

OPERANT AND NONOPERANT VOCAL RESPONDING
IN THE MYNAH: COMPLEX SCHEDULE CONTROL
AND DEPRIVATION-INDUCED RESPONDING

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Several recent studies have been concerned with operant responses that are also affected by nonoperant factors, (e.g., biological constraints, innate behavior patterns, respondent processes). The major reason for studying mynah vocal responding concerned the special relation of avian vocalizations to nonoperant emotional and reflexive systems. The research strategy was to evaluate operant and nonoperant control by comparing the schedule control obtained with the vocal response to that characteristic of the motor responses of other animals. We selected single, multiple, and chain schedules that ordinarily produce disparate response rates at predictable times. In multiple schedules with one component where vocal responding ("Awk") was reinforced with food (fixed-ratio or fixed-interval schedule) and one where the absence of vocal responding was reinforced (differential reinforcement of other behavior), response rates never exceeded 15 responses per minute, but clear schedule differences developed in response rate and pause time. Nonoperant vocal responding was evident when responding endured across 50 extinction sessions at 25% to 40% of the rate during reinforcement. The "enduring extinction responding" was largely deprivation induced, because the operant-level of naive mynahs under food deprivation was comparable in magnitude, but without deprivation the operant level was much lower. Food deprivation can induce vocal responding, but the relatively precise schedule control indicated that operant contingencies predominate when they are introduced.

Key words: deprivation-induced responding, DRO, multiple schedule, chain schedule, operant level, extinction, vocal responding, mynahs

Historically, a reason for exploring the extent of the operant and nonoperant control of mynah vocal behavior was the possible contribution of that animal's well-articulated mimicry to the study of human speech acquisition. A basic assumption of this strategy was that at least part of the vocal responding of the mynah was under operant control. The possibility of learning appeared essential if the word mimicry of the mynah was to be extended to some of the complexities of human language suggested by Premack (1970), including the use of words to represent objects, sentences, interrogatives, and the use of words to teach new words. Operant control of vocal behavior was demonstrated with a number of

animals including chickens (Lane, 1960, 1961), parakeets (Ginsburg, 1960), mynah birds (Ginsburg, 1963; Grosslight, Harrison, & Weiser, 1962; Grosslight, Zaynor, & Lively, 1964), guinea pigs (Burnstein & Wolff, 1967), cats (Molliver, 1963), dogs (Salzinger & Waller, 1962), monkeys (Leander, Milan, Jasper, & Heaton, 1972; Myers, Horel, & Pennypacker, 1965), sea lions (Schusterman & Balliet, 1970) and dolphins (Lilly, 1965) (also see review by Salzinger, 1973). The initial impetus for learning about human language acquisition through operant conditioning of the vocal behavior of animals lost considerable momentum in the early 1970s with the large advances of two alternative approaches to the study of communication systems in animals. The most influential development was the finding that chimpanzees could be taught to communicate with a considerable nonvocal but symbolic vocabulary that had features in common with human language (e.g., Gardner & Gardner, 1969; Premack, 1970). Their strategy was to study an animal with a larger potential than the mynah and to use a nonvocal language

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more appropriate to the animal's natural capacities. A second development (e.g., Marler, 1970a, b) suggested the study of the natural learning of vocal communication systems in animals such as song birds dialects to gain information about the natural acquisition of communication systems. In this context, it is not surprising to note that in the wild the calls of the mynah are largely determined by imitation, but it only imitates neighboring mynahs and not other species. This is not the case in captivity where the mynah also imitates man.

Another reason for studying the extent of operant and nonoperant control of vocal behavior in the mynah concerns the special relation of avian vocalizations to nonoperant emotional and reflexive systems. Because of these relations, Skinner (1957) suggested that avian vocal responses may be difficult to modify with operant reinforcement. Our attempt to produce "cooing" in pigeons supported that view: operant reinforcement was unsuccessful, but attack against another pigeon reliably produced cooing. Consistent with the view of avian vocalization as primarily an emotional response, Collias and Joos (1953, p. 176) state that the principal vocalizations of the domestic chick are distress calls and pleasure notes. There is considerable evidence that avian vocal responses in the natural setting are largely produced by variables which usually have a greater effect on innate fixed-action patterns and reflexive responses than on operant responses. Some of these variables are the stage of the breeding cycle (e.g., Davis, 1958; Forsythe, 1970), presentation and/or removal of social stimuli (e.g., Collias & Joos, 1953; Hoffman, Searle, Toffey, & Kozma, 1966; Schusterman, Balliet, & St. John, 1970), conditioned and unconditioned stimuli (e.g., Cowles & Pennington, 1943; Collias & Joos, 1953), and critical ages (e.g., Marler, 1970a).

The extent of operant and nonoperant control during operant conditioning has recently become a major research area. Most studies have been concerned with the extent to which the rate of the operant response is affected by nonoperant factors such as (a) constraints and/or advantages arising from special relations between the specie and the type of response and/or reinforcer (e.g., Bolles, 1970; Seligman & Hager, 1972); (b) the occurrence of apparently innate behavior patterns such as

instinctive drift (e.g., Breland & Breland, 1961; Boakes, Poli, Lockwood, & Goodall, 1978) and interim behaviors (Staddon & Simmelhag, 1971) that are produced by the presentation and/or removal of reinforcers; (c) the effects of respondent conditioning, which might include elicited effects of a conditioned stimulus such as autoshaping (Brown & Jenkins, 1968) or elicited effects of an unconditioned stimulus such as biting a response bar (Hake & Campbell, 1972; Pear, Moody, & Persinger, 1972). The general strategy of the present experiment was to determine the extent of operant and nonoperant control of mynah vocal responding by examining the extent to which the schedule control obtained was comparable to that obtained with other motor responses of other animals. To detect possible differences, we selected single, multiple, and chain schedules (Experiments 1, 2, and 3) that ordinarily produce extreme high and low rates of responding at predictable points in the schedule. To determine the level of vocal responding in the absence of operant procedures, vocal responding was measured before the introduction of operant reinforcement (operant level) in Experiment 5 and after removal of operant contingencies (extinction) in Experiment 4. The results revealed that food deprivation alone induced considerable nonoperant vocal responding during operant level and extinction, but that this responding could be brought under schedule control.

EXPERIMENT 1: MULTIPLE SCHEDULE WITH FIXED-RATIO AND DIFFERENTIAL- REINFORCEMENT-OF-OTHER- BEHAVIOR COMPONENTS

Little is known about the rates and patterns of mynah vocal responding under schedules of reinforcement because Fixed Ratio 1 (FR 1) is the only schedule that has been used to this point and the most complex schedule arrangement has been a multiple schedule (mult) with FR 1 in one component and extinction (EXT) in the other (Grosslight et al., 1962). If mynah vocal responses are not elicited by stimuli associated with food, then responding should come under the control of schedules that control low as well as high rates of vocal responding. A reasonably severe test would be a mul-

tiple schedule in which food is dependent on a differential-reinforcement-of-other behavior (DRO) schedule in one component and food is dependent on completion of a moderate valued FR in the other. Such FR schedules ordinarily generate moderately high response rates (key peck, bar press) while in the DRO schedule reinforcement is dependent on not emitting a particular response. This type of test was initially used by Lane (1960) with the chirping response of chickens. Although discrimination learning was evident, Lane's data were from early in discrimination learning (fourth hour of training) when considerable responding (an average of three responses per min) still occurred during the DRO component. The present experiment involved many more sessions in order to evaluate the terminal and steady state responding that could be achieved under this procedure.

