Operant conditioning in the indigo snake¹

PAUL R. KLEINGINNA, JR., *University of Miami, Coral Gables, Fla. 33146*

It was demonstrated that indigo snakes can be conditioned to operate a contact relay and press a key. The other major findings were: (1) Water can be an effective positive reinforcer for snakes; (2) the cumulative records of snakes show a step-shaped pattern; (3) snakes can respond at high rates for short periods of time; (4) snakes can sustain an FR4 schedule; and (5) moulting does not completely disrupt the effects of conditioning.

The purposes of the study were (1) to operantly condition the indigo snake, and (2) to obtain for the indigo snake cumulative records that could be compared with those of other reptiles, as well as with fish, birds, and mammals.

Only a few studies have been concerned with conditioning in snakes. In the first study, Takemosa & Nakamura (1935) trained snakes to escape from an experimental box. Snakes usually try to get out of enclosures, and it was only necessary for the snake to find the opening. Kellogg & Pomeroy (1936) used a T maze having the alleys filled with cold water and a goalbox filled with warm water. The number of errors decreased with practice, although errors increased during and after the moulting period. The snakes had to be retrained after moulting, showing apparently no savings from earlier conditioning. The third study (Wolfe & Brown, 1940) used a two-choice multiple T maze. The dry runways were heated to temperatures between 48 and 55 deg C by the sun or electric lightbulbs and the goalbox maintained at 27 to 35 deg C. There was no indication of learning. The same Es then attempted to condition snakes to escape from the electric-shock side of a two-compartment box with a connecting doorway. Again, there was little sign of learning. Crawford & Bartlett (1966) used positive reinforcers instead of the negative reinforcers of the previous studies. Reinforcement was a young chicken and a small bowl of water. The apparatus was a wooden alleyway with a starting box and a goalbox. The snakes receiving reinforcement showed little change in latency and running time, while the unreinforced control snakes increased their latency and running times. The study therefore showed extinction or at least habituation. The last study dealt with escape from vibratory stimulation (Crawford & Holmes, 1966). The apparatus

was a two-compartment chamber. Most of the snakes showed a progressive decline in escape time.

SUBJECTS

Three indigo or gopher snakes, *Drymarchon corais couperi*, were used as Ss. The Ss were approximately 6 ft in length and 4 to 6 years old. At the beginning of the study, the three Ss weighed 840, 770, and 748 g. The Ss were obtained from the Miami Serpenterium, where they had been given ad lib water and weekly food, consisting of live baby rats and chickens. During the experiment, the Ss were force-fed dry pellets or semi-liquid food. They were given no water except during the experimental sessions. All Ss were experimentally naive.

APPARATUS

The experimental chamber was 23 x 12 x 10 in. high, with floor and ceiling made of hardware cloth. The operanda were an exposed wire connected with a contact relay and a pigeon key. Also located within the experimental chamber were a 10-W light and a liquid pump tube. The area at one end of the tube was shaped to hold approximately six water reinforcements (0.5 cc per reinforcement), the amount being controlled by a drainage hole.

GENERAL PROCEDURE

The snakes were run 7 days a week throughout the study. When not run, the Ss were housed in separate 10 x 10 x 18 in. hardware-cloth home cages.

EXPERIMENT 1

CRF on the Pressure Key and the Rising Contact Wire

The main purpose of the first experiment was to determine whether or not snakes could be conditioned to touch a contact wire or press a key. S 1 was used in Experiment 1. At the beginning of the experiment, the S was allowed a 24-h period in which to adapt to the experimental chamber and to find the water hopper that was filled by the E. The free-operant level of responding on the key was recorded for the first 24 h in the experimental chamber. S 1 pressed the key once in the 24-h period.

Subject 1 was then switched to a CRF schedule of water reinforcement for touching a short wire in the experimental chamber. A reinforcement consisted of 0.5 cc of tap water. A 10-W light in the chamber was presented simultaneously with the reinforcement, and had a duration of 2 sec. The sessions lasted 24 h. For the first seven sessions, the wire was located .25 in. from the water hopper, then, during

the next 21 sessions, the wire was raised successively to .50, .75, and 1.00 in. above the water hopper. The rates at the different levels were the following: At the .25 level, the mean number of responses per session was 70, with a range from 0 to 353; at the .50 level, the mean was 223, with a range from 11 to 435; at the .75 level, the mean was 84, with a range from 0 to 243; and at the 1.00 level, the mean was 68, with a range from 2 to 266.

Next, S 1 was switched to CRF for pressing the key. Prior to this experimental change, S 1 had never been reinforced for pressing the key. However, the wire had been moved by steps in the direction of the key until, in the final phase of wire-contingency sessions, the wire was actually placed over the key. Experiment 1 attempted to facilitate key responding with the method of successive approximations (Skinner, 1953). This approach was considered practical because the contact wire could be activated by a significantly lighter touch than the pressure key. During the 10 24-h sessions on the CRF key schedule, the S's mean rate was 103, with a range from 0 to 589, which was well over the free-operant level.

