OPERANT CONTROL OF VOCAL BEHAVIOR IN THE CAT¹

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Evidence of operant control of vocal behavior in the cat is presented: (1) On mult FR 12 S^A schedule, cats miaowed rapidly during periods of S^P and much less or not at all during S^A. (2) This control was re-established following reversal of stimuli. (3) The frequency distribution of response durations was shifted to both shorter and longer values by the differential reinforcement of shorter or longer response durations respectively. Since both the frequency and duration of vocal responses were shown to be under the control of the schedule of reinforcement, it is concluded that at least some of the vocal behavior of the cat is susceptible to operant control.

There has been considerable speculation in the past as to whether vocal behavior in subhuman species could or could not be subject to operant control. In recent years, studies with birds (Ginsburg, 1960, Lane, 1961), and with dogs (Salzinger and Waller, 1962) have provided clear evidence that the frequency of occurrence of vocal behavior in these species was susceptible to operant control.

The present experiments extend observations to the cat. Stimulus control over frequency of miaowing was obtained and differential reinforcement of response durations was effective in modifying the length of miaows. That the nature as well as the frequency of the vocal response can be changed by reinforcement contingencies has important implications for theories of emergence of verbal behavior.

METHOD

Apparatus

The experimental chamber was a lucite box 23 x 13 x 12 in. with a hinged top raised above

the sides leaving a 1-1/2 in. clearance space between the top and the sides. For isolation and sound-proofing the chamber was enclosed within a ventilated refrigerator shell, the inside measurements of which were 36 x 23 x 15 in. At one end of the lucite chamber were arranged the stimulus light and a feeder. A green bulb was on the left side outside the transparent end panel of the chamber. The bulb was 25 watts, 110 volts AC, operated in series with a 300 ohm resistor to reduce heating and to lengthen bulb life. Within the chamber was a white tubular bulb (GE: F 91048-AX) used for response feedback.

A Gerbrands liquid feeder, with a 1.0 cc ladle, delivered a smooth homogenized mixture of equal parts of canned pink salmon and Liquid Lactum (Mead Johnson).

The response-detector was a high output crystal microphone mounted within the refrigerator but outside the lucite chamber, beyond the reach of the cats. The microphone output was fed into a conventional audio amplifier, the output of which was rectified and led to the grid of a triode with a sensitive relay in its plate circuit (Fig. 1). The triode was normally conducting, and the rectified audio signal was applied as a negative voltage to the grid, biasing it to below cutoff level. By this means, the audio signal in the experimental chamber was converted to a digital pulse.

Subjects

Four cats: two adult mongrel, one male (#3) and the other female (#5), and two four

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month old Siamese littermates, male (#6) and female (#7) were used. All were maintained between 65% and 75% of their *ad libitum* body weight.

Fig. 1. Circuit diagram of the voice operated relay. R_1 sets the sensitivity. R_2 regulates the duration of the output pulse.

PROCEDURE AND RESULTS

Each cat was deprived and trained to eat from the food magazine in the experimental chamber. They were placed on CRF until they were miaowing at a steady rate. FR reinforcement was then imposed and the ratio was gradually increased. Ratios greater than 15 were soon followed by irregular rates of responding; regular responding returned when the FR was returned to a lower value. Hence the definitive work was done using a FR less than 15. Sessions were of 1 hr duration.

Experiment 1: Stimulus control

During the session, 6 min periods with the green light present (S^D) alternated with 2 min periods of no light (S^A). When the S^D was present, vocal responses were reinforced on an FR schedule; FR 12 for Cat #3 and FR 10 for Cats #5, 6 and 7. During periods of S^D , the white light in the box came on at the beginning of each vocal response and remained on for the duration of the response plus approximately 30 milliseconds. There was no such response feedback during S^A periods.

Over the course of about five to 15 sessions a high rate of responding developed during both S^D and S^A periods. The response rate during S^A then gradually decreased to almost zero, while characteristic patterns of responding developed in S^D in all cats. Figure 2 shows typical small sections of two different sessions

of Cat #3. There is some variability in rate in S^D and occasional local irregularity of the cumulative record. After each reinforcement there is a period of no responding. During these post-reinforcement pauses, the cats were seen to be licking around the food magazine where they had spilled some of the salmon mixture. When this "cleaning up" had been finished, the cats began to miaow repetitively until the next food presentation.

