SCHEDULE CONTROL OF THE VOCAL BEHAVIOR OF CEBUS MONKEYS¹

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The vocal behavior of three *Cebus* monkeys was maintained by fixed-ratio schedules of response dependent reinforcement at values between fixed-ratio 1 and fixed-ratio 15. In one monkey that was exposed to variable-interval, fixed-interval, and conjunctive fixed-ratio fixed-interval schedules of reinforcement, vocal responding occurred at a low rate, but schedule-appropriate patterns were maintained. The rates and patterns of responding engendered indicated that the vocal operant can be brought under schedule control in the monkey by the use of response-dependent reinforcement.

Animal vocalizations have been described by Skinner (1957) as instinctive, innate, and well-defined emotional responses, and as such, distinct from human vocalizations, which are modifiable by schedules of reinforcement. Recent research indicates, however, that the vocalizations of cats (Molliver, 1963), dogs (Salzinger and Waller, 1962), guinea pigs (Burnstein and Wolff, 1967), dolphins (Lilly, 1965), sea lions (Schusterman and Feinstein, 1965), and chicks (Lane, 1960, 1961; Lane and Shinkman, 1963) can be modified by response-dependent reinforcement. The conclusions resulting from attempts to gain control of the vocal behavior of non-human primates continue to stress emotional origins and insensitivity to the effects of reinforcement contingencies (Lilly, 1961). Typical of this position is the comment that "... voluntary vocalization is an extremely difficult, if not impossible process for a monkey; generally, vocalization for them is only part of the response to the emotional needs built up in the organism

(cooing for food, barking in anger, screaming in pain, *etc.* Lilly, 1961, p. 65)."

Myers, Horel, and Pennypacker (1965) demonstrated that increased rates of vocalization by *Cebus* monkeys can be maintained by delivery of food pellets and brought under the control of discriminative stimuli. The purpose of the present experiment was further to investigate schedule control of the vocal operant in monkeys.

METHOD

Subjects

Three young adult male, jungle-born monkeys (*Cebus albifrons*) were maintained at 85% of their free-feeding weights. The pre-experimental free-feeding weights of the animals, designated C-148, C-160, and C-164, were 1365, 1504, and 1350 g, respectively. All monkeys were naive with respect to the operant conditioning of vocal behavior; Monkey C-148 had been used in an eyelid conditioning study (Milan and Pennypacker, 1970). Water was continuously available except during the experimental session.

Apparatus

Each animal's home cage, measuring 18.5 in. high, 14 in. wide, and 13.5 deep (46 by 14 by 13.5 cm), served as the experimental space. The experimental chamber was a large, walk-in audiometric chamber (Industrial Acoustic Corporation Model No. 401-A) illuminated by a 60-w bulb. A 19 in. (48 cm) square stimulus panel contained a microphone and a loud-

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speaker located in the upper right and left corners, respectively, and a food magazine mounted along the vertical centerline 6.5 in. (18 cm) above the cage floor. A mixture of Noyes pellets, of which half were 90-mg sucrose and half were 90-mg dextrose pellets provided reinforcers. A 300-msec, 1000-Hz tone of moderate intensity provided feedback for vocal responses. All experimental procedures were controlled by electromechanical equipment and data were recorded by digital counters and cumulative recorders.

Procedure

At the start of each daily session, the home cage was mounted on a platform in the experimental chamber, the guillotine door of the cage was raised, and the stimulus panel was attached to the cage front. Approximately 1 hr after the experimental session ended the monkey was fed its daily ration of Purina monkey chow, fresh fruit, and multiple vitamin supplement.

Monkeys C-160 and C-164 were first subjected to eight days of magazine training, during which a response feedback tone was associated with delivery of a food pellet. Two and three days, respectively, of recording free-operant base rates followed magazine training. Monkey C-148, which had previously been magazine trained, was initially given two days of free-operant base rate recording. Food pellets were not delivered during base rate recording sessions.

After free-operant base rates were established, the vocal conditioning procedure was initiated. Initially, all vocal responses were followed by presentation of a response-feedback tone and a food pellet. After the probability of vocal responses had increased, the criteria for a recorded vocal response were changed to that in effect for the major portion of the experiment. There were two criteria; first, the monkey's vocal response had to operate a voice-operated relay (Grason-Stadler Model E7300 A-1); and second, the experimenter, who constantly monitored the vocal behavior of the subjects through the speaker channel of the voice relay, had to confirm the response by pushing a switch. The vocal response had to be between 1000 and 3000 Hz, greater than 52 dB in intensity, and exceed 30 msec in duration to operate the voice relay. The experimenter had 300 msec in which to

