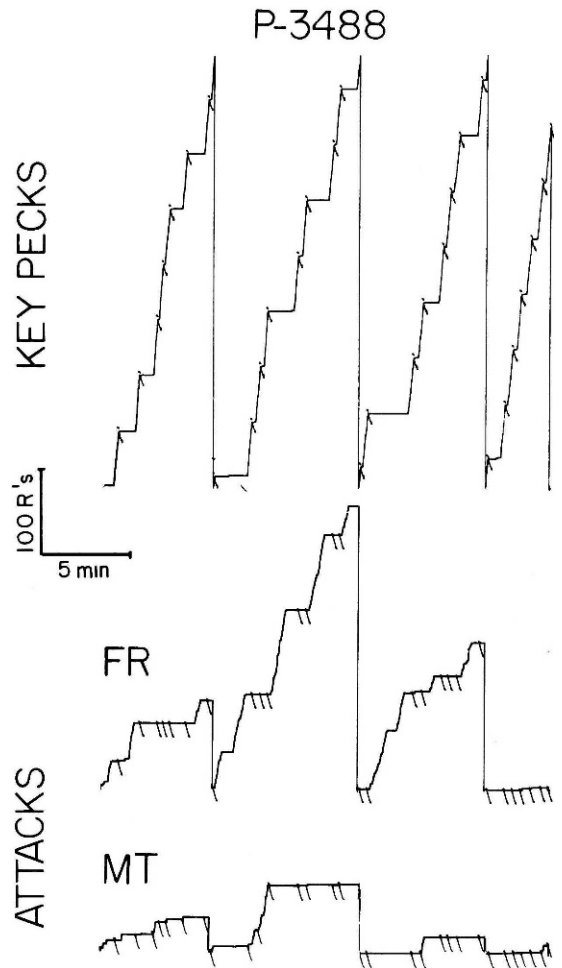By contrast, conditional probability of attack for P-3488 increased during the MT phase

Fig. 3.   Representative cumulative records of key pecking and attacking for P-3488 under a fixed-ratio (FR) and yoked matched-time (MT) session. The response pen steps up with the occurrence of each key peck or attack. All pips indicate food deliveries. The key peck and attack records reset together after approximately 500 key pecks.

from the levels obtained during the FR phase. Because of the divergence among attack measures for P-3488, the FR and MT comparison was repeated for this pigeon with the previous results replicated. Within the first session (not shown) of the MT phase, conditional probability immediately decreased to near zero and then gradually increased to an average of approximately 0.65. Reinstatement of the FR schedule resulted in a gradual decrease in conditional probability to about 0.37. The subsequent exposures to the MT and FR phases resulted in abrupt transitions (not shown) to either higher (MT phase) or lower
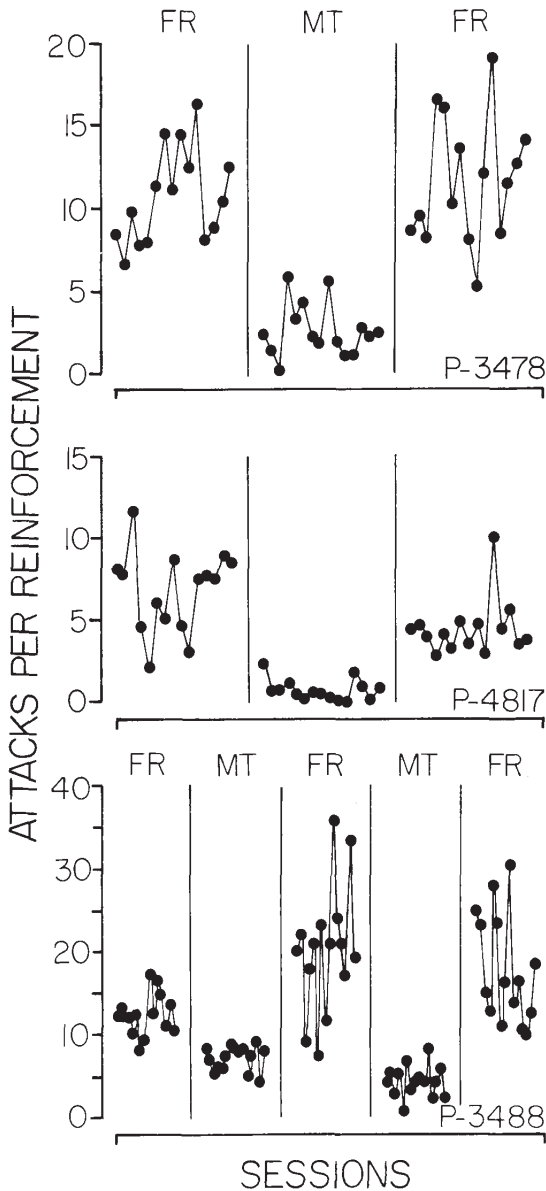
Fig. 4. Attacks per reinforcement from the last 15 sessions under the fixed-ratio, yoked matched-time, and subsequent fixed-ratio phases for each pigeon with additional matched-time and fixed-ratio phases for P-3488.

Fig. 5. Conditional probability of attack from the last 15 sessions under the fixed-ratio, yoked matched-time, and subsequent fixed-ratio phases for each pigeon with additional matched-time and fixed-ratio phases for P-3488.

(FR phase) conditional probabilities, in comparison to the gradual transitions obtained during the first exposure.

Rates and patterns of key pecking were disrupted upon re-exposure to the FR schedules. Long pauses occurred at the beginning of the first session and key pecking, once initiated, was frequently interrupted by breaks

in responding. Characteristic patterns of responding developed within the second session for each pigeon with no prolonged pausing occurring after 6 sessions of the condition for P-4817 and P-3488 and 12 sessions for P-3478. Reinstatement of the FR schedules reduced average interreinforcement time for P-4817, had no substantial effect on average interreinforcement time for P-3478, and increased the average interreinforcement time for P-3488. The third exposure to the FR condition for P-3488 reduced average interreinforcement time. The average interreinforcement time and standard deviations for the last 15 sessions

Table 2

Mean interreinforcement times and standard deviations in s for the last 15 sessions under the initial fixed-ratio phase, the yoked matched-time phase, and the subsequent fixed-ratio phase for P-3478 and P-4817 in Experiment 1.