Subjects

The species of Hill Mynah in this and subsequent experiments was *Gracula religiosa*. All of the mynahs were purchased from a dealer who imported them from India. The two experimentally naive mynahs in this experiment were less than 2 years old at the start of the experiment, but of unknown exact age. They were housed in individual cages located in the regular animal facility, where they had visual and auditory access to other mynahs and to pigeons. Each cage contained a perch and food and water cups. The subjects were deprived of food for about 18 to 20 hours before the daily sessions, and they weighed about 80% to 85% of their free-feeding weight (160 g for Mynah 581 and 220 g for Mynah 90). After each session, they were given enough food to keep their weight at that level. The food given in the experimental chamber was a grape-flavored mynah food (Myers Mynah Bird Food), which was in irregular pieces typically about 1 mm to 5 mm on the longest dimension. Purina chick starter was used for the supplementary feedings in the home cage.

Vocal Response

The vocal response was similar to the "awk"-type response initially described and conditioned by Grosslight and Lively (1963) and Grosslight et al. (1962). It was the only type of vocal response heard in the experimental chamber. Sounds other than the "awk"-type

response were rarely heard in the animal housing facility: there were only rare instances of whistles, screeches, and an occasional word imitation. The "awk" response in the experimental chamber was of low pitch, with predominant frequencies between 1,000 and 2,000 Hz, and brief, usually between 100 and 200 msec. Bertram's (1970) monograph of mynah vocal behavior in the wild describes several sudden, short vocal responses (e.g., a "chip-call" which may be used in the context of alarm, and an "um-sound" which occurs when the bird is active and aroused), but none of the descriptions fit the "awk" response. However, in discussing the development of adult vocal behavior, Bertram did mention a "juvenile squawk" which in the wild replaces an initial food-begging call and lasts from 1 week to 3 months of age, but may continue longer, "particularly in captivity, when waiting to be provided with food" (Bertram, 1970, p. 165). In the wild, the "juvenile squawk" is usually replaced by the "um sounds" (Bertram, 1970).

Apparatus

The experimental compartment measured 30 cm deep by 23 cm high by 30 cm wide. The inside walls were covered with a 1.5-cm layer of foam rubber to reduce noise which might result from movements against the walls and, for the same reason, the hardware cloth floor was coated with a silicone rubber compound. To eliminate noises originating outside, the experimental compartment was located inside two outer compartments, both of which were lined with acoustical tile and separated by Fiberglas insulation. To reduce possible vibrations from the building, a mattress was placed between the chamber and the table upon which it rested. A fan provided ventilation and masked noises originating outside the chamber by increasing the background noise in the experimental compartment to 65 dB.

The front panel of the experimental compartment contained four stimulus lights, a food magazine, and a magazine light. The 2.5-cm-diameter stimulus lights, two red and two white, were located 25 cm from the floor, just above a transparent nylon screen ceiling. The ceiling prevented the noise that might result from pecking the stimulus lights or a television camera which was also located above the transparent ceiling. Illumination in the compartment was provided by either the red or

white stimulus lights, depending on the experimental conditions. A brief (140 msec) offset of these lights provided response feedback. The food magazine was centered at the bottom of the front panel. It consisted of an 8-cm-wide by 9-cm-high box which protruded about 5 cm into the compartment. The mynahs could obtain food from a Lehigh Valley pigeon tray (LVE 1347) through an opening at the top of this box. A wire grid over the top of the box prevented the mynahs from reaching food when the food tray was not in the raised position. A hydraulic damper reduced the noise from the operation of the food tray. A small white light directly above the food magazine illuminated the food tray during its operation. The stimulus lights, the only other lights in the chamber, were extinguished during the operation of the food tray. Experience indicated that magazine training, a long process at best with the mynah (see Grosslight & Lively, 1963), took longer when the mynah had to put its head into a wall aperture to reach the food tray. Water was available continuously from a soft plastic cup secured in the left rear corner of the experimental compartment.

A low impedance microphone (Grason-Stadler, E7300A-201) was placed on a portion of the hardware cloth floor that extended behind the rear wall of the experimental compartment. Sound waves from the experimental compartment reached the microphone by traveling down through the hardware cloth floor of the experimental compartment and up through the hardware cloth behind the rear wall of the experimental compartment where the microphone was located. The microphone was encased in foam rubber which kept it from touching the hardware cloth floor and picking up vibrations from the floor per se. Vocal responses were defined by a Grason-Stadler voice-operated relay (VOR) (E7300A) adjusted to operate when there was an 8 dB increase in noise level that lasted at least 80 msec. The minimum time between successive responses was 15 to 18 msec. Continuous monitoring of the vocal responses was possible by means of an amplifier and the speaker of a tape recorder located in the adjacent control room. Our monitoring of the sessions indicated that the response requirements discriminated reliably between vocal responses and common extraneous noises: hopping, wing

flapping, etc., were rarely observed to operate the relay while the vocal "awk"-type responses nearly always operated the relay. The essential sound and sound-sensing characteristics of the experimental compartment and the voice-operated relay were checked periodically and whenever our monitoring revealed that vocal responses were occasionally not activating the VOR or that extraneous sounds were. These checks were accomplished by using a General Radio Sound Survey Meter, type 1555-A (Scale B) and a 1000 Hz sine wave. Continuous visual observation was possible by means of a television camera.

Procedure

Magazine training and conditioning were followed by a 3-month period during which we explored various procedural and environmental variables such as deprivation levels, reinforcers, food magazines, VOR requirements, FR requirements, and stimulus conditions. Then both subjects were exposed to a multiple schedule with FR1 in each component. The red and white stimulus lights signaled the components which alternated after each reinforcer. The FR requirements were gradually increased over the next 3 months with the requirement the same in each component. For Mynah 90, this was FR 10 maintained with a 5-sec food magazine exposure. Mynah 581 maintained an FR 5 with a 3-sec magazine exposure. Due to the small size of the mynah, the absence of a crop, and frequent drinking, we were concerned that the mynah might literally become bloated after several reinforcers in a short time. As one way to reduce this possibility and the pauses that might occur under such conditions, a 60-sec blackout was imposed following each reinforcer in an attempt to space the reinforcers. Vocal responses did not occur during the blackout. Each daily session lasted 2.5 hr, which usually included 45 to 60 reinforcers. After a minimum of 5 sessions of mult FR FR with the terminal ratio requirements, the schedule was changed to mult FR DRO with the white stimulus light signaling FR and the red signaling DRO. During the initial 8 to 10 sessions, the DRO requirement was increased from 15-sec (Mynah 90 had two initial sessions with DRO 90-sec) to 90-sec (Mynah 90) or 150-sec (Mynah 581) usually by 15-sec increments. For Mynah 90, the DRO

was eventually increased to 150 sec. For Mynah 581, the DRO was gradually increased to 210 sec. At least 10 sessions were provided at the longest DRO before returning to mult FR FR for 20 sessions.

RESULTS

Figure 1 shows a session-by-session analysis of the vocal responding in each component of the multiple schedule. The top graph for each subject shows response rate and the bottom one shows the mean pause time from the end of the blackout to the first response or the reinforcer, whichever occurred first. For both subjects, response rates in the two components were about equal at about 4 (Mynah 581) or 7 (Mynah 90) responses per min during mult FR FR. On transition to mult FR DRO, response rate during the DRO component initially increased over that in the FR component. However, response rate during the DRO component eventually dropped to a nearly zero level. Near the end of the mult FR DRO condition, there were several sessions during which no vocal responses were emitted during the DRO component. When mult FR FR was reintroduced, the near-zero response rate of the previous DRO component gradually increased to the level of the FR component and the level previously obtained during mult FR FR.

Examination of the mean pause times reveals that the DRO pause exceeded that of the constant FR component but that consistent differences were not obtained until the longest DRO requirement. On the return to mult FR FR, pause time in the previously DRO component gradually decreased to the level of the constant FR component and the level previously obtained during mult FR FR.