confirm the response. In other words, each sound that operated the voice relay would "set-up" a 300-msec holding circuit; if the experimenter heard a vocal response, he would press the hand switch, and the feedback tone would be presented. The dual criteria for responses were necessary because the animals often operated the voice relay by pounding on the stimulus panel with their fists. The dual criteria served two purposes: they insured that only vocal responses were consistently followed by food presentation, because the experimenter made the confirming response only when a vocal response was detected; and, they reduced the possibility of experimenter bias, because reinforced responses also had to satisfy requirements of the voice relay. The duty of monitoring the vocal responding was randomly alternated daily among three different experimenters. The vocal behavior of all monkeys was initially maintained by fixed-ratio (FR) schedules of food presentation. With the FR schedule, a pellet was delivered upon completion of a fixed number of responses. Thus, with an FR 5, every fifth response was followed by food delivery. When stable responding was achieved on FR 1 or any of the succeeding FR schedules, the response requirement was increased.

The vocal responding of Monkey C-148 was also maintained by variable-interval (VI), fixed-interval (FI), and conjunctive fixed-ratio fixed-interval (*conj* FR FI) schedules of food delivery. With an FI 0.5-min schedule, the first response after 0.5 min was followed by food delivery. With a VI 0.5-min schedule, a response was followed by food delivery on the average of twice per minute, but the actual intervals between food presentations varied in duration. The VI schedule was arranged according to a random series of equi-probable intervals. The actual intervals were obtained from an unpublished report (Children's Research Center Document #6821, University of Illinois, Urbana). The conjunctive fixed-ratio 6 fixed-interval 1.5-min (*conj* FR 6 FI 1.5-min) schedule required that both the FR 6 and FI 1.5-min requirements be met to achieve food delivery. The schedule manipulations for all monkeys, the order in which they were studied, and the number of sessions at each schedule value are presented in Table 1. Initial sessions for C-148 were 60 min in duration; later sessions were reduced to 30

min. All sessions for C-160 and C-164 were approximately 30 min in duration.

RESULTS

Each of the three monkeys had very low baseline response rates before response-dependent reinforcement was introduced. Monkey C-148 immediately increased the rate of vocalization after conditioning procedures were instituted (Figure 1). The predominant vocal response could best be described as a "bark". A sonogram revealed that the vocal response had a duration of 60 msec, a fundamental fre-

Fig. 1. Mean vocal response rates for all three monkeys on FR schedules in consecutive seven day blocks. Refer to Table 1 for the specific schedule values and number of sessions at each value.

quency of 1360 Hz, and several harmonic components. The vocalization rate of C-148 reached asymptote at 11 responses per minute. Examples of typical cumulative records obtained at different FR values for C-148 are shown in Figure 2.

The ratio performance of monkey C-148 was characterized by variable durations of post-reinforcement pausing and also some pauses before reinforcement. During the post-reinforcement pauses, C-148 was usually intensely active, shaking the cage, and beating on the stimulus panel, but at the initiation of vocal responding, C-148 positioned itself in front of the stimulus panel. The pauses before reinforcement were a result of insufficient vocal intensity to operate the voice relay. The frequency of the pre-reinforcement pauses and lengthened post-reinforcement pauses in-

Fig. 2. Representative cumulative records for three different FR schedules of reinforcement for Monkey C-148. Diagonal marks indicate reinforcement. Reset of the response pen in the bottom record occurred after 5-min intervals.

creased during the 30-min sessions and the behavior became increasingly difficult to maintain in the latter half of the 60-min sessions. This observation led to the restriction of all sessions to 30-min duration.

Monkeys C-160 and C-164 demonstrated slower acquisition compared to C-148 (Figure 1). Their response rates increased substantially after the sixth and seventh weeks. Each eventually developed response rates approximately 25 times higher than their operant baseline rates. The predominant vocal response emitted by C-160 can be described subjectively as a high-pitched whistle. A sonogram revealed that the response had a 50-msec duration, a fundamental frequency of 2250 Hz, and several harmonics of the fundamental frequency. The predominant vocal response of C-164 can best be described as a "chirp" (no sonogram was obtained of C-164's vocal response). Cumulative records for C-160 (Figure 3) and C-164 (Figure 4) exhibited typical FR response patterns (Ferster and Skinner, 1957). The top record in Figure 3 is an example of Monkey C-160's steady state performance at an FR 10 schedule of reinforcement. There was a consistent pattern of responding at this ratio value; the post-reinforcement pauses were of a uniform duration throughout the session and no changes in overall response rates occurred within the session. The middle record shows

early FR 15 performance and the bottom record shows terminal FR 15 performance. The bottom record exhibits a departure from the more consistent pattern of responding in the two records above. The increased duration of post-reinforcement pauses and the lowered local rates of responding, observed in the terminal FR 15 record, resulted in the lowered overall response rate average during Week 15 (Figure 1) for Monkey C-160.