Finally, the session length was reduced from 24 h to 2 h. For the five sessions under this condition, S 1 averaged 212 responses per session, with a range from 174 to 243.

EXPERIMENT 2

Transition from CRF Key to FR4 Key

The purpose of Experiment 2 was to determine whether or not a snake would make the transition from a CRF schedule to a FR4 schedule. S 2 was used in this experiment. After a 24-h adaptation period, S 2 was put on a CRF schedule on the contact wire. During the 24-h sessions on this schedule, the snake's mean number of responses per session was 191, with a range from 0 to 668.

The contingency was then changed from the wire to the key. For 23 24-h sessions on the CRF key schedule, the S averaged 58, with a range from 0 to 328. Then the session length was reduced from 24 h to 1.5 h for 20 sessions, in which the mean was 17 responses per session.

Finally, S 2 was switched to a FR schedule of reinforcement on the key. On this schedule, the S averaged 16 responses per 1.5-h daily sessions for the first 8 days, then did no more responding for the next 28 sessions. This absence of responding caused the Es to conclude this experiment. A comparison of cumulative records for CRF and FR4 schedules on the key can be made from Fig. 1. The two cumulative records both have the characteristic step-shaped pattern and appear to differ

Fig. 1. Comparison of cumulative records for CRF and FR4 schedules.

typically respond more rapidly and pause for a short period after each reinforcement to eat (Skinner, 1938; Ferster & Skinner, 1957). Bitterman (1964) found somewhat similar step-shaped cumulative records for another reptile, the turtle. This reptile's FR records were also generated by a low response rate, but unlike snakes, turtles usually paused after each reinforcement to eat.

Experiment 2 demonstrated that a snake can be kept responding on a key with only one reinforcement for every four responses. However, the snake did not change its pattern of responding when the schedule changed from CRF to FR4 as some mammals and birds do (Ferster & Skinner, 1957). The snake touched the operanda several times, regardless of the schedule, before turning to the water hopper to drink.

Experiment 3 was probably the most interesting part of the study since S3 generated such high rates of responding. For short periods of time, the neck responses of S3 were comparable to the highest rates generated by either mammals' leg movements or birds' head movements.

A final conclusion from data on Ss 2 and 3 was that, while moulting reduced the average number of conditioned responses per session, it did not completely destroy the response pattern as Kellogg & Pomeroy's (1936) study suggested. On certain moulting days, the Ss responded well. However, the decrease in average number of responses per session may be due, in part, to an increased sensitivity of the snake's skin during moulting. This increased sensitivity may lead to a decrease in general activity. A snake's skin is so sensitive during moulting that if the old

only in the number of reinforcements indicated.

For S2, records were kept of the average number of responses during moulting and the five sessions preceding and following. The mean number of responses during moulting was less than the mean for the surrounding sessions. In order of occurrence, the averages were 50, 6, and 23 responses per session. S2 had one session with 53 responses while it was moulting.

EXPERIMENT 3

Transition from CRF Wire to FR4 Wire

Because of the difficulties encountered in attempting to transfer S2 from CRF key responding to FR4 key responding, the Es attempted the schedule transition with a contact relay wire for S3. The results on previous snakes had indicated that rates of responding were somewhat higher on the wire than on the key.

Subject 3 began with several days of adaptation to the experimental chamber. Then the wire was placed more than 1 in. above the water hopper at the approximate position of the key. However, the key was nonfunctional during the entire experiment.

Subject 3 averaged 35 responses per session for each of the 30 daily 1.5-h sessions on CRF. The daily total of responses ranged from 0 to 409. The rate might have been somewhat depressed, since the snake had moulted during this phase of the experiment.

Subject 3 was then switched to a FR4 schedule of reinforcement. The mean number of responses per 1.5-h session on FR4 jumped to 226, with a range from 0 to 1,730. A new and interesting pattern of responding was responsible for this increase. On the 4th day of the FR4 schedule, the S put its head in the drinking area and moved its neck (or anterior body) in short rapid movements over the contact wire. This performance would produce all the water the S could drink. The pattern was displayed four times, as revealed in the cumulative records and observed by the Es.

Fig. 2. Comparison of head and neck responding.

In Fig. 2, a normal response pattern of hitting the wire with the head (Fig. 2A) can be compared with the unusual neck responding (Figs. 2B and 2C). Figure 2A represents a total of 192 responses, while Figs. 2B and 2C represent 1,730 and 1,132 responses, respectively.

Records for S3 were also kept for the mean number of responses per 1.5-h session during moulting as well as for the five preceding and following sessions. In order of occurrence, the averages were 50, 16, and 28 responses. S3 made 192 responses on one of the moulting sessions.

DISCUSSION AND CONCLUSIONS

Experiment 1 demonstrated that a snake could be conditioned to touch a contact wire and, after conditioning, make the transition to a key contingency. The response rate after conditioning was much higher than the free-operant level of responding. It was also demonstrated that water was an adequate reinforcer for snakes deprived of water for periods of even less than 24 h.