Table 1 summarizes the response measures for the last 10 sessions of mult FR DRO. The running rate (i.e., the response rate during the time after the first response in a component until the delivery of the reinforcer) indicates that once the first response in a ratio occurred, the rest of the responses in the ratio were emitted about three times faster than the overall response rate. That responding followed the pause-and-run pattern characteristic of a fixed-ratio schedule is indicated by the finding that the ratio pause consumed about two-thirds of the time for each completed ratio.

In the DRO component, the mean pause time was longer and missed the DRO pause requirement of 2.5 min by only an average of .1 min for Mynah 90 or the requirement of 3.5 min by .2 min for Mynah 581. The mean time per reinforcement was shorter in the FR component, but it is doubtful that even the nearly 3 to 1 difference in reinforcement density for Mynah 581 could account for the differences in the response measures.

EXPERIMENT 2: MULTIPLE SCHEDULE WITH FIXED-INTERVAL AND DIFFERENTIAL-REINFORCEMENT- OF-OTHER-BEHAVIOR COMPONENTS

To equate more closely the densities of reinforcement in the high and low response rate components of a multiple schedule, Experiment 2 employed a multiple schedule with fixed interval (FI) and DRO components that had equal time requirements. For example, in a session with mult FI 3-min DRO 3-min where no responses occurred during DRO, the FI schedule should maintain a higher response rate but the reinforcement densities of the two schedules should be equal at 1 per 3-min.

Procedure

The subjects and apparatus were unchanged, and Experiment 2 was conducted in three phases similar to those in Experiment 1. In the first phase, identical FI schedules were employed in both the red and white components. To increase the FI responding, two vocal responses were required at the end of the FI. As in Experiment 1, a 60-sec blackout followed each reinforcement, and the red and white components alternated following each blackout. After at least 20 sessions of mult FI 3-min FI 3-min (Mynah 90) or mult FI 2.5-min FI 2.5-min (Mynah 581), the schedule in the white light was changed to DRO 30-sec. Over the initial 8 to 10 sessions, the DRO was increased, usually by 15- to 30-sec increments, until it was as long as the FI. This multiple schedule was in effect for at least 50 sessions. The third phase was a return to the initial multiple schedule for 20 sessions. Sessions lasted 2.5 hr (Mynah 581) or 3 hr (Mynah 90).

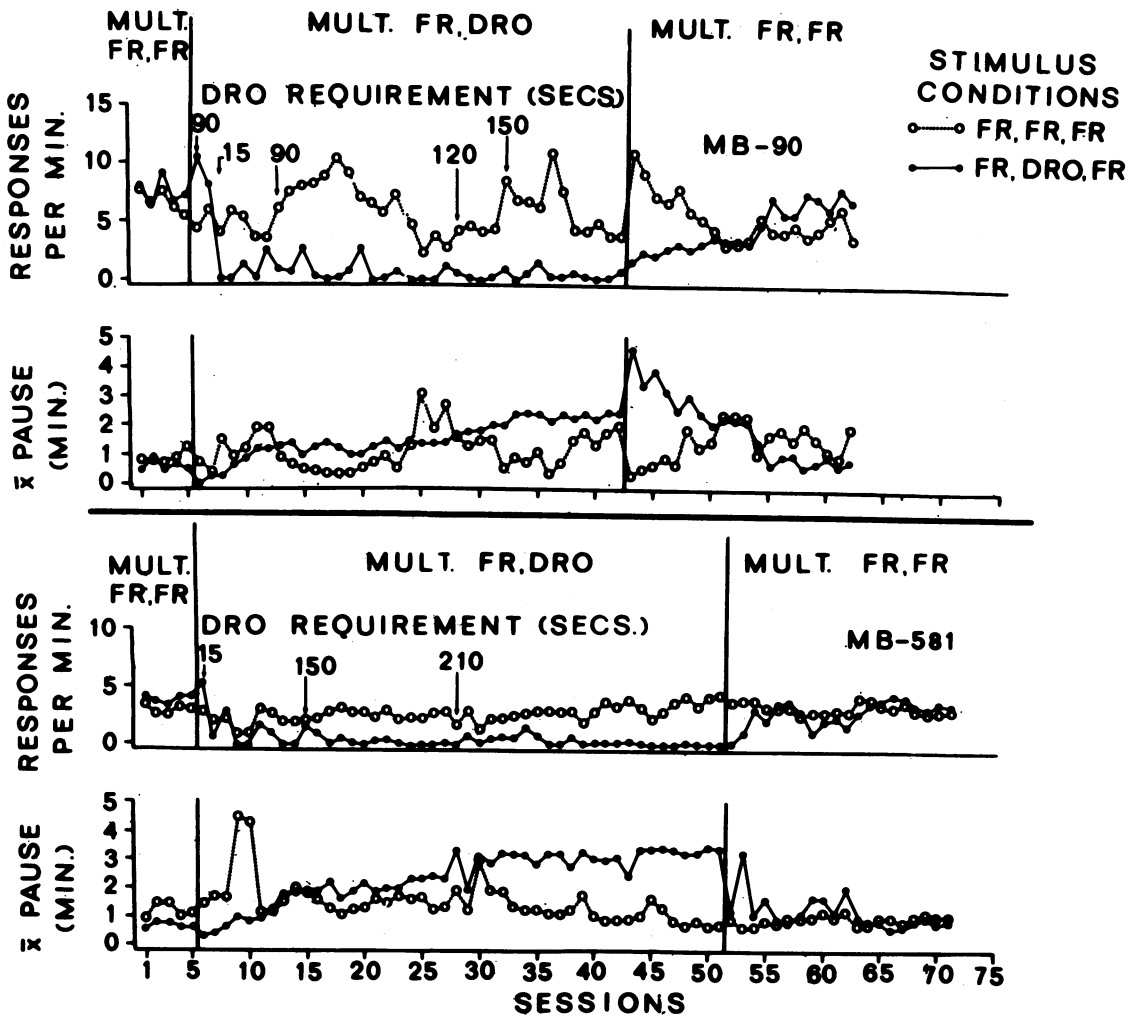


Fig. 1. Development of schedule control during mult FR DRO. For each mynah, the top graph shows the response rate during each component and the bottom graph shows the mean pause time during each component. On the introduction of mult FR DRO, the DRO requirement was gradually increased, usually by 15-sec increments each session. Because of space limitations, these initial changes have not been indicated on the graphs between DRO 15 sec and 90 sec for Mynah 90 and between 15 and 150 sec for Mynah 581.

Table 1
Response Measures for the Last 10 Sessions of Mult FR DRO in Experiment 1

	<i>Mynah 90</i>				<i>Mynah 581</i>			
	<i>FR 10</i>		<i>DRO 2.5 min</i>		<i>FR 5</i>		<i>DRO 3.5 min</i>	
	<i>Avg.</i>	<i>Avg.</i>	<i>Avg.</i>	<i>Avg.</i>	<i>Avg.</i>	<i>Avg.</i>	<i>Avg.</i>	
	<i>Mean</i>	<i>dev.</i>	<i>Mean</i>	<i>dev.</i>	<i>Mean</i>	<i>dev.</i>	<i>Mean</i>	<i>dev.</i>
Response rate (resp/min)	5.2 ± 1.9		.5 ± .3		3.5 ± .5 ^a		.1 ± .1	
Running rate (resp/min)	14.8 ± 1.2				10.9 ± 1.1			
Mean pause (min)	1.5 ± .6		2.4 ± .1		1.0 ± .2		3.3 ± .2	
Time/reinf. (min)	2.2 ± .6		2.8 ± .2		1.5 ± .2		4.0 ± .6	