P-3478						P-4817					
FR		MT		FR		FR		MT		FR	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
44.5	21.1	42.9	20.1	43.2	33.0	104.3	46.5	103.4	45.5	49.2	11.9
47.0	19.2	44.1	15.5	38.3	14.4	84.4	23.9	82.7	23.3	50.0	11.4
57.4	21.6	60.3	20.4	35.0	12.8	85.4	26.2	83.7	24.8	49.2	9.9
48.4	24.4	47.1	25.2	37.1	15.9	73.8	16.8	74.5	17.7	55.4	14.0
48.6	33.1	48.1	30.4	39.0	30.4	58.6	11.4	60.7	11.3	53.2	8.2
45.8	30.1	49.6	34.3	40.0	27.8	60.8	11.4	58.8	11.7	50.7	8.4
59.6	33.5	60.4	31.1	48.9	30.4	64.8	14.1	65.2	13.9	49.5	11.3
45.6	19.9	46.8	17.9	43.3	25.9	59.9	19.4	60.3	19.6	44.2	6.6
50.9	21.7	50.0	18.9	45.1	24.8	71.8	16.6	71.7	18.0	57.9	14.8
45.3	15.2	45.2	11.5	45.2	36.8	70.9	17.8	70.0	16.4	55.9	11.1
37.9	18.5	39.1	20.6	42.8	25.9	78.6	33.7	79.2	30.5	56.5	13.4
39.3	18.3	40.5	16.8	36.8	11.3	66.6	21.4	66.5	21.4	53.8	12.9
43.1	17.7	43.9	20.8	38.9	23.6	89.5	27.7	91.0	28.8	51.7	12.5
43.5	19.8	42.0	15.5	46.6	32.0	104.3	65.1	97.2	60.8	53.4	11.1
40.6	17.4	39.9	17.8	36.5	13.1	80.3	33.5	78.6	35.0	51.1	12.3

across conditions are shown in Table 2 for P-3478 and P-4817 and in Table 3 for P-3488. Interreinforcement times were obtained through direct measurement of cumulative records from each condition.

DISCUSSION

With response-based (FR) and time-based (MT) schedules equated for rate and temporal distribution of reinforcement, number of attacks per reinforcement and duration of attack per reinforcement decreased during the time-based schedules from the levels obtained during the response-based schedules for each pigeon. These decreases occurred immediately following the transition from the FR to the MT schedules. Reinstatement of the FR schedules raised the levels of induced attack even when re-exposure resulted in either small increases or decreases in the average interreinforcement times from those obtained under the initial FR phase.

Conditional probability of attack per reinforcement, however, decreased for P-3478 and P-4817, while increasing for P-3488 during the MT phase. Observations of P-3488 revealed a change in its overall behavioral pattern following the transition from the FR to the MT phase. During the FR phase, several completed ratios were followed generally by a long bout of attack after which key pecking was again initiated and several additional ratios completed (see Figure 3). This pattern of key pecking and attack typically occurred throughout the session and is reflected in the relatively low conditional probability of attack during the FR phase. During the MT phase, P-3488 began to display stereotyped ''circling'' of the chamber area following food presentation. This circling behavior may have resulted in more exposure to the target and an increased number of attack initiations. It is interesting to note that while the conditional probability of attack increased during the MT phase, attacks per reinforcement and the duration of attack per reinforcement decreased. The divergence among the attack measures underscores the importance of using a variety of measures in analyzing induced behavior, as well as evaluating the appropriateness of each measure of the strength of induced behavior (cf. Allen et al., 1981; Webbe et al., 1974).

The present results are similar to those of Huston and DeSisto (1971) comparing levels of interspecific attack during FR and FT schedules of intracranial stimulation (ICS) equated for average reinforcement frequency. The mean number of attacks by rats directed against frogs was greater under FR conditions

Table 3

Mean interreinforcement times and standard deviations in s for the last 15 sessions under the fixed-ratio phases and yoked matched-time sessions for P-3488 in Experiment 1.

P-3488									
FR		MT		FR		MT		FR	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
39.9	25.7	38.6	23.6	58.8	48.5	59.6	47.4	49.5	41.1
34.9	20.1	35.8	22.7	60.6	51.6	63.4	50.3	46.3	32.4
42.4	29.6	41.5	27.3	52.5	31.9	52.6	31.7	46.4	32.2
46.8	32.9	48.9	33.8	60.8	47.4	61.1	46.1	45.6	32.0
42.3	21.8	41.6	21.8	58.2	42.1	57.6	42.9	57.3	48.1
53.2	36.2	55.4	32.2	33.5	26.6	35.6	26.5	45.6	32.9
37.5	24.2	37.8	24.4	49.3	38.8	50.4	37.7	51.9	42.0
51.5	36.6	49.6	35.8	43.8	30.9	45.2	28.7	59.3	49.7
42.1	34.9	43.7	32.9	52.2	34.9	56.9	34.8	40.8	24.2
44.0	39.1	45.7	38.4	52.4	44.1	54.0	42.3	37.2	20.7
44.0	31.7	43.9	31.6	63.7	48.3	67.5	52.2	43.4	29.7
51.3	35.1	50.3	30.7	56.7	55.2	57.5	54.2	35.0	16.1
50.1	28.9	50.8	34.0	48.4	37.2	49.9	35.7	45.2	22.4
48.9	38.1	52.6	39.3	77.1	63.6	78.3	62.0	48.2	28.0
48.3	31.9	48.3	28.6	57.6	47.9	58.9	46.7	43.8	26.3

than during conditions in which ICS was presented independently of responding. It was suggested that a response requirement might be a more potent inducer of attack than schedule intermittency. Similar results were reported by Flory and Everist (1977) and Cherek et al. (1973) with some experimental subjects. In Flory and Everist, rate of attack by pigeons against taxidermically prepared target pigeons decreased during a response-independent reinforcement phase for 2 of 4 subjects from that during a FR phase. Cherek et al., comparing response-initiated FI and FT schedules equated for reinforcement frequency, reported decreased rate of attack against a restrained conspecific during the response-independent (FT) phase with 1 of 3 pigeons.