Fig. 3. Representative cumulative records for two different FR schedules of vocal responding by Monkey C-160. The middle record shows performance during an early session of FR 15, while the lower record shows terminal FR 15 performance. Diagonal marks indicate reinforcement. Reset of the response pen occurred after 5-min intervals.

The top and middle records of Figure 4 show early and later performance of Monkey C-164 on an FR 4 schedule of food presentation. The FR schedule performance of this monkey was characterized by variability in response rates, variability in post-reinforcement pauses, and variability in interresponse times. These are typical records obtained at these values for Monkey C-164. Table 1 summarizes the mean response rates for the last three sessions at each schedule for all animals.

Cumulative records obtained from two consecutive sessions of vocal responding by C-148 maintained by a VI 0.5-min schedule of food presentation are presented in the bottom half of Figure 5. These two records were ob-

tained after only 10 days' exposure to the VI schedule and without the requirement of having to operate the voice relay. Thus, they are records of vocal responses recorded by the experimenter. With continued exposure to the VI 0.5-min schedule and inclusion of the voice relay criterion, response rates gradually declined until they reached asymptote at the 3.8 responses per minute reported in Table 1. Cumulative records for the last three days on VI 0.5-min demonstrated a stable pattern of responding at reduced rates, as compared to Figure 5. At the end of this study of vocal responding, lever presses by C-148 were reinforced on the same VI 0.5-min schedule. The top records in Figure 5 were obtained on the second and third day of lever pressing.

Fig. 4. Representative cumulative records for two different FR schedules of vocal responding by Monkey C-164. The top record shows performance during an early session of FR 4, while the middle record shows terminal FR 4 performance. Diagonal marks indicate reinforcement. Reset of the response pen occurred after 5-min intervals.

Two consecutive sessions of FI 1.5-min are shown in Figure 6. The FI 2-min record shown in Figure 6 is the first day's performance on that schedule. The monkey's pattern of vocal responding adjusted within that session to the increase in the FI value. The pattern of positively accelerating responding toward the point of food delivery (Ferster and Skinner,

Table 1

Summary of schedules and mean results of last three sessions at each schedule value.

MONKEY C-148			MONKEY C-160			MONKEY C-164		
Schedule	Number of Sessions	Resp/min	Schedule	Number of Sessions	Resp/min	Schedule	Number of Sessions	Resp/min
FR 1	23	5.9	FR 1	36	4.0	FR 1	42	5.6
FR 2	3	5.8	FR 2	25	11.7	FR 2	9	10.7
FR 3	37	8.4	FR 4	6	14.6	FR 3	4	13.6
FR 4	19	9.6	FR 5	7	23.2	FR 4	3	14.6
FR 5	28	10.5	FR 8	6	20.9	FR 6	11	23.8
FR 7	7	10.4	FR 10	17	13.0	FR 7	9	25.4
			FR 5	8	10.3	FR 10	29	21.6
						FR 15	5	21.2
VI 0.5-min	31	3.8						
FI 0.5-min	1	3.4						
FI 1.0-min	8	3.8						
FI 1.5-min	6	3.8						
FI 2.0-min	3	2.6						
conj FR 6 FI 1.5	9	0.6						
FR 4	6	2.9						
Extinction	5	1.1

Fig. 5. Representative cumulative records for VI 0.5-min schedule of lever pressing and vocal responding by Monkey C-148. Diagonal marks indicate reinforcement and reset of the response pen in the vocal responding records occurs after 5-min intervals.

1957) was apparent in the FI records. A consistent characteristic of the vocal responding of Monkey C-148 on FR schedules (Figure 2),

Fig. 6. Representative cumulative records for FI 1.5-min, FI 2-min, conj FI 1.5 FR 6, and extinction of vocal responding by Monkey C-148. Diagonal marks indicate reinforcement.

VI 0.5-min (Figure 5), and FI schedules (Figure 6) was the decrease in response rate during the session. When the FI schedules were in effect, the rate of responding towards the end of the session was so reduced that very few responses were made before the reinforced response.

The *conj* FR 6 FI 1.5-min schedule of food presentation maintained a rate of responding (middle records in Figure 6) lower than that maintained by the FI 1.5-min schedule. The characteristic decrease in response rates by Monkey C-148 was evident in the *conj* schedule by increased duration of the post-reinforcement pauses.