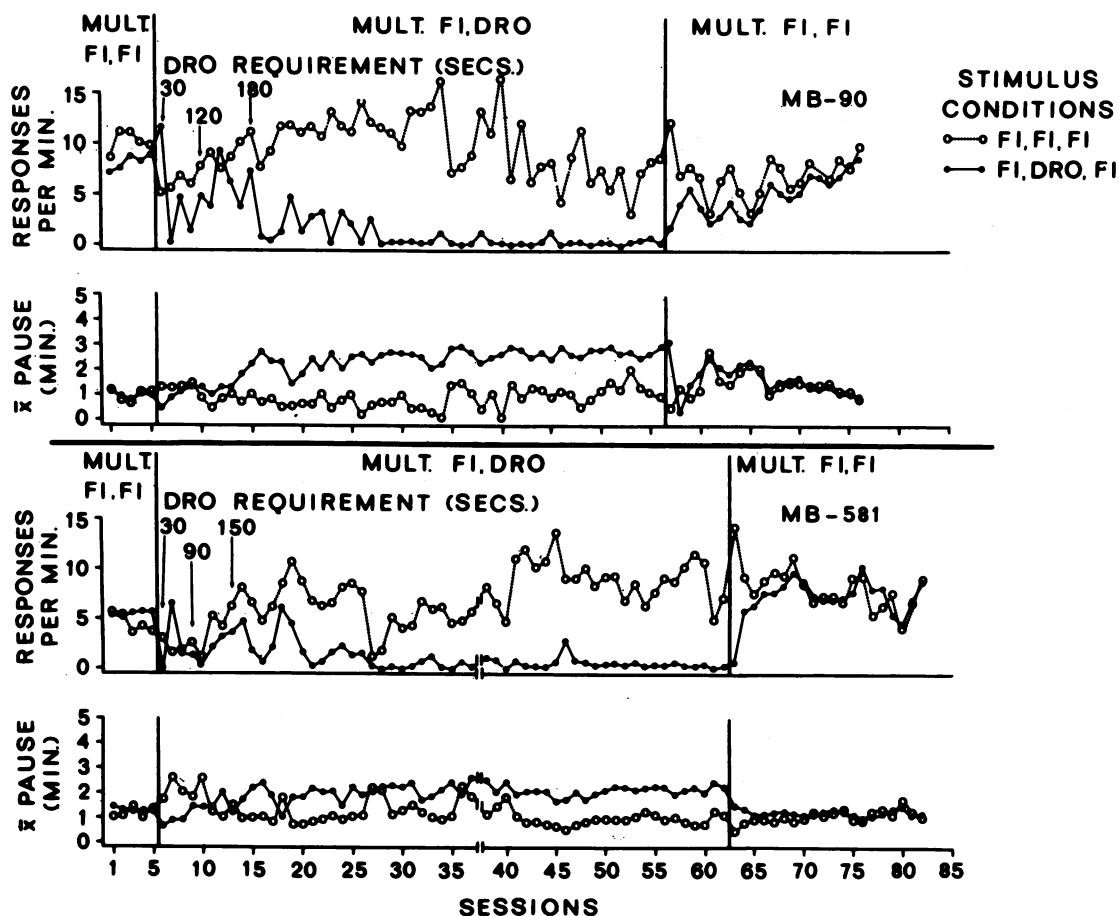


Fig. 2. Development of schedule control during mult FI DRO. For each subject, the top graph shows the response rate during each component and the bottom graph shows the mean pause time during each component. On the introduction of mult FI DRO, the DRO requirement was gradually increased, usually by 15- to 30-sec increments each session. Because of space limitations, not all of these initial changes have been shown on the figure between DRO 30 and 180 sec for Mynah 90 and between 30 and 150 sec for Mynah 581. Also because of space limitations, 80 sessions were omitted from mult FI DRO of Mynah 581. The time at which these sessions were deleted is indicated by the breaks in the graphs after session 38.

RESULTS

Figure 2 demonstrates the effects of the FI and DRO schedules on response rate (top) and pausing (bottom). During the initial mult FI FI, response rates and pauses in the two components were comparable. The change to mult FI DRO was accompanied by changes in the DRO component: response rate gradually dropped to a near-zero level and the average pause increased above the average FI pause, nearly to the duration of the DRO requirement. On the return to mult FI FI, the response rate in the component that had been DRO increased and pausing decreased until

these two measures were comparable to the other FI component.

Table 2 summarizes the response measures for the last 10 sessions of mult FI DRO. The response rate in the FI component was several times greater than the DRO rate, and the FI pause, which consumed about 40% of the fixed interval, was less than half the DRO pause. As in Experiment 1, there were several DRO sessions without vocal responses during DRO, and the average DRO pause in these final sessions approached very nearly the DRO requirement. The time per reinforcement was only slightly longer in the DRO component, making it unlikely that reinforcement density

Table 2
Response Measures for the Last 10 Sessions of Mult FI DRO in Experiment 2

	<i>Mynah 90</i>				<i>Mynah 581</i>			
	<i>FI 3 min</i>		<i>DRO 3 min</i>		<i>FI 2.5 min</i>		<i>DRO 2.5 min</i>	
	<i>Mean</i>	<i>Avg. dev.</i>	<i>Mean</i>	<i>Avg. dev.</i>	<i>Mean</i>	<i>Avg. dev.</i>	<i>Mean</i>	<i>Avg. dev.</i>
Response rate (resp/min)	7.5 ± 1.4		.4 ± .2		8.5 ± 1.6		.3 ± .1	
Running rate (resp/min)	12.3 ± 1.4				14.0 ± 1.6			
Mean pause (min)	1.2 ± .3		2.8 ± .1		1.0 ± .2		2.2 ± .1	
Time/reinf. (min)	3.2 ± .3		3.8 ± .5		2.6 ± .1		3.6 ± .6	

instead of schedule contingencies could account for the response rate and pause differences.

The cumulative response records of Figure 3 show that the DRO component is characterized by the absence of responding, and that when responding did occur (arrows), it was usually followed by a long pause. Responding during the FI component was characteristic inasmuch as an initial pause was followed by responding which continued until reinforcement.

EXPERIMENT 3: CHAIN SCHEDULE WITH FIXED-RATIO VOCAL AND FIXED-INTERVAL KEY-PECK COMPONENTS

Fixed-ratio vocal responding in the first component of the chain schedule allowed access to a second component where key pecking was reinforced with food according to an FI schedule. Any vocal response during the second component reset the FI. In this way, it was possible to determine if vocal re-

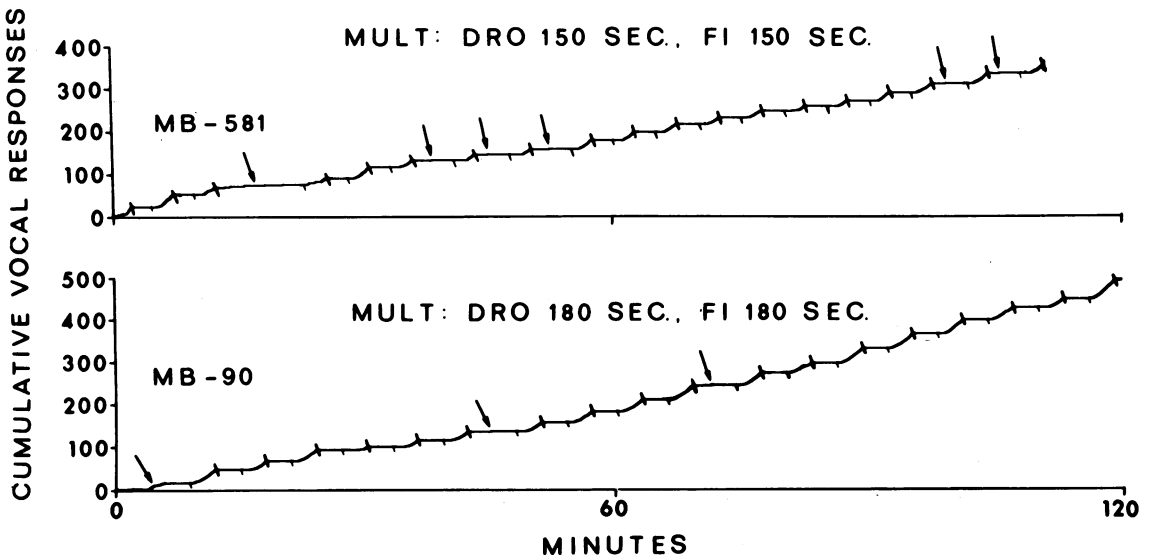


Fig. 3. Illustrative cumulative response records from 1 of the last 10 sessions of mult FI DRO. Reinforcers during the FI stimulus are indicated by displacements above and below the response line; reinforcers during DRO are indicated by a downward displacement only. The arrows point to-responding during DRO.

sponses could be maintained even though they were never temporally contiguous with food.