The reliably lower number and duration of attack per reinforcement observed during the yoked MT phase for each pigeon in the present experiment, as well as the decrease in conditional probability of attack for 2 pigeons, provide little support for the general contention that rate of reinforcement is the sole controlling variable determining levels of induced behavior during schedules of food presentation. Rather, these results suggest that some aspects of schedule contingencies other than rate of reinforcement, such as the operant requirement, are important in determining levels of induced responding.

EXPERIMENT 2

Several aspects or functions of a response requirement under an intermittent schedule of reinforcement may be important in determining levels of induced attack. One aspect is the discriminability or predictability of food presentation. Different aspects of reinforcement contingencies, such as stimuli associated with the passage of time and different response–reinforcer relationships (e.g., contingent versus noncontingent reinforcement), may exert discriminative control over behavior (Appel & Hiss, 1962; Killeen, 1978; Lattal, 1975).

Under a FR schedule, operant responding is differentially associated with and therefore predicts food delivery. In the absence of stimuli predicting food during the MT phase, behavior incompatible with attacking (e.g., pacing in front of the food hopper) may have emerged as a terminal behavior (Staddon & Simmelhag, 1971) thereby reducing the overall level of attack. Therefore, the lower levels of attack obtained during the MT phases of Experiment 1 may have resulted from the removal of discriminative or predictive stimuli signaling food delivery, rather than from the removal of the operant response requirement per se.

Another interpretation is that conditions during the MT phase may have been similar to

those under variable-time (VT) schedules, which have been suggested to generate low overall levels of induced or ''interim'' behavior (Staddon, 1977; Staddon & Simmelhag, 1971). For example, Staddon and Simmelhag reported lower levels of interim activities under VT schedules than under comparable FT schedules of food presentation. These differences have been attributed to the lack of a discriminable S^Δ or interim periods under aperiodic (e.g., VI or VT) schedules of food presentation (Staddon, 1977). Schedule-induced or interim behavior occurs predominantly during periods with low probability of reinforcement or in the presence of stimuli which signal the absence of food (Falk, 1971, 1977; Killeen, 1975; Staddon, 1977). Because the probability of food soon after a previous food presentation is higher under a VI or VT (aperiodic) schedule in comparison to FI or FT (periodic) schedules, the initiation of ''terminal'' or food-related behavior is suggested to occur sooner after food delivery under aperiodic schedules (cf. Staddon; Staddon & Simmelhag), thereby reducing the time allocation to interim activities.

Although the temporal distribution of food presentations was aperiodic under both the FR and MT schedules in Experiment 1, the FR conditions generated consistently higher levels of attack than the MT conditions. The behavior generated by the ratio requirement during the FR phases may have effectively divided the interfood interval into discriminable S^Δ or interim versus food-related or terminal periods. As such, the addition of exteroceptive stimuli, which differentially signal interim versus terminal periods during the interfood intervals of the MT phase, might allow levels of attack to increase to those obtained during the FR phase. Killeen (1975) reported increases in interim activity (general locomotion) by pigeons during a FT 60-s schedule when an added stimulus signaled food delivery in 12 s. It was suggested that the added stimulus became a discriminative stimulus for terminal activity. At the same time, the absence of the stimulus acted as a S^Δ predictably signaling a period of nonreinforcement, thereby engendering an increase in interim locomotor activity.

Experiment 2 compared levels of induced attack during chained FR 1 FR 74 and chained MT MT schedules of food presentation equated for rate and temporal distribution of both component schedule changes and food deliveries. The Chained FR 1 FR 74 schedule was chosen because it is comparable to a simple FR schedule in that a fixed number of responses is required for reinforcement and the distribution of interreinforcement times is determined by the behavior of the pigeon. An FR 1 schedule was employed in the first component of the chained schedule so that the interfood interval would effectively be divided into an interim or pause period and a terminal or run period, each correlated with a different exteroceptive stimulus. These stimuli, in the absence of the behavior generated by a ratio requirement (chain MT MT), serve a discriminative function by signaling food availability. Additionally, to assess whether decreases in the level of attack during the MT phases were a function of incompatible behavior maintained in the area of the food hopper, each pigeon's location in the chamber with respect to the food hopper and the target pigeon was recorded.

METHOD

Subjects

Pigeons 3478 and 3488, with their respective target pigeons, again served as subjects.

Apparatus

The experimental chamber was the same as in Experiment 1 with two exceptions: (1) sets of two green and two red 1.4-W houselights were mounted 10 cm apart behind a translucent strip along both the front and rear walls of the chamber 6.5 cm above the response key and 7.5 cm above the top of the front shield of the restraint unit; and (2) a three-panel floor was installed. Each panel measured 12.5 × 35 cm and divided the chamber widthwise into three equal divisions. Microswitches were mounted beneath each panel such that a force in excess of 125 g (1.25 N) activated the microswitch and provided a measure of the total time spent on each panel.

Procedure

A chained FR 1 FR 74 schedule of food presentation was established for both pigeons. In the presence of a green keylight and green houselights, one key peck changed the keylight and houselights to red after which the

Table 4

Summary of Conditions and Number of Sessions Under Each for Experiment 2.