Fig. 2. Portion of record from Cat #3 on schedule of Mult FR 12 S^A . The pen is in the lower position during periods of S^A .

The stability of the pattern is illustrated by the four sessions at about two-month intervals of Cat 3 shown in Fig. 3. Cumulative records A, B, and C clearly show the rate differences under the two stimulus conditions. There is rarely more than an occasional single response during the 2 min periods of S^A . When the S^A ends and the green light in the box comes on again, the cat immediately proceeds to "miaow" at a high rate. Record D of Fig. 3 shows a phenomenon that was observed frequently during these experiments: a change in the schedule during S^D may temporarily produce a large increase in S^A responding. In the particular instance reproduced in record D, responses of a long duration only were reinforced during S^D (see below). The rate of responding was high during the first three S^A periods in this record, but gradually diminished to zero by the sixth and seventh periods.

Cats 6 and 7 also showed the development of stimulus control within two weeks after they had been placed on a multiple schedule. There was a gradual and irregular but persistent decrease in S^A responding during the time in which they were run. Two representative sections of records from Cats 6 and 7 at dif-

Fig. 3. Four sessions of Cat #3 spaced about two months apart. The rate difference between S^D and S^A periods demonstrates stimulus control in records A, B, and C. Record D shows breakdown and then recovery of stimulus control when a new procedure is added to the schedule.

ferent stages of this acquisition of stimulus control are shown in Fig. 4. Record A of Cat 6 after three days of exposure to the multiple

Fig. 4. The development of discriminative stimulus control in Cats 6 and 7. The schedule is multiple FR 10 S^A . Cat 6: record A three days and B 13 days after being placed on the multiple schedule. Cat 7: record C six days and D 13 days after the multiple schedule was imposed. (The pen is depressed during periods of S^A .)

schedule shows a very high rate of responding during S^A . Record B shows a much lower rate during S^A 13 days after the multiple schedule was imposed. Records C after six days and D after 13 days show an even greater decrease in the S^A response rate of Cat 7.

Experiment 2: Discrimination reversal

Cat 5 was subjected to the procedure described in Experiment 1 for eight daily sessions. At the end of this period, good stimulus control had developed as shown by the low value of the ratio of rate of responding in S^A to that in S^D (Fig. 5). The stimulus conditions were then reversed. Six min periods of total darkness, during which the cat was reinforced on FR 10, alternated with 2 min S^A periods with the stimulus light on. The initial low rate of responding during the new S^D and the high rate during S^A was the basis of a large increase in the ratio of S^A rate to S^D rate. During subsequent sessions this ratio rapidly fell to a value almost as low as before reversal.

Fig. 5. The effect of a stimulus reversal on the ratio of S^A to S^D rates of responding. The cat was not run on days 11, 12, 19 and 21.

Experiment 3: Modification of response-duration

The frequency distribution of response durations was recorded for each daily session of Cat #3. Figure 6 (left column) shows this distribution for five consecutive daily sessions run under the procedure of Experiment 1, Mult FR 12 S^A . The modal duration was less than 0.2 sec. A response duration requirement was then imposed. Only those vocal responses greater than 0.4 sec in duration "counted",

Fig. 6. Modification of response by a duration requirement. The left hand column shows the frequency distribution of response durations for five consecutive days with no response duration requirement. The middle column shows the distributions for five days with the requirement that responses must be greater than 0.4 sec in duration to count for reinforcement. The right column shows the distributions for five consecutive days after the response duration requirement had been removed. The averaged distributions in each column are presented in the bottom row.

i.e. 12 responses, each longer than 0.4 sec had to be emitted for each reinforcement. The response feedback light was now turned on only when the duration requirement had been met; when a "miaow" had continued for 0.4 sec the feedback light came on and remained on for the remainder of the response duration and then a further 30 milliseconds. This procedure was continued for nine daily sessions.

An immediate shift to the right of the duration distribution occurred in the first session in which a minimum response duration was required. Thereafter the peak of the distribution was always at a value greater than 0.4 sec as compared with its previous value of less than 0.2 sec. This is illustrated in Fig. 6 in which the central column of distributions shows five consecutive daily sessions with the response duration requirement in force. Approximately one half of all the responses were between 0.4 and 0.6 sec in duration. The form of the distribution remains very similar from day to day.