This schedule also allowed a comparison of the rate characteristics of the vocal response and key pecking. The low rates of the vocal response, particularly the running rate, suggested that the rate of the vocal response has some inherent limits. The comparison with the key peck attempted to determine if the low vocal rates were peculiar to that response or also characteristic of other responses of the mynah.

Subject

Mynah 14 was less than 2 years of age but of unknown exact age, and weighed 200 g under free-feeding conditions. The housing, deprivation, and reinforcer were the same as in the previous experiments. The vocal responding of this bird had previously been reinforced with food, but this was discontinued at the start of key-peck training and 2 months before the introduction of the vocal component of the chain.

Apparatus

The experimental compartment was unchanged except for a Gerbrand's pigeon key 5 cm to the left of the food magazine and 8 cm up from the floor. The 1.5-cm-diameter key was transilluminated with a red light. A force of 10 g against the key defined a response and produced a brief (140 msec) blink of the key illumination.

Procedure

Key pecking was shaped in the presence of the two red stimulus lights. Each key response was followed by 2-sec access to the food tray, and each reinforcement was followed by a 60-sec blackout. Over the next 14 sessions, the ratio requirement was gradually increased to FR 25. Then the schedule was changed to FI 1-min for 5 sessions and then to FI 2-min with 2 responses being required after the FI had elapsed. Sessions lasted 90 min.

The chain schedule began in the presence of the white stimulus lights and with the key unlit. The white light changed to red following a single vocal response. The schedule in the red light was the same as before except that the blackout was followed by reinstatement of the initial white-light condition. Vocal responses during the terminal key-pecking

stimulus blinked (140 msec) the red stimulus lights and reset the FI requirement for the key peck. The vocal reset contingency necessarily separated food reinforcement and vocal responding by at least the duration of the FI. During the first 3 sessions of the chain schedule procedure, no vocal responses occurred, and key-peck stimulus probes lasting for 5 reinforcements were presented every 30 to 60 min to insure maintenance of key pecking. During the next 14 sessions, after vocal responding had started, the vocal requirement was gradually increased to FR 10. The subject remained on the chain schedule about 12 months during which several parameter changes were made to maintain more responding.

RESULTS

Figure 4 shows a segment of an illustrative cumulative record after Mynah 14 had been on the chain schedule for 1 year and the fixed ratio had been increased in increments of 1 from 1 to 10 with 8 to 10 sessions at each value. In the representative record shown, the schedule was chain FR 9 vocal FI 30-sec key peck with 2 responses required at the end of the fixed interval. The food magazine cycle was 10 sec. Over the 9 sessions on this chain schedule, Mynah 14 paused an average of .7-min during the initial white component before

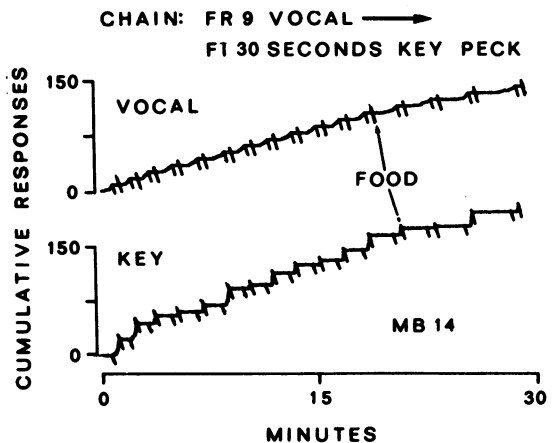


Fig. 4. Illustrative segments of cumulative response records for chain FR 9 vocal FI 30-sec key peck. The upper curve shows vocal responses and the lower curve shows key pecking. The downward displacement of the response pen indicates onset of the second component (key) and the displacement above and below the response curve indicates food reinforcement and the start of the first component (vocal).

emitting a vocal response and had an overall rate of 7.6 vocal responses per min. There were no key pecks during the initial component. During the terminal red component, Mynah 14 made no vocal responses but averaged about 19 key pecks per min. The average pause before starting to key peck was .5-min. However, a comparison of the average running rates of the vocal response (16.7 ± 1.95) with the average running rate of the key pecking (115.6 ± 18.50) suggests the vocal response does have some inherent limits. These differences are also evident in the slope of the vocal and pecking cumulative records in Figure 4.

EXPERIMENT 4: VOCAL RESPONDING DURING EXTINCTION AND FREE FOOD

Another way to evaluate operant control is to observe how quickly and the extent to which response rate and specific patterns of responding change when reinforcement is discontinued. When extinction has been introduced in previous animal vocal conditioning studies, it has ordinarily been arranged during one component of a multiple schedule while reinforcement has been continued during the other component (Ginsburg, 1963; Grosslight, et al., 1962, 1964; Lane, 1960, 1961; Molliver, 1963; Salzinger & Waller, 1962). Only Lane (1960, 1961) and Leander et al. (1972) have introduced extinction without any reinforcement during an entire session. Leander et al. (1972) introduced extinction for one cebus monkey and found that responding decreased over 6 sessions to about 1 response per min compared to about 2.5 to 10 per min during reinforcement. Lane (1960, 1961) arranged extinction sessions for two chickens. For the one bird for whom quantitative data were presented, the rate of chirping dropped from 115 to 8 responses per min after 5 hours of producing an empty food tray on FR 20. Lane (1961) also noted that both birds showed a more gradual decline than is usually found with the key-peck response of pigeons. In the present experiment, extinction sessions were introduced for three mynahs and continued for more sessions than in the previous studies.

Several free-food sessions, with food continuously available in the chamber in addition to the response-dependent presentations, were ar-

ranged to determine if the responding that endured after many extinction sessions was simply operant-level responding or was still related to the food reinforcer in some way. Some food-related factor would be indicated if responding dropped to a near-zero level during free-food sessions but not during extinction sessions.

Procedures

The experimental chamber was unchanged. The three mynahs (90, 581, and 98) were maintained at about 85% of free-feeding body weight and had been running in daily sessions for at least one year. The schedule of reinforcement immediately before extinction had been in effect for at least 15 sessions. These schedules were mult FI 3-min FI 3-min for Mynah 90, mult FI 2.5-min FI 2.5-min for Mynah 581, and mult FI 7-min FI 3-min for Mynah 98. An FR 2 (Mynahs 90 and 581) or FR 4 (Mynah 98) was required after the fixed time interval had elapsed. A 30-sec (Mynah 98) or 60-sec (Mynahs 90 and 581) blackout followed each 3-sec (Mynah 581) or 5-sec (Mynah 90 and 98) delivery of food reinforcement. For Mynahs 581 and 98, extinction simply involved inserting a different but empty food tray; all other stimulus events including the presentation of the food tray occurred as during the reinforcement condition. For Mynah 90, extinction was run in the red stimulus, because stimulus events (presentation of the food tray and the change from one component to the next) were prevented from occurring. Extinction was in effect for at least 50 2-hr to 3-hr sessions.

