CONCURRENT AVOIDANCE OF SHOCKS BY PIGEONS PECKING A KEY

ELENICE A. DE MORAES FERRARI AND JOÃO CLAUDIO TODOROV

UNIVERSIDADE ESTADUAL DE CAMPINAS AND UNIVERSIDADE DE BRASÍLIA

Three pigeons were studied on concurrent, unsignaled, avoidance schedules in a two-key procedure. Shock-shock intervals were two seconds in both schedules. The response-shock interval on one key was always 22 seconds, while the response-shock interval associated with the other key was varied from 7 to 52 seconds in different experimental conditions. Response rates on the key associated with the varied schedule tended to decrease when the response-shock interval length was increased. Responding on the key associated with the constant schedule was not systematically affected.

Key words: concurrent schedules, unsignaled avoidance, negative reinforcement, key pecking, pigeon

Although the investigation of concurrent schedules of positive reinforcement has been extensive (cf. Catania, 1966; de Villiers, 1977; de Villiers & Herrnstein, 1976; Herrnstein, 1970), there have been few studies of concurrent schedules of negative reinforcement. A few studies have examined schedules of negative reinforcement as one component of the concurrent pair (e.g., Catania, Deegan, & Cook, 1966) and others have studied procedures in which the schedules were not independent (e.g., Verhave, 1961). Sidman (1962), using avoidance schedules, was the first to study concurrent independently programmed schedules of negative reinforcement. Baum (1973) studied time allocation in concurrent variable-interval schedules of timeout from shocks. More recently, data on choice between shock-free periods in concurrent chained schedules (Hutton, Gardner, & Lewis, 1978; Lewis, Moon, & Hutton, 1976) and data on concurrent variable-interval avoidance schedules have been reported (Logue & de Villiers, 1978; Poling, 1978).

In previous experiments, negative reinforcement has been used to both train pigeons to peck keys and then to maintain the behavior (Alves de Moraes & Todorov, 1977; Ferrari, Todorov, & Graeff, 1973; Gorayeb & Todorov, 1977; Todorov, Ferrari, & Souza, 1974). The present experiment extended these investigations to concurrent schedules of negative reinforcement using a procedure similar to Sidman's (1962).

METHOD

Subjects

Three adult pigeons from uncontrolled derivations of the species *Columba livia* and caught wild, were used. A fourth pigeon was eliminated from the experiment because of persistent responding on only one key. Their average weight was 321 g, with average height of 24 cm. Pigeon MF3 was experimentally naive; the other two had experience with unsignaled (Pigeon DL) or signaled (Pigeon CG) avoidance schedules. During the experiment the birds lived in individual home cages and had free access to food and water.

Apparatus

A standard chamber measuring 33 by 30 by 32.5 cm was used. Two translucent response keys 2 cm in diameter, separated by 4 cm, were located in one wall, 21 cm from the floor and 12.5 cm from the side walls. The right response key could be transilluminated by a

This report is based on a dissertation submitted by Elenice A. de Moraes Ferrari to the Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto as a partial requirement for the degree of Doutor em Ciências. The research was supported by grant 70/1440 from the Fundação de Amparo à Pesquisa do Estado de São Paulo to J. C. Todorov. Reprints may be obtained from Elenice A. de Moraes Ferrari, Departamento de Fisiologia e Biofísica, Universidade Estadual de Campinas, 13100 Campinas, S.P., Brasil.

red light and the left key by a yellow light. Houselights were off throughout the experiment. A minimum force of .1 N was required to operate the response keys.

Subjects had electrodes chronically implanted around the pubis bones (Azrin, 1959). Shock duration (35 msec) was controlled by a pulse former and delivered through a modified Foringer shock source equipped with a 40-k ohm series resistor. Shock intensity (10mA) was measured by using a 1-k ohm resistor in place of the birds. Shock-shock (SS) and response-shock (RS) intervals were controlled by electronic timers. Standard electromechanical equipment, located in a separate room, was employed for automatic scheduling and recording of events.

Procedure

Shaping and maintenance of unsignaled avoidance behavior. Bird MF3 was trained with the shaping procedure described by Ferrari et al. (1973). Birds DL and CG had been used in an earlier experiment with the same procedure. The major characteristics of this procedure were: (a) differential reinforcement (through interruption of a train of shocks) of successive approximations to the key-pecking response, (b) manual control of the shock intensity, and (c) the key light as the only source of illumination. Only the right key was transilluminated (red); the left key was dark and inoperative. Once key pecking occurred, a free operant avoidance schedule (Sidman, 1953) was instituted with the RS interval equal to 22 sec and the SS interval equal to 2 sec. The duration of the shaping sessions was 2 hr or the time necessary for the emission of 100 key-pecking responses, whichever happened first. This training continued with daily sessions of 90 min until all pigeons were receiving less than 20% of scheduled shocks.