P-3478		P-3488	
Condition	Sessions	Condition	Sessions
Chained FR 1 FR 74	126	Chained FR 1 FR 74	258
Chained MT MT	33	Chained MT MT	21
Chained FR 1 FR 74	77	Chained FR 1 FR 74	152

74th key peck produced food and a subsequent return to the FR 1 component of the chained schedule. Target pigeons were continuously available and attack recorded. Attack measures were the same as in Experiment 1 and were recorded separately for each component schedule. The chained FR FR schedule remained in effect until all measures of attack showed no systematic trends in both components for at least 20 consecutive sessions.

Daily durations of component times for the last 20 sessions of the chained FR 1 FR 74 phase were obtained through the direct measurement of event-pen markings on the cumulative records. These component-duration distributions were used to generate 20 chained MT MT schedules in which both components were yoked interval-by-interval to the preceding chained FR 1 FR 74 schedule-component distributions. During the chained MT MT phase, the response key was covered, components were signaled by houselight changes from green to red, and component changes and food presentation occurred independent of responding. The 20 yoked chained MT MT schedules were repeated until there were no systematic trends in measures of attack for 20 sessions. During the final phase, the chained FR 1 FR 74 schedule was reinstated. Table 4 summarizes the order of experimental conditions and the number of sessions under each condition for both pigeons.

To ensure that attacks were never followed immediately by either component schedule change or food presentation, a 5-s COD was programmed between an attack and a change in discriminative stimuli or food presentation under all phases of the experiment. Experimental sessions were conducted typically 6 days per week and terminated after 30 food presentations.

RESULTS

The patterns of key pecking obtained for both pigeons were similar to those under the simple FR schedules of food presentation in Experiment 1. Pausing was followed by a key peck resulting in component change, after which key pecking was maintained at a high and steady rate until food presentation. Attack occurred predominantly in the first component, shortly after food presentation. Representative cumulative records from the last 20 sessions under the chained FR 1 FR 74 schedule and the yoked chained MT MT schedule are shown in Figures 6 and 7 for P-3478 and P-3488, respectively. Occasionally, a pause can be seen following component change, especially for P-3488. Attack typically was restricted to the first component, but occasional brief attack bouts can be seen at the beginning of the second component. For both pigeons, a greater number of attacks was generated under the chained FR FR schedules than under the yoked chained MT MT schedules. The pattern of key pecking upon reinstatement of the chained FR 1 FR 74 schedule (not shown) consisted of long pauses at the beginning of the session followed by characteristic patterns of responding for P-3478 and characteristic patterns of responding throughout the first session for P-3488.

As in Experiment 1, the number of attacks per reinforcement decreased during the chained MT MT phase from that occurring during the chained FR FR phase for both pigeons. Figure 8 shows summaries of the number of attacks per reinforcement for each component of the chained schedules across conditions. Typically, a greater number of attacks was generated during the first component of the chained schedule than the second component (with the exception of some sessions for P-3478 during the chained MT MT phase). Decreases occurred in both
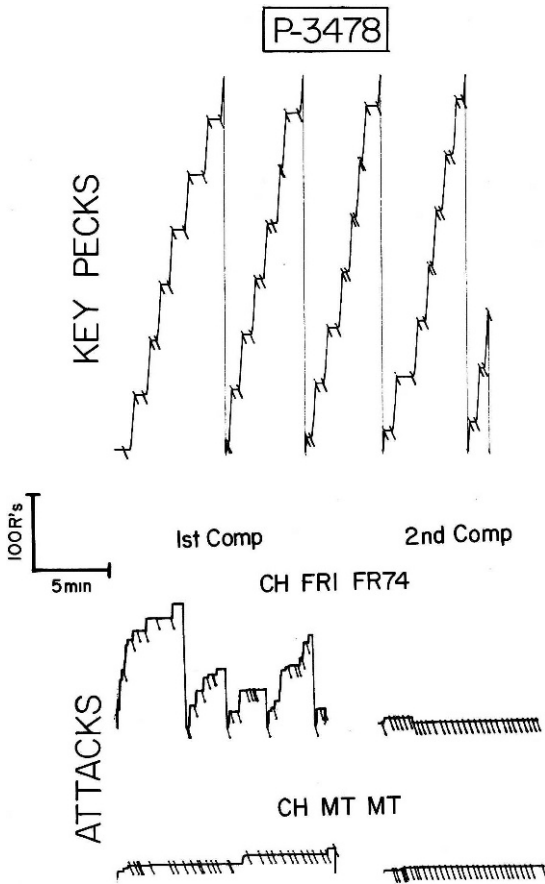
Fig. 6.   Representative cumulative records of key pecking and attacking under a chained FR 1 FR 74 and yoked chained MT MT session for P-3478. The first pips in the key peck record indicate component schedule changes, whereas the second pips indicate food presentations. The response pen for both the key peck and attack records reset after approximately 500 key pecks. Pips during the first-component attack records represent component schedule changes, whereas pips during the second-component attack records indicate food presentations.

components during the chained MT MT phase. Transitions to the lower levels of attack occurred within the first session for P-3478 and within five sessions for P-3488. Reinstatement of the chained FR 1 FR 74 schedule increased the number of attacks per reinforcement to levels either comparable to (P-3478) or greater than (P-3488) those obtained during the initial chained FR phase. Once again, duration of attack per reinforcement varied directly with the number of attacks per reinforcement and is not shown.