Mynahs 98 and 581 were also tested under the above multiple schedules of reinforcement while food was continuously available in the experimental chamber. The schedules of reinforcement were the same as the above except that the food was now in the food tray and each presentation of the tray lasted 10-sec. In addition, during alternate sessions food was also freely available from the home-cage food cup that had been placed in the experimental chamber. This free-food procedure lasted at least 15 sessions.

RESULTS

Figure 5 shows the response rate during each extinction session (right ordinate) and compares it to the reinforcement condition by ex-

pressing the rate during each extinction session as a percentage of average response rate for the last 10 sessions of the reinforcement condition (left ordinate). Responding decreased during extinction, but it was variable and more often than not it was more than 25% of the rate during the reinforcement condition. Although the average absolute response rates were low (1.68, 3.53, and 1.49 responses per min during the initial 50 extinction sessions for Mynahs 90, 581, and 98 respectively), these rates were 26% (Mynah 90) to 43% (Mynah 581) of the rate during the reinforcement condition.

Two additional manipulations with Mynah 90 evaluated possible roles of the home-cage feeding in the maintenance of extinction responding. Two possibilities were (a) an adventitious correlation of vocal responding and the home cage feeding, or (b) a learned temporal relation between the end of the session and the home cage feeding in which the vocal responding might be elicited by temporal stimuli associated with food. First, a DRO 3-min schedule was arranged between vocal responding and termination of the session during extinction sessions 40 through 58. Second, the food normally given at the end of the session was delayed 2 to 3 hours during sessions 67 through 82. Neither manipulation appeared to affect vocal responding, because responding averaged 26% of the reinforced level during the period of the DRO schedule and 27% of the reinforced level when the home-cage feeding was delayed as compared to 26% during the 39 sessions before either manipulation.

Figure 6 shows the pattern of responding during the 25th extinction session. The characteristic FI pattern was still evident for the two mynahs whose vocal responses produced the empty food tray. A within-session increase in responding was characteristic after 10 to 20 extinction sessions. For example, the percentage of vocal responses in the first half of the session for the last 10 reinforcement sessions was 43, 48, and 56 for Mynahs 90, 581, and 98 respectively, but these percentages decreased to 3, 35, and 3, respectively, for the extinction sessions after the first 20. This analysis included extinction sessions with 10 or more responses.

Figure 7 suggests that some food-related factor was involved in the vocal responding during extinction, because comparison of Figures

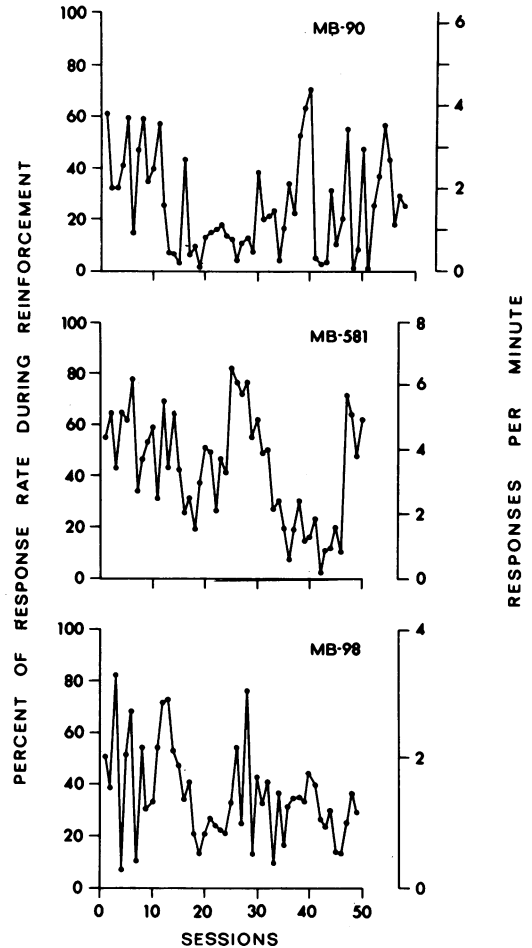


Fig. 5. Absolute response rate (right ordinate) during each of the initial 50 or 58 (Mynah 90) extinction sessions in Experiment 4, and response rate expressed as a percent of the average of the last 10 reinforcement sessions (left ordinate).

5 and 7 reveals that the absolute rates with free food available (Figure 7) were much lower than rates during extinction (Figure 5) for these same animals.

EXPERIMENT 5: THE EFFECTS OF FOOD DEPRIVATION ON OPERANT-LEVEL VOCAL RESPONSES

Vocal responding nearly ceased when free food was available in the chamber. However, that finding does not necessarily mean that the vocal responding that endured through many extinction sessions occurred because of any previous contingency between vocal re-

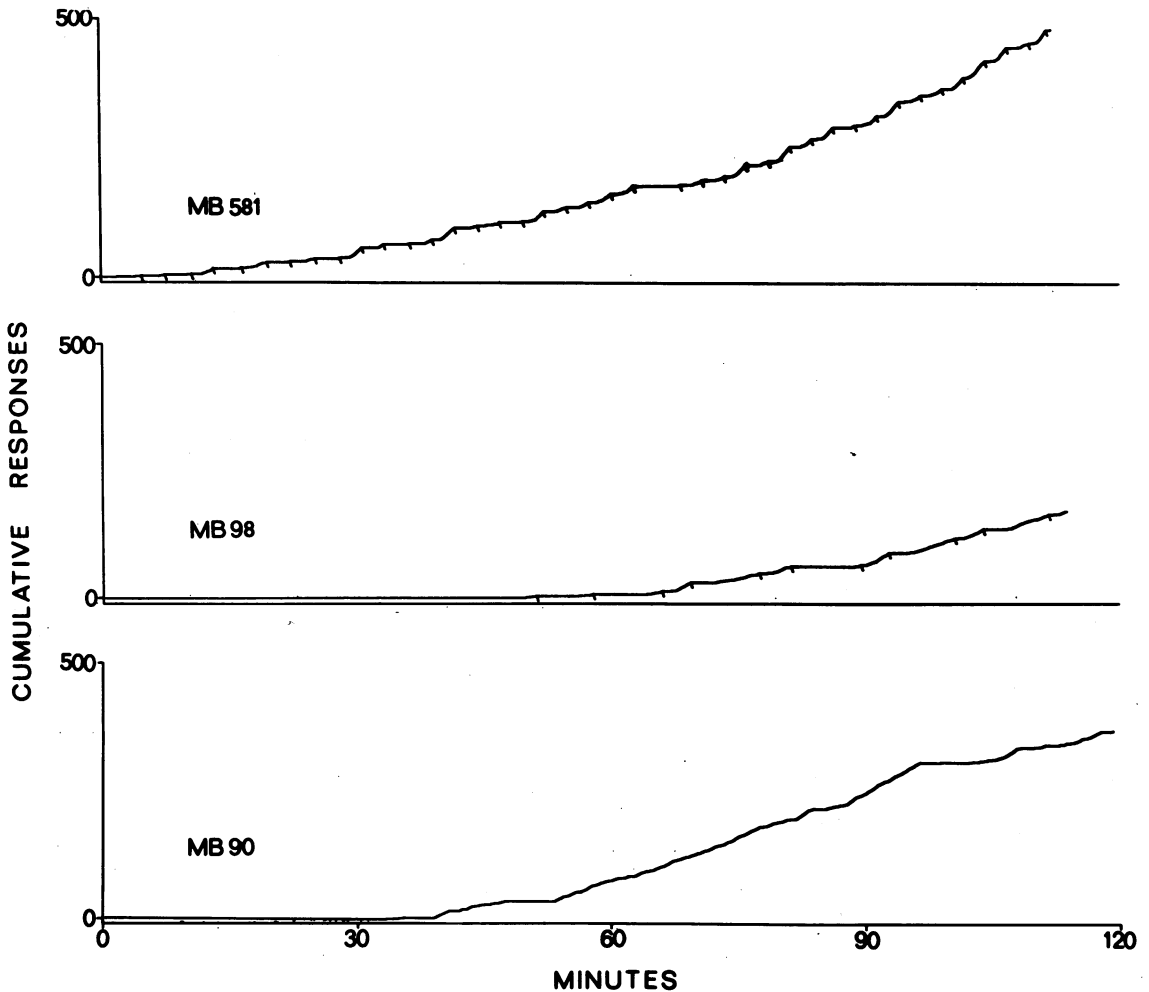


Fig. 6. Illustrative cumulative records from the 25th extinction session in Experiment 4. See text for schedule of each subject.