Because of low response rates, cumulative records had a characteristic step-shaped pattern, usually with a drinking pause only after several reinforcements were delivered. Mammals and birds on a CRF or ratio schedule

skin is removed immediately after the eyes have cleared again, the snake often dies.² The situation is made more complex by evidence that "many species seek water to soak themselves at this time, since they lose a good deal of body liquid along with the old skin [Carr, 1963, p. 102]."

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NOTES

1. The author gratefully acknowledges the many helpful suggestions of Dr. Daniel B. Cruse in this work.
2. Haast, W. Personal communication, 1966.

Variations in fluid intake following shifts between water and saccharin solution

VINCENT DI LOLLO and PETER N. MEYER, *The University of Western Australia, Nedlands, W.A. 6009, Australia*

Four groups of 12 nondeprived rats each were presented with an additional bottle (B2) in the home cage for 1 h each day. Intake from B2 was measured during preshift (10 days), Shift 1 (5 days), and Shift 2 (5 days). The bottle, B2, contained either tap water (W) or .25% saccharin solution (S) for each group as follows: WWW, SSS, SWS, and WSW, where the three letters refer to the contents of B2 during preshift, Shift 1, and Shift 2, respectively. Intake from B2 was uniformly greater when it contained saccharin solution, but neither positive nor negative contrast effects were obtained at any stage of the experiment.

A negative contrast effect is demonstrated if, following a decrement in the amount of reward, performance drops below the level set by a control group always maintained at the lower amount. Conversely, a positive contrast effect is obtained if, following an increment in reward, performance overshoots the appropriate control level. Both phenomena were originally demonstrated by Crespi (1942), who, instead of nonshifted controls, used extrapolated preshift values as the basis for postshift comparisons. The omission of control groups led to the

objection that a positive contrast effect may represent an increment in performance attributable to the effect of additional acquisition trials following the shift (Spence, 1956). The objection was supported by subsequent experimentation that provided ample confirmation of negative, but not of positive, contrast effects under appropriate control conditions (e.g., Schrier, 1967).

A positive contrast effect in the intake of saccharin solution has been reported recently by Gandelman & Trowill (1969). The design involved a group of rats maintained on ad lib food and water throughout. A second bottle, presented to each S for 1 h on each day, contained saccharin solution for the first 13 days, water for the next 3, and again saccharin solution for the final 7 days. The mean amount of saccharin intake during the third stage exceeded that of the first stage, and this was taken as evidence of positive contrast. Clearly, since a control group always maintained on saccharin solution was not run, intake differences between first and third stages could represent the incremental effect of additional trials rather than a positive contrast effect.

The study reported here investigated variations in fluid intake following shifts to both water and saccharin solution in relation to the intake level of nonshifted controls.

SUBJECTS

The Ss were 48 male albino rats from the colony maintained at the University of Western Australia. They were approximately 120 days old at the beginning of the experiment and were housed individually. All Ss were maintained on ad lib food and water throughout the experiment.

PROCEDURE

All testing took place in the home cages. The part of the experimental procedure common to all groups consisted in the presentation of a second bottle (B2) for 1 h each day in addition to the maintenance water bottle (B1) always present in the cage. In every case, B2 was fitted with a leakproof metal spout manufactured by Atco Mfg. Co., Napa, California. The orifice of this type of spout is sealed by two metal balls, one behind the other, that make a distinct clicking sound while the S is licking. The maintenance bottles were fitted with ordinary metal spouts that allowed some leakage and thus obviated accurate measurement of fluid intake. The contents of B2 were either 0.25% (w/v) saccharin solution (sodium saccharin and plain tap water) or just plain tap water, depending on the experimental condition. The experiment was conducted in three stages: preshift (10 days), Shift 1 (5 days), and Shift 2 (5 days). The 48 Ss were assigned randomly to the following four groups of 12 Ss each: Group WWW, Group WSW, Group SSS, and Group SWS. The three letters in each group designation indicate whether B2 contained water (W) or saccharin solution (S) during preshift, Shift 1, and Shift 2, respectively.

RESULTS

The amount of fluid intake from B2 was measured after each daily session, with a resolution of 0.25 ml. The mean B2 intake scores for each group on each day of the experiment are shown in Fig. 1.

By the second day, all Ss drank from B2. During preshift there was a clear separation between the groups receiving saccharin solution and those receiving plain water. On the 1st day of Shift 1, there was a pronounced decrement in the mean intake of Group SWS but only a small, though significant, increment in Group WSW [$F(1,11) = 6.98, p < .05$]. During Shift 1, the mean intake of Group WSW increased markedly and that of Group SWS showed a gradual decrement, but neither group reached the level of the respective controls. Over the 5 days of Shift 1, Group SWS drank more from B2 than did the WWW controls [$F(1,22) = 10.63, p < .005$].

On the 1st day of Shift 2, Group WSW showed a sudden drop in mean intake, and Group SWS showed a sudden increment