For P-3478, the conditional probability of attack per reinforcement decreased during the
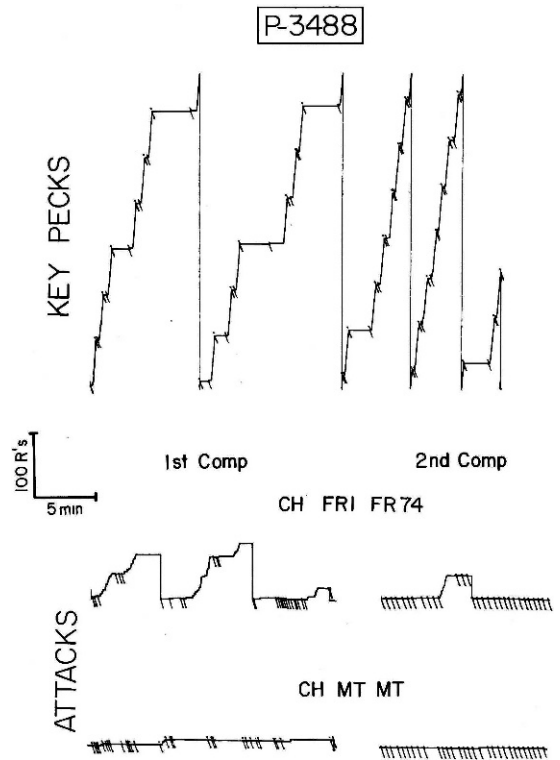
Fig. 7.   Representative cumulative records of key pecking and attacking under a chained FR 1 FR 74 and yoked chained MT MT session for P-3488. The first pips in the key peck record indicate component schedule changes, whereas the second pips indicate food presentations. The response pen for both the key peck and attack records reset after approximately 500 key pecks. Pips during the first-component attack records represent component schedule changes, whereas pips during the second-component attack records indicate food presentations.

chained MT MT phase as it did during the simple MT phase of Experiment 1. Figure 9 shows the conditional probability of attack for both pigeons across conditions. The decrease was largely a function of decreases in attack during the first component, as the probability of attack in the second component remained constant across conditions. In contrast to the results of Experiment 1, the conditional probability of attack also decreased during the chained MT MT phase for P-3488. Informal observations of P-3488 during the chained MT MT phase revealed that no stereotyped circling behavior developed as it had during the MT phases of Experiment 1. Reinstatement of the chain FR 1 FR 74 schedule resulted in increases in conditional probability of attack in the first component for
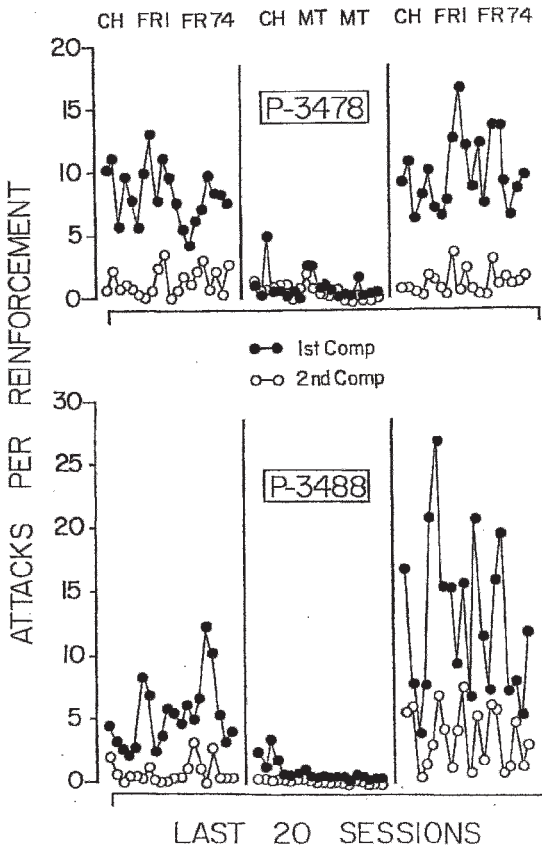
Fig. 8. Attacks per reinforcement from the last 20 sessions under the chained FR 1 FR 74, yoked chained MT MT, and subsequent chained FR 1 FR 74 phases for both pigeons. Filled circles represent attack during the first component of the chained schedules. Open circles represent attack during the second component of the chained schedules.
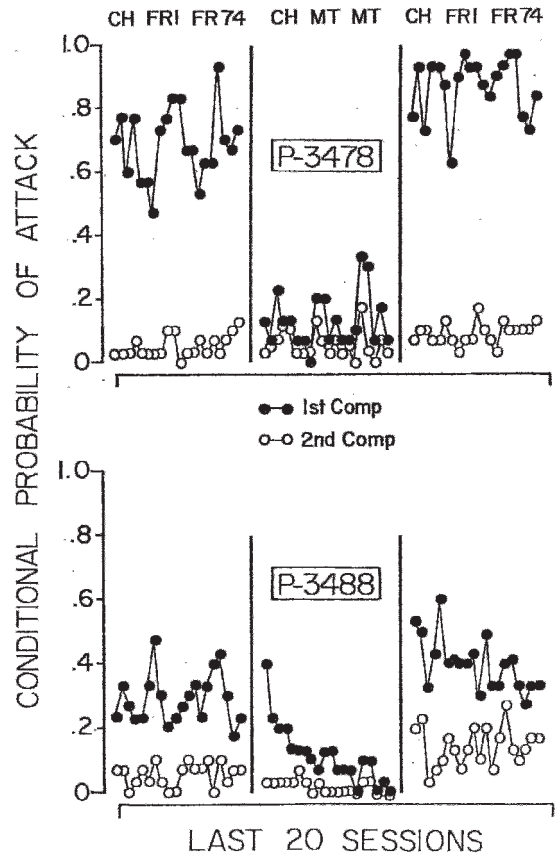
Fig. 9. Conditional probability of attack from the last 20 sessions under the chained FR 1 FR 74, yoked chained MT MT, and subsequent chained FR 1 FR 74 phases for both pigeons. Filled circles represent attack during the first component of the chained schedules. Open circles represent attack during the second component of the chained schedules.

P-3478 and in both the first and second component for P-3488.

The location of both pigeons with respect to the feeder and target-pigeon areas was recorded continuously during each component across experimental conditions. The chamber floor was divided into three equal panels. Panel 1 was located immediately in front of the response key and food hopper, Panel 3 was immediately in front of the target pigeon, and Panel 2 was in between the other panels. Floor-panel recordings and informal observations of both pigeon's locations during experimental sessions revealed that both pigeons rarely stepped on Panel 3 and all attacks occurred while the experimental pigeon stood

on Panel 2. Key pecking was conducted entirely from Panel 1. Attack could not occur from Panel 1.