Introduction to concurrent schedules of unsignaled avoidance. In this phase, all subjects were exposed to a procedure designed to induce responding on both keys. The right key now was yellow and the left key red. Only one key was lit per session, the operative key alternating each session. The RS and SS intervals (22 and 2 sec, respectively) were the same for each key. Daily alternation was continued until less than 20% of shocks programmed by the SS timer were received for six

consecutive sessions. The next phase was characterized by the successive alternation of the red and yellow keys within the session. Two avoidance schedules (both with RS = 22 sec, SS = 2 sec) were associated with the two keys and presented in succession, i.e., as a multiple schedule. Initially each schedule was presented during 45 min (half of the session); component duration was diminished successively to 30, 15, and 5 min, with at least six sessions at each duration.

The concurrent schedule was introduced during the next session. Component durations of the multiple schedule were progressively reduced from 5 min until both response keys were simultaneously illuminated, so that concurrent avoidance schedules, with RS = 22 sec, SS = 2 sec in one component (red), and RS = 22 sec, SS = 2 sec in the other (yellow), were in effect. Two independent timers controlled the RS and the SS intervals for each schedule, delivering the shocks programmed for each schedule. The components were in effect simultaneously and independently so that, on this schedule, pecks on a given key were effective only with regard to the schedule associated with that key. Thus, pecking the yellow key was ineffective regarding the contingencies established by the avoidance schedule associated with the red key, and vice versa. Changeovers were recorded when a given key was pecked following one or more pecks in the other key.

Manipulation of RS interval. Different conditions were established through the manipulation of the RS intervals associated with the left red key with durations ranging from 7 to 52 sec. The RS interval associated with the right yellow key always was set at 22 sec. Other features of the schedules, SS intervals (2 sec), shock duration (35 msec), and shock intensity (10 mA) remained the same throughout conditions. Values of the RS interval (red) were studied in the sequence 22, 12, 32, 7, 17, and 52 sec. Each condition continued for at least 14 daily 90-min sessions and until response and shock rates were stable. The stability criterion required that for the last six sessions: (a) the average rates from the first three and last three sessions did not differ by more than 10% of the average of all six sessions; (b) the rates did not differ more than 10% from the minimum or maximum value of the last ten sessions in that condition; and (c)

the rates did not show ascending or descending trends.

RESULTS

Figure 1 shows 5 min samples of cumulative records from the three subjects, taken from the last session under three of the schedules (RS = 17 and 22; RS = 22 and 22; RS = 32 and 22). The samples are representative of behavior throughout the session. For Birds MF3 and DL, the distribution of vertical marks, indicating shocks delivered, shows that responses typically followed shocks on the key associated with the shorter RS interval, while responses tended to occur later on the key associated with the longer RS interval. Direct observation of these two subjects showed that after shocks on one schedule, responses occurred on both keys. This characteristic pattern of alternate responding resulted in postshock responses in

the shorter RS interval component and pre-shock responses in the longer RS interval component. Cumulative records for Bird CG indicate a characteristic pattern of sustained responding, with longer periods of continual responding on the key associated with the shorter RS interval. Spaced responding occurred on both keys, however.

Figure 2 shows mean response rates on each key and changeover rates over the last six sessions of each condition. No session deviated by more than 10% from the average points. Duplicated points indicate replication of two schedules for Bird MF3 (RS = 7 and 22 sec; RS = 17 and 22 sec). Responses rates on the red key tended to decrease with increases in RS interval duration associated with that key. Responding on the yellow key was not systematically affected; for Birds MF3 and DL, response rates on yellow tended to decrease whereas rates did not vary for Bird CG.

Changeover data are presented for one direction, computed as half of the total number of changeovers. For all three subjects, the rates tended to decrease as the RS interval associated with the red key was increased. The data for the three birds differ, however, as to the relationship of changeover rates to response rates on the red key. For Birds MF3 and DL, there was an approximately constant number of

Fig. 1. Cumulative response records for Birds MF3, DL, and CG, for the last session in the experimental condition. Shocks are shown as vertical deflections of the pen. For each pair of curves, the upper one refers to responding on the red key, and the lower one to responding on the yellow key. Corresponding RS values are shown at the bottom of each column.