sponding and food. Another possibility is that the free food simply reduced food deprivation and that food deprivation alone had induced most of the enduring extinction responding. Food deprivation has been shown to increase general activity in a variety of animals (e.g., see review by Baumeister, Hawkins, & Cromwell, 1964) and, more specific to vocal behavior, the literature contains references to the "begging" calls of young birds (e.g., Bremond, 1963) including mynahs (Bertram, 1970) and the increased vocalization of young birds when hungry (e.g., Collias, 1962, 1963). To determine if deprivation alone could account for most of the enduring extinction responding, three mynahs were tested at three levels of food deprivation prior to any conditioning,

then conditioned, and then tested again during extinction.

Procedure

Three experimentally naive mynahs (designated D, F, and G) served as subjects. The housing conditions and experimental apparatus were the same as for the other birds.

The basic procedure was a multiple schedule with FR 5 in each of 2 10-min components. As before, each component was signaled by red or white stimulus lights. Six complete alternations of the two components comprised the two-hour session. Before conditioning and during extinction, the food magazine was presented for 5-sec but was empty. The operant level and the first block of extinction sessions

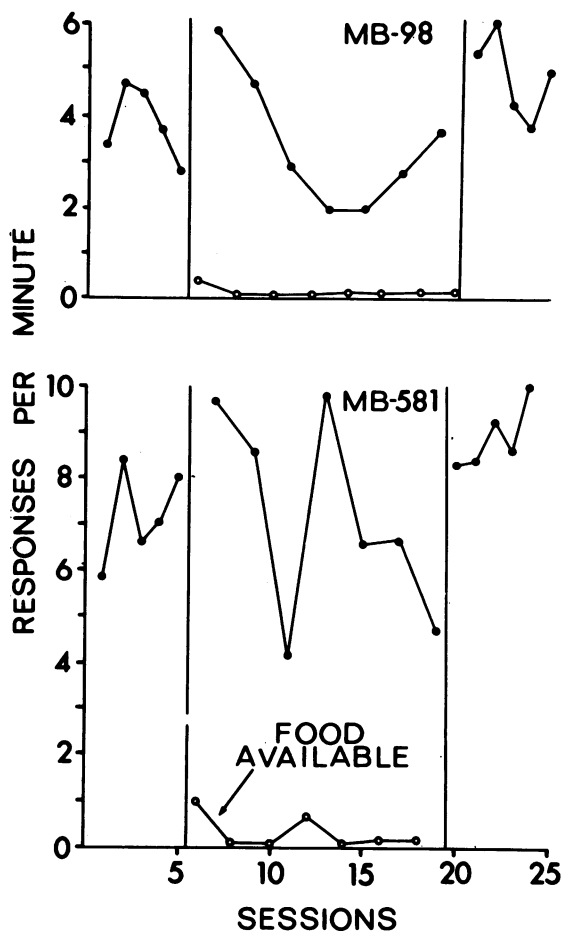


Fig. 7. Responses per minute in Experiment 4 when food was response dependent only (solid circles) and when food was response dependent and available continuously in the chamber (open circles).

for Mynah D were done without presentations of the food magazine, but there were two other blocks of extinction sessions that were the same as for the other two birds (i.e., the empty food magazine was presented after every fifth response).

Operant level was evaluated under two or three levels of food deprivation. Under 18 to 20 hours of food deprivation, the birds were given enough food after each session to maintain about 85% of free-feeding weights. If this food was not consumed within approximately 4 hours, the food tray was emptied, thereby leaving 18 hours deprivation before the start of the next session (18 to 20 hours of food deprivation if the session time is included). Under 0 to 2 hours food deprivation, food was continuously available in the home cage but

not in the experimental chamber; hence, the birds were deprived 0 to 2 hours depending on the time elapsed in the session. Under 0 hours food deprivation (Mynahs G and F only), the home-cage food tray was continuously available in the home cage and in the experimental chamber. Ordinarily, each deprivation condition was in effect 10 to 20 sessions before it was changed to another one. Each deprivation condition was usually repeated two to four times. The exact number of sessions and the number of times each condition was tested are presented in column 2 of Table 3.

To compare the rates of operant level vocal responding with the rates under reinforcement and extinction, the birds were then tested under mult FR 5 FR 5 with food in the magazine. During the reinforcement condition, the birds were food deprived approximately 18 hours at the start of the session. With the exception of the first extinction test for Mynah D (33 sessions), extinction tests lasted about 70 to 80 sessions.

RESULTS

Column 4 in Table 3 shows that the overall rates of vocal responding during operant level was a function of hours of food deprivation. Birds G and F had averaged overall vocal rates of at least 1.5 responses per min at 18 to 20 hours deprivation, but averaged only about 1 vocal response every 2 to 4 min with 0 to 2 hours deprivation, and fewer responses than that with food available continuously. The effect of deprivation was not so large for Mynah D, who had a much lower absolute operant level, but even this bird made about twice as many vocal responses per session under 18 to 20 hours deprivation as under 0 to 2 hours deprivation. Most of the responding at 18 to 20 hours deprivation can be designated as deprivation-induced vocal responding, because it occurred during operant level and because of the large difference between 0 to 2 hours deprivation and 18 to 20 hours deprivation.

During the reinforcement condition, vocal responding increased to overall rates that generally ranged from 3 to 5 responses per min. The deprivation induced responding at 18 to 20 hours of deprivation was 43% (Mynah G), 36% (Mynah F), and 4% (Mynah D) of the

rate of responding during reinforcement (column 5 of Table 3).

Extinction responding ordinarily reached its lowest levels by the 20th extinction session, including sessions with no responding; hence, data from session 21 on were considered stable and are presented in Table 3. During the extended extinction conditions, overall vocal responding dropped to near operant level (Mynah D) or below (Mynahs G and F), suggesting that most of the enduring extinction responding could be attributed to deprivation-induced vocal responding.

There was considerable variability in responding across the operant level and extinction sessions as is indicated by some average deviations (column 6, Table 3) that are larger than the mean overall rates. This was partly due to many sessions with no responding at all (column 7). The data in column 7 are also consistent with the operant level rate of vocal responding as a function of deprivation: there were fewer no-response sessions at 18 to 20 hours deprivation than at the lesser deprivation levels.

The pattern of vocal responding within the operant level and extinction sessions was similar to that shown in Figure 6, with more responding occurring after the middle of the session. For sessions with at least 10 responses, the percentage of vocal responses during the first half of operant-level sessions with 18 to 20 hours deprivation was 40%, 24%, and 27% for Mynahs, G, F, and D, respectively, and 19%, 12%, and 9% during stable extinction sessions. During the reinforcement condition, the percentages in the first half were generally higher, averaging 36, 52, and 37 respectively for Mynahs G, F, and D.

DISCUSSION

Although this series of experiments revealed that food deprivation per se could induce vocal responding, operant control appeared to predominate. In fact, the vocal responding of the mynah came under the control of fairly complex schedules. Multiple schedules with FR or FI in one component and DRO in the

Table 3

Vocal responding during operant level under three deprivation conditions and during reinforcement and extinction conditions.