The percentage of session time per component spent on Panel 2 (the panel providing access to attack) across conditions is shown in Figure 10 for both pigeons. During the chain FR 1 FR 74 phases, more time was spent on Panel 2 during the first component than the second for both pigeons. This location differential correlates with the greater levels of attack during the first component of the chained FR 1 FR 74 schedule. During the chained MT MT schedule, there were small decreases in the percentage of time on Panel 2 during both components for P-3488. For P-3478, however, more time was spent on Panel

2 during both components of the chained MT MT phase than during the chained FR 1 FR 74 phases. Observations of P-3478 revealed that the pigeon paced before the target, but rarely attacked.

The average component durations and standard deviations for the last 20 sessions of each condition are shown in Tables 5 and 6 for P-3478 and P-3488, respectively. Component durations were obtained through direct measurement of cumulative records from each condition. Comparable mean values and distributions of first and second component durations were obtained between the initial chained FR 1 FR 74 and the yoked chained MT MT sessions for both pigeons. This indicates that comparable rates and temporal distributions of food presentation were also obtained between the two conditions. For both pigeons, second component durations were considerably more periodic (smaller standard deviations) than first component durations, indicating that the aperiodicity in interreinforcement times is largely a function of the variability in postfood pause time or first-component durations. Reinstatement of the chained FR 1 FR 74 schedule resulted in small decreases in the interreinforcement times from the first exposure for P-3488. The average interreinforcement time was comparable in both the two exposures to the chained FR 1 FR 74 and in the simple FR schedules of Experiment 1 for P-3478. A large increase in interreinforcement time occurred for P-3488 under the chained FR 1 FR 74 schedules of Experiment 2 from those obtained under the simple FR 65 schedule of Experiment 1.

DISCUSSION

Experiment 1 showed that the ratio response requirement was an important determinant of levels of schedule-induced attack. One manner in which a response requirement might exert control over levels of induced attack is through its discriminative function. That is, the response requirement might serve as a discriminative or predictive stimulus in relation to the presentation of food, particularly during aperiodic schedules of reinforcement. Experiment 2 compared levels of induced attack during response-based and time-based schedules equated not only with respect to rate and temporal distribution of reinforcement, but also with respect to the discrimina-
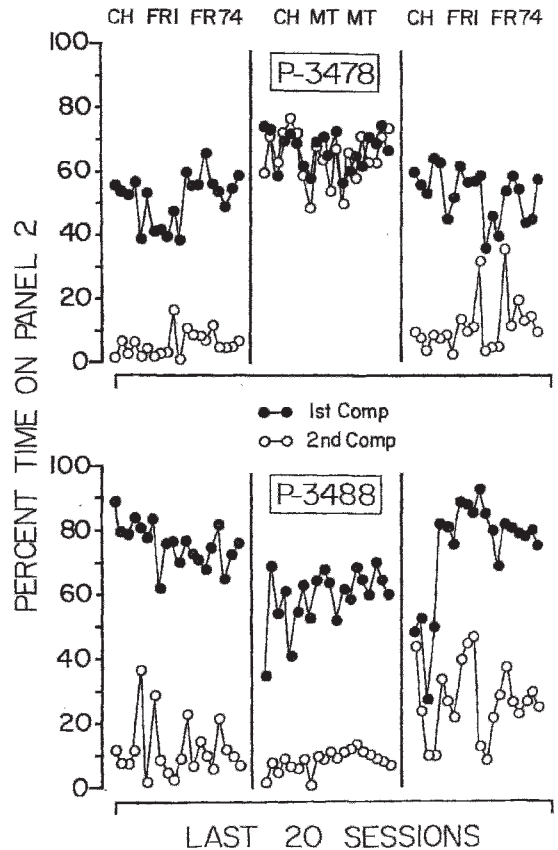

Fig. 10. Percentage of session time spent on floor panel #2 (indicating potential access to the target pigeon) per component for the last 20 sessions under the chained FR 1 FR 74, yoked chained MT MT, and subsequent chained FR 1 FR 74 phases for both pigeons. Filled circles represent the percentage of session time on panel 2 during the first component. Open circles represent the percentage of session time on panel 2 during the second component.

tive aspects of the contingencies of reinforcement.

When levels of attack were compared between chained FR 1 FR 74 and chained MT MT schedules of food presentation yoked interval-by-interval for both component schedule change and food delivery, the number of attacks per reinforcement, the duration of attacks per reinforcement, and the conditional probability of attack decreased following the transition to the response-independent time-based schedule. The decrease in conditional probability of attack and the lack of any stereotyped behavior patterns during the chained MT MT phase for P-3488 suggests

Table 5

Mean component times and standard deviations in s for the last 20 sessions under the Chained
FR 1 FR 74 schedules and the yoked Chained MT MT sessions for P-3478 during Experiment 2.