Because the *conj* FR 6 FI 1.5-min schedule effected an appreciable reduction in response rate, responses were reinforced under an FR 4 schedule for six days before experimental extinction was introduced. Table 1 shows that introduction of FR 4 resulted in the pre-*conj* schedule rate. During extinction, the feedback stimulus was presented for effective responses but food pellets were never delivered. Response rates decreased over sessions and the consecutive cumulative records presented in Figure 6 show the typical negative acceleration of extinction (Ferster and Skinner, 1957).

DISCUSSION

The results of this experiment clearly demonstrate that FR schedules of food presentation can increase rates of vocal responding and that the pattern of vocal responding is dependent upon the schedule. Just as with other operants, the FR schedules usually maintained the characteristic pattern of post-reinforcement pause followed by a relatively steady rate of responding. The VI schedule generated a relatively steady rate of responding, while the FI schedule generated post-reinforcement pausing followed by a pattern of positively accelerated responding. The *conj* FR 6 FI 1.5-min schedule generated a lower response rate than the FI 1.5-min schedule alone. The lowered response rate with *conj* schedules has been reported by Herrnstein and Morse (1958). There is some evidence to indicate that this may be a function of the interaction of the specific FI and FR requirements, since Hitzing and Kaye (1969) did not observe decreased response rates. The schedule-specific patterns of responding indicate that the vocal responding was not elicited by food presentation.

The use of the tone as feedback for every effective response was a departure from the procedure employed by Myers *et al.*, (1965) and may, in part, have been responsible for obtaining higher FR rates in the present study.

Besides establishing the tone as a response feedback, the extended magazine training for C-160 and C-164 provided for adaptation to a situation where food was presented, before an assessment of the baseline response rates. If vocalizations were elicited products of emotional stimuli, as Lilly (1961) suggested, then the baseline rates obtained for C-160 and C-164 should be higher than if they were measured in a situation where the monkey had not had a history of receiving food. As noted from Figure 1, these baseline rates were very low, even with this food presentation history.

The specific procedure in this experiment was decided upon to solve a difficult methodological problem. It would have been desirable for the output of the voice relay to be the sole criterion of the response, but this would have required extensive frequency and wave-form filtering of the input, and a consequent narrowing of the potential response class. Also, because the characteristics of vocal responses have been demonstrated to vary as a function of schedule manipulation (Lane and Shinkman, 1963), a relatively wide potential response class was desirable for an initial investigation such as this. Even with the relatively large response class utilized in this study, as many as 40% of the steady-state vocal responses did not operate the voice relay. It is interesting to note that each monkey developed a unique vocal response with this procedure.

The main disadvantage with the present procedure was the inherent delay between the vocal response and confirmation by the experimenter. The slow acquisition of C-160 and C-164 may have been a result of this "delay of reinforcement". These two monkeys were very active in the experimental cage, and delay of reinforcement has been shown to retard the kind of response differentiation (Perin, 1943) occurring in the acquisition of a low probability response such as the vocal response. Monkey C-148 was probably not so effected during acquisition because of its low probability of vocal responding during other activity. The use of the 300-msec limit on the delay between the voice relay output and the experimenter's response was beyond the human reaction times (approximately 150 msec) to suprathreshold auditory stimuli (Woodworth and Schlosberg, 1954, p. 20), so failing to confirm within 300 msec was virtually never a problem.

A major difference between the monkey vocal response and other response classes investigated in the operant paradigm appears to involve the "effortfulness" of the operant vocal response. The low response rates and the inability to maintain consistent responding at larger FR values suggest that the vocal operant is a difficult response for the *Cebus* monkey. A comparison of the cumulative records for lever pressing and vocal responding (Figure 5) maintained by the same VI 0.5-min schedule of food presentation showed lower response rates for vocal responding, even though vocal responding was measured *without* the voice relay. In other studies, manipulations of the "effort" required to produce an effective response have consistently shown that increasing the effortfulness results in decreased response rates (Chung, 1965; Elmsore and Brownstein, 1968; Mowrer and Jones, 1943; Skinner, 1950). Skinner found that as the effort required increased, the rate of responding decreased, but the characteristic pattern of FI responding remained. Thus, the "effortfulness" interpretation fits well with the vocal responding data, where the responding displayed the usual schedule patterns, but at reduced rates.

The displays of regular concentrations of energy on the sonograms for Monkeys C-148 and C-160 leads to an interesting speculation. The regularity of the energy bursts and of the intervals between bursts suggests harmonic intervals rather than those of format frequencies. In contrast to format frequencies, which are obtained from the resonance properties of the oral cavity, the presence of harmonics implies glottal activity. It has been contended that the vocalizations of non-human primates in the natural environment, like those of human infants, are a function of the oral cavity resonances (Lieberman, 1968). This difference implies that the vocal responses evoked in the natural environment are a product of different structures than those maintained by response-dependent food presentation. Further study to determine the basis of these vocalizations seems to be indicated.

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