Condition	Sessions ^a	Weight before session	Resp/min	Percent of reinforcement condition	Average deviation	Percent sessions, no response
<i>Mynah G</i>						
Operant level, 18-20 hrs	37(1,4)	189	1.58	43%	1.19	5%
Operant level, 0-2 hrs	30(2,5)	211	.25	7%	.35	50%
Operant level, 0 hrs	12(3)	207	.21	6%	.19	25%
Reinforcement	30	193	3.64	—	.88	0%
Extinction	55 ^b	184	.56	15%	.63	11%
<i>Mynah F</i>						
Operant level, 18-20 hrs	83(2,4,6,8)	193	1.84	36%	2.00	17%
Operant level, 0-2 hrs	48(1,3,9)	223	.47	9%	.45	38%
Operant level, 0 hrs	41(5,7)	221	.05	1%	.07	66%
Reinforcement	29	200	5.08	—	1.59	0%
Extinction	53 ^b	191	1.06	21%	.82	9%
<i>Mynah D</i>						
Operant level, 18-20 hrs	49(1,3,5,7)	149	.14	4%	.17	39%
Operant level, 0-2 hrs	56(2,4,6,8)	155	.08	2%	.12	59%
Reinforcement	13	152	4.88	— ^c	1.33	0%
Extinction	13 ^b	146	.22	6%	.21	23%
Reinforcement	74	160	3.35	— ^c	1.26	0%
Extinction	58 ^b	161	.41	11%	.40	17%
Reinforcement	47	161	2.62	— ^c	.62	0%
Extinction	54 ^b	160	.22	6%	.23	17%

^aThe numbers in parentheses show the order of blocks of 10 to 20 sessions during operant level.

^bFirst 20 sessions of extinction are not included (e.g., if 55 sessions are indicated, there were actually 75).

^cIn calculating the percentage of the response rate during reinforcement, the rates during the three reinforcement conditions were averaged.

other indicated that vocal responding was not simply elicited by stimuli associated with food. Rather, the pattern of vocal responding was characteristic of the pattern ordinarily produced by FR and FI schedules while the DRO component also resulted in the pausing characteristic of that schedule. Similarly, in the chain schedule, fixed-ratio vocal responding was maintained in the initial component even though it was never contiguous with food reinforcement. In the second component of the chain schedule, a DRO vocal schedule resulted in no vocal responses and a fixed-interval schedule controlled a pattern of increased key pecking characteristic of that schedule. Previous experiments with mynahs had shown stimulus control (Ginsburg, 1963; Grosslight et al., 1972, 1964) but had not gone beyond FR 1 in terms of schedules. Perhaps most important was the steady-state vocal responding that resulted under all the schedules. For example, under each procedure, there were several consecutive sessions with few or zero vocal responses during the DRO component, while the FR or FI schedules in the other component maintained characteristic patterns of responding. The steady-state performance suggests that the mynah may be a useful experimental subject regardless of whether one is interested in vocal responding.

The sizable rate of nonoperant vocal responding was initially suggested by the extinction responding which averaged 25% to 40% of the rate during the reinforcement condition for 50 2- to 3-hour sessions. For the three naive mynahs tested for operant level under 18 to 20 hours food deprivation, operant level was 4%, 35%, and 43% of the rate during reinforcement during the 40 to 80 2-hour sessions. Previous studies of avian vocal conditioning may not have observed this degree of operant level or extinction responding because (a) extinction and operant level procedures were not introduced, (b) reinforcement was never completely discontinued since extinction was introduced during only one component of a multiple schedule, or (c) extinction sessions were not continued for so many sessions. Lane (1960, 1961) did report an operant level of about 20% in a 30-min test for the chirping response of one chicken. Grosslight et al. (1962) reported low absolute rates of vocal responding (one response every 6 to 10 minutes) for 2 mynahs over 5 operant level sessions, but

these rates were 20% to 30% of the rate during the reinforcement condition, and the lower rates could have been due to a more stringent requirement for the vocal response. While nonoperant vocal responding was not a major aspect of the earlier studies, the percentage of nonoperant responding is in the range of the present study.

It is doubtful that the enduring extinction and operant-level responding can be attributed to any operant or respondent learning with respect to the home cage feedings, such as (a) adventitious reinforcement of vocal responding by the home cage feeding or (b) a learned temporal relation between the end of the session and the home cage feeding in which vocal responding might be elicited by temporal stimuli associated with food. First, if either were the case, the degree of positive acceleration of responding observed within extinction and operant level sessions would have also been expected during reinforcement sessions, because the mynahs were always fed a sizable portion of their food after the session including the reinforcement sessions. Second, the temporal relation between the end of the session and the home-cage feeding was not very precise, and for one bird the home-cage feeding was delayed 2 or 3 hours with no reduction in extinction responding. Finally, requiring a 3-min pause to terminate a session did not reduce vocal responding, as would have been expected if vocal responding had been adventitiously reinforced by the postsession feeding.

The possibility that the enduring extinction responding was largely deprivation-induced was first suggested when free food in the experimental chamber reduced vocal responding to a near-zero level and below the level obtained during the extinction sessions. In Experiment 5, operant level vocal responding in naive mynahs was a direct function of hours of food deprivation. The near-zero levels under no deprivation or continuous food suggest that most of the responding during the operant level at 18 to 20 hours deprivation can be designated deprivation-induced responding. Subsequent reinforcement and extinction tests at 18 to 20 hours food deprivation revealed that the enduring extinction responding occurred either at a lower rate or at a rate not much higher than operant level, suggesting that most of the enduring extinction respond-

ing could be attributed to deprivation-induced vocal responding.

The finding that unconditioned vocal behavior of the mynah increases with hours of food deprivation is similar to the relation between general activity and food deprivation (e.g., see review by Baumeister et al., 1964). Vocalization could simply be a type of activity that increases with food deprivation. In the experimental chamber, there are relatively few activities that could be said to be occasioned by that relatively sterile environment other than hopping, pecking, vocalizing, drinking, and, when food is available, eating. There is also some reason to believe that a vocal response might increase specifically with increased food deprivation. That vocalization may be biologically linked to food deprivation as to other sources of discomfort is suggested by the "distress" and "begging" calls of young food-deprived birds (e.g., see Bremond, 1963; Collias, 1962). The "awk" response of the mynah may have a special relation to food deprivation if it is related to the "juvenile squawk" that Bertram (1970, p. 165) reported for mynahs in captivity "when waiting to be provided with food."

There are at least two possible explanations of the increase in vocal responses within extinction and operant level sessions. First, it might simply be related to the increased food deprivation with the passage of time spent in that situation. On the other hand, the vocal responding may be abnormally lower in the beginning of the session because of the recent contrast with an auditory and visual environment, i.e., the animal room, which more vigorously stimulates vocalization. Both views retain some plausibility at the present time.

Some directions are suggested by this study. First, the dependence of the "awk" response on food deprivation raises the question as to whether other depriving operations (e.g., water, activity, social) might show similar or separable effects upon this vocal response. Another approach is to determine whether extinction and deprivation produce similar effects with other responses and/or vocal calls of the mynah. This may be of particular interest, because, as mentioned above, the "awk" response may have a special relation to food deprivation. Second, in addition to a naturally occurring influence by food deprivation, the low rates of the vocal response, particularly

the running rate, suggested that the rate of the vocal response as an operant has some inherent limits. Our specific response requirements do not seem responsible, because the "awk" responses in the natural (home cage) environment sounded the same to us as the deprivation-induced response in the experimental chamber and the food-reinforced vocal response. One possibility is that this response (either occurring "naturally" or under reinforcement control) requires considerable physical effort (see also Leander et al., 1972). However, the low rate of the vocal responding does not necessarily imply greater effort and there are other possibilities such as a latent period or a duration feature imposed by the physical mechanism producing the sound.

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