P-3478											
CH FR1 FR74				CH MT MT				CH FR 1 FR 74			
FR 1		FR 74		MT		MT		FR 1		FR 74	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
24.3	13.7	24.7	6.3	25.4	13.6	23.7	5.3	19.3	7.0	24.4	3.9
27.2	17.1	26.5	6.1	28.9	16.4	25.5	5.3	18.9	15.5	25.3	5.5
27.0	24.0	20.2	4.9	27.1	24.5	18.9	6.5	22.1	14.0	27.0	8.6
26.8	17.3	25.8	4.9	28.2	16.8	25.5	4.6	20.8	15.3	27.5	7.0
28.7	16.7	25.3	5.7	28.9	16.7	25.6	4.6	23.9	12.4	27.3	6.8
26.5	16.3	25.3	4.8	24.3	16.0	25.4	5.9	17.7	13.3	29.6	14.2
23.1	16.1	24.4	4.6	24.8	16.9	25.4	4.1	23.2	11.7	26.3	7.6
30.6	21.4	24.6	3.7	29.9	20.2	25.2	3.0	24.9	11.8	26.5	5.2
22.9	19.2	24.7	6.1	21.9	18.2	23.2	5.3	23.8	16.0	26.9	9.3
26.6	17.0	28.9	8.2	25.9	16.2	25.3	7.9	40.3	35.5	27.8	8.6
28.1	24.6	25.9	5.8	27.5	23.4	26.8	6.1	43.2	41.9	43.3	11.2
28.6	18.0	28.4	5.7	28.6	17.2	27.9	6.3	26.1	17.2	24.8	3.6
29.0	17.8	27.9	6.9	28.4	17.8	28.2	7.2	27.6	19.0	25.4	6.6
28.2	16.4	22.2	4.8	30.2	17.9	21.6	5.9	18.0	9.0	23.7	4.1
30.0	26.0	28.6	8.1	28.6	24.2	25.0	6.3	22.6	19.0	26.1	6.7
27.8	28.4	27.6	9.7	26.0	29.6	26.6	8.1	32.8	26.8	25.6	6.3
21.8	11.4	31.8	11.6	21.3	11.6	30.0	12.9	22.6	25.6	28.3	8.0
26.4	12.4	30.2	12.6	24.6	10.3	30.2	12.2	28.3	18.8	26.1	5.4
28.0	23.4	27.6	9.1	26.7	20.3	26.0	9.0	29.1	19.5	29.0	9.5
31.2	31.3	30.0	6.9	30.7	29.6	29.5	5.8	27.6	20.7	27.0	6.2

that the increase in this measure during the MT phase of Experiment 1 may have been related to the repeated exposure to the target pigeon resulting from the circling behavior previously observed. Subsequent reinstatement of the chained FR 1 FR 74 schedule increased attack to levels comparable to (P-3478) or higher than (P-3488) those during the initial exposure.

Exteroceptive stimuli differentially correlated with periods of food nonavailability and periods of food availability did not produce comparable levels of induced attack during the chained FR1 FR 74 and yoked chained MT MT phases. These data differ from the findings of Killeen (1975) where the addition of a stimulus signaling food presentation during a response-independent time-based schedule increased the levels of induced behavior. These data also fail to support the suggestion by Staddon (1977) that interim behavior occurs at low levels during aperiodic schedules due to the nondiscriminability of S^Δ or interim periods. It might be suggested that the exteroceptive stimuli associated with the two components of the chained MT MT failed to exert discriminative control over responding.

However, Figure 10 shows the time spent on Panel 2 by P-3488 to be distinctly under the control of the two component schedules. Data from floor panel recordings also suggest that the decrease in levels of attack during the chained MT MT phase cannot be attributed to an increase in behavior in the area of the food hopper (i.e., an increase in time spent on Panel 1). Transition to the chained MT MT phase increased the percentage of time spent on Panel 2 for P-3478 during both components.

The results of Experiment 2 suggest that aspects of the ratio requirement other than its discriminative properties serve to control levels of induced attack.

GENERAL DISCUSSION

In both Experiments 1 and 2, amount and probability of schedule-induced attack were related to whether an operant response was required. In both experiments, the number of attacks per reinforcement and the conditional probability of attack were greater under response-based than response-independent schedules of food presentation. Experiment 1

Table 6

Mean component times and standard deviations in s of the last 20 sessions under the Chained FR
1 FR 74 schedules and the yoked Chained MT MT sessions for P-3488 during Experiment 2.

P-3488											
CH FR 1 FR 74				CH MT MT				CH FR 1 FR 74			
FR 1		FR 74		MT		MT		FR 1		FR 74	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
150.5	191.9	39.6	9.5	144.8	189.8	38.9	9.5	140.8	207.1	54.7	39.1
120.3	130.0	36.1	18.9	115.1	128.6	33.4	18.0	93.7	102.2	32.6	11.8
120.3	122.4	33.9	11.8	117.7	120.9	32.1	11.5	59.1	66.5	36.9	16.5
60.9	106.0	38.8	23.5	64.1	103.2	37.3	23.1	104.5	116.6	45.8	35.0
77.8	113.7	46.6	88.2	77.9	112.5	45.9	87.5	79.6	75.5	52.4	93.2
42.9	67.4	26.5	5.1	42.7	68.1	25.1	5.4	62.3	99.3	38.2	27.5
40.6	59.2	29.2	10.2	39.8	57.2	25.7	9.7	104.6	132.2	40.6	30.8
41.0	54.8	29.8	13.3	43.3	53.8	28.3	14.5	78.5	9.2	34.4	15.2
54.8	71.3	29.8	10.9	55.0	62.9	28.3	10.5	92.0	129.3	43.8	38.7
48.4	54.9	29.8	6.8	49.1	53.1	27.4	4.1	109.1	131.3	45.6	33.1
53.4	80.7	29.4	6.2	55.0	79.4	28.0	5.6	146.8	193.5	57.0	91.8
52.8	82.5	36.6	25.4	52.8	81.7	35.6	25.1	67.1	79.4	40.9	21.3
42.5	40.5	33.5	21.8	43.4	38.2	34.5	21.5	49.5	54.6	38.7	21.8
64.5	66.4	34.2	8.7	68.2	64.3	32.5	7.9	27.7	24.9	37.6	21.9
58.5	75.5	28.8	6.3	62.6	79.9	28.2	6.0	58.3	67.5	49.3	38.4
60.8	72.4	32.2	18.9	61.0	70.3	30.5	18.8	52.3	51.8	42.3	28.1
31.0	39.5	30.1	14.8	32.7	38.5	28.1	13.9	50.6	60.9	32.8	24.0
41.7	50.2	33.1	12.4	41.9	53.6	31.6	12.3	26.5	23.4	36.4	24.5
69.2	94.5	33.7	11.6	69.8	93.3	32.2	11.4	34.3	37.2	34.8	21.2
42.9	46.2	28.2	9.2	44.3	45.0	27.6	9.1	30.4	32.8	32.8	25.1

compared levels of induced attack under simple fixed-ratio (FR) and matched-time (MT) schedules equated for rate and temporal distribution of food presentation. Experiment 2 examined whether the decreases in levels of attack during the MT phases were the result of the removal of the discriminative or predictive functions of the behavior generated by the ratio requirement rather than to the removal of an operant response requirement per se. However, the provision of exteroceptive stimuli differentially associated with the absence or presence of food availability failed to produce comparable levels of attack during the response-based (chained FR 1 FR 74) and response-independent time-based (chained MT MT) phases. The failure to find comparable levels of attack during response-dependent and response-independent schedules, equated for rate and temporal distribution of reinforcement, does not support the general contention that rate of food presentation or inter-reinforcement time is the main, if not sole, variable governing amount and probability of schedule-induced behavior.