On the 10th day after the 0.4 sec duration requirement had been added, the response feedback was modified to make the light come on at the beginning of each response and remain on for the duration of the response plus 30 milliseconds. This is identical to the response feedback procedure before the response-duration-requirement was imposed.

Figure 7 shows the distribution of durations of all responses for three daily sessions prior to the change in response feedback and the distribution for the three days following the change. The effect of the change in response feedback is small. When the light came on at the start of each response, there was a shift of responses greater than 0.6 sec to slightly shorter values. The mode of the distribution remained unchanged. The general form of the distribution also remained the same and the effect of the response-duration is clearly seen under both feedback conditions.

The duration requirement was later removed. Figure 6 (right column) shows the data for five consecutive days under this condition at a relatively stable state. The distributions rapidly shifted to the left. There was more day-to-day variability after removal of the duration requirement than had been seen under the previous conditions but the distributions shifted toward the shape they had before imposition of the duration require-

THE EFFECT OF TIME OF ONSET OF RESPONSE FEEDBACK

Fig. 7. The effect of time of onset of response feedback. Twelve responses greater than 0.4 sec duration are required for each reinforcement. Left distribution: response feedback comes on after the duration requirement has been satisfied. Right distribution: feedback comes on at the start of the response. Data are for three consecutive days under each condition.

ment. The five sessions in the three conditions had been averaged to give the summary shown at the bottom of Fig. 6. With no response requirement, the mode of the distribution was at 0–0.2 sec. When the duration contingency was added, the mode shifted to 0.4–0.6 sec. The mode then shifted back to its original low value when the duration requirement was removed.

During the time that the duration requirement was imposed there were a number of responses emitted during S^D that were shorter than 0.4 sec in duration and therefore did not “count” towards satisfying the reinforcement requirement. Thus, under the condition of the duration requirement, the mean number of responses per reinforcement was 17.9. Obviously, with no duration requirement under the procedure of Experiment 1 Mult FR 12 S^A , the mean number of responses per reinforcement was 12. The question therefore arises as to whether this difference of number of responses per reinforcement itself constitutes a change in schedule sufficient to produce the shift in response distribution seen in Fig. 6.

A control experiment was performed to determine whether or not the response duration distribution could be shifted to both longer and shorter values independent of the number of responses per reinforcement. Data from six consecutive days are presented in Fig. 8. During the first three days the duration requirement imposed was that responses must be greater than 0.4 sec to be counted. The frequency distribution of response durations for these three days is shown in the left hand distribution with a modal duration of 0.4–0.6 sec. On the subsequent three days, only responses less than 0.5 sec duration were counted for reinforcement. The distribution of duration of responses under this condition is shown in the right hand distribution. The mode of this distribution lies between 0.2 and 0.4 sec in duration. During this latter condition the mean number of responses per reinforcement was 19.1 as compared with 17.9 for the former procedure. Thus, although the addition of a new differential reinforcement requirement may be expected initially to produce an increased number of responses per reinforcement, in this procedure the duration distribution can be shifted in both directions while the number of responses per reinforcement remains essentially unchanged.

DISCUSSION

The frequency of occurrence of vocal responses in the cat has been shown to depend

Fig. 8. Duration distribution under two different conditions. Left: greater than 0.4 sec duration requirement. Right: less than 0.5 sec duration requirement.

on the schedule of reinforcement. It was very much higher on an FR than in the presence of an S^A. Discriminative stimulus control was demonstrated by reversal of the stimuli. Vocal behavior in this species, as in the chick and dog, therefore comes under operant control, though this does not mean, of course, that all vocal behavior is necessarily operant in nature.

Response differentiation of vocal behavior depending on reinforcement contingencies has also been demonstrated. The relative frequency distribution of response durations was shifted to the right when a minimum response duration for reinforcement was imposed. This shift in distribution has been shown to be primarily dependent on the duration requirement and not on other subtle schedule changes secondary to the duration requirement.

As it has been demonstrated that both the frequency of occurrence and the duration of vocal responses in subhuman species can come under operant control, it is clear that the evolutionary differences between human and subhuman vocal behavior are not as sharply demarcated as might previously have been assumed.

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