Other experiments that have compared levels of induced behavior under response-dependent and response-independent schedules of reinforcement have reported conflicting results. These might be attributable to procedural differences. For example, studies that have reported greater levels of induced behavior during response-independent than response-dependent schedules of reinforcement have studied induced drinking in rats (Burks, 1970; Falk, 1961b; Schaeffer et al., 1966). Two of these studies did not equate rate or temporal distribution between response-dependent and response-independent conditions (Falk, 1961b; Schaeffer et al.), while another equated average rate, but not temporal distribution of food presentations (Burks). Two of the studies did not impose a COD between induced drinking and food deliveries, leaving open the possibility that the increases in drinking may have been the result of adventitious reinforcement, particularly at short interreinforcement intervals (Burks; Schaeffer et al.).

Studies that have reported lower levels of induced behavior during response-independent schedules in either all or in some subjects have examined schedule-induced attack (Cherek et al., 1973; Flory & Everist, 1977; Huston & DeSisto, 1971). In one study taxi-

dermically prepared targets were employed rather than live target pigeons (Flory & Everist). Another study employed restrained live target pigeons, but the restraint unit was mounted to the side of the front wall rather than the rear of the chamber and a response was required to access the target pigeon (Cherek et al.). Finally, Huston and DeSisto examined interspecific attack during schedules of response-dependent and response-independent ICS. In each of these studies a COD was programmed between the attack and the presentation of reinforcement.

The numerous procedural differences in the studies make comparison of the present results difficult. Nevertheless, the data suggest that variables other than the presence or absence of a response requirement operate on induced attack. Effects of operant requirements may vary depending on the particular induced behavior. For example, levels of induced attack may be more sensitive than induced drinking to the response requirement. Alternatively, the response requirement per se may not control levels of induced behavior, but rather aspects of reinforcement contingencies inherent within fixed-ratio schedules may be responsible for the present results.

One aspect of the fixed-ratio reinforcement contingency that may operate to control levels of induced behavior is the response–reinforcer relationship. In contrast to time-based schedules, rate of reinforcement is directly related to rate of responding (i.e., the greater the rate of responding, the greater the rate of reinforcement). This relationship generates a characteristic pattern of responding that consists of a pause followed by an abrupt transition to a high and constant rate until reinforcement. Capehart, Eckerman, Guilkey, and Shull (1980) demonstrated that postfood pause time is controlled differently during FR and FI schedules matched for average interreinforcement time. Over a wide range of interfood times, ratio schedules maintained substantially longer pause times than matched FI schedules. Since induced behavior generally is restricted to the interim or pause time periods under intermittent schedules of reinforcement, the differences in responding and pause-time allocations under ratio and interval schedules may be relevant to the differences in attack levels obtained in the present study under the FR and MT conditions.

Alternatively, there may be aversive aspects of the fixed-ratio response requirements leading to increased levels of induced behavior. Numerous studies have demonstrated that pigeons or rats will respond to terminate or escape from stimuli associated with schedules of positive reinforcement (e.g., Appel, 1963; Ator, 1980; Azrin, 1961; Brown & Flory, 1972; Dardano, 1973; Dinsmoor, Lee, & Brown, 1986; Thompson, 1964) This escape behavior usually occurs in the early postreinforcement period, when the probability of reinforcement is low. Azrin et al. (1966) and Hutchinson et al. (1968) suggest that induced attack during ratio schedules may be a function of the aversive elements related to response number required for reinforcement. Thus, aggression may be elicited by such aversive elements in a manner similar to that occurring during periods of extinction or when electric shock is presented. Similarly, Doughty, Meginley, Doughty, & Lattal (2004), using a concurrent chains procedure, showed that pigeons preferred segmented terminal links without response requirements (FT FT) over comparable segmented terminal links which required responding (FI FI). It was suggested that responding in discriminated periods of nonreinforcement, such as that in the initial segment of the FI FI terminal component, was aversive. Under a periodic response-dependent schedule of reinforcement, the time after reinforcement is a discriminated period of nonreinforcement during which operant responding may be aversive. During this period, other reinforcers available in the environment, such as attack or escape, may be potentiated. This ''aversiveness'' interpretation is supported by experiments in which levels of attack increase in a direct relation to ratio requirement (Allen et al., 1981; Flory, 1969b; Hutchinson et al., 1968; Knutson, 1970; Lyon & Turner, 1972; Webbe et al., 1974). Thus, in both Experiments 1 and 2, ''ratio-induced'' attack may have summated with levels of attack generated by the intermittency of reinforcement to produce greater levels of attack during the FR and chained FR FR phases than during the yoked MT and chained MT MT phases.

In conclusion, the present data show that elements inherent in some operant response requirements are important determinants of the levels of induced behavior observed during

schedules of food presentation, and support the suggestion by Allen et al. (1981) that response-based and time-based schedules may differ in the manner in which they control amounts and probabilities of induced behavior. Finally, the study of induced behavior during different schedules of reinforcement, like the study of drug effects on schedule-maintained behavior (cf. Branch, 2006), may yield understanding not only of this class of behavior, but of the nature of schedules as well.

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