Fig. 2. Rates of responses and changeovers as a function of the RS interval on the red key. Rates are averages over the last six sessions of each condition. Filled circles refer to data from the red key, unfilled circles to data from the yellow key, and triangles to changeovers. For Bird MF3 the first determination of the duplicated points is indicated by the number 1.

responses on the red key for each changeover, while for Bird CG that ratio tended to decrease as the RS interval on the red key was increased.

Figure 3 shows rates of shocks received on each schedule as a function of the RS interval associated with the red key. The points are averages over the last six sessions of each condition, with a maximum deviation of 10% from the mean values. For Bird MF3, the number of shocks tended to decrease with increases in RS length associated with the red key, while shocks from the RS interval associated with the constant (yellow) component varied asystematically (between 24 and 200 shocks/hr). Similar trends are shown in the data for Bird DL, except for the longest RS interval (52 sec). For Birds MF3 and DL, shock rates always were higher on the schedule associated with the shorter RS interval of the concurrent pair. Data for Bird CG show rates lower than those for the other birds. For this subject, moreover, with RS intervals between 12 and 52 sec, changes in the RS interval associated with the red key did not systematically affect rates of shock on either schedule.

DISCUSSION

The present results indicate the acquisition and maintenance of stable rates of key pecking by pigeons on concurrent free-operant avoidance schedules. Response rates on the key associated with the varied schedule (red) were inversely related to the duration of the RS

interval programmed for that key, decreasing as the duration increased. These results replicate and extend previous findings regarding key pecking by pigeons shaped and maintained through negative reinforcement (Ferrari et al., 1973; Gorayeb & Todorov, 1977; Todorov et al., 1974), and performances of rats on concurrent schedules of shock avoidance (Sidman, 1962).

An interesting feature of the data is that the rate of responding in the constant component (yellow) did not increase as the response rate on the varied key decreased; in other words, the data provide no evidence of behavioral contrast (cf., Catania, 1973; Rachlin, 1973; Reynolds, 1961). This finding extends to concurrent schedules the observations reported by Gorayeb and Todorov (1977) on multiple schedules of free operant avoidance of shocks by pigeons pecking a key.

For two birds (MF3 and DL), decreased responding on the varied key was accompanied by decreased responding associated with the constant component (yellow). These subjects characteristically responded on both keys after shocks, and most of the shocks delivered were scheduled by the shorter RS interval of the concurrent pair. This pattern, also observed by Sidman in rats (1962, p. 257), results in a general tendency for a decrease in response rates on each key as the RS interval in the varied component is increased. By comparison, the data for Bird CG show a predominant continual responding pattern for most of the values of RS length used, and response rates on the constant (yellow) key were not systematically affected by changes in the RS associated with the red key. It is not clear why the procedure generated such different patterns of responding. The species and/or the operant selected for the study cannot serve as explanations for these differences, since related findings on the response patterns were reported by Sidman (1962) for bar pressing by rats in a similar procedure.

REFERENCES

- Alves de Moraes, A. B., & Todorov, J. C. Signalled free-operant avoidance of shock by pigeons pecking a key. *Journal of the Experimental Analysis of Behavior*, 1977, 27, 281-291.
- Azrin, N. H. A technique for delivering shock to pigeons. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 161-163.

Fig. 3. Received shock rates as a function of the RS interval on the red key. Rates are averages over the last six sessions in each condition. Filled symbols refer to data from the red key and unfilled symbols to data from the yellow key. For Bird MF3 the first determination of the duplicated points is indicated by the number 1.

- Baum, W. M. Time allocation and negative reinforcement. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 313-322.
- Catania, A. C. Concurrent operants. In W. K. Honig (Ed.), *Operant Behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966.
- Catania, A. C. Self-inhibiting effects of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 517-526.
- Catania, A. C., Deegan, J. F., & Cook, L. Concurrent fixed-ratio and avoidance responding in the squirrel monkey. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 227-231.
- de Villiers, P. A. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- de Villiers, P. A., & Herrnstein, R. J. Toward a law of response strength. *Psychological Bulletin*, 1976, **83**, 1131-1153.
- Ferrari, E. A. M., Todorov, J. C., & Graeff, F. G. Non-discriminated avoidance of shock by pigeons pecking a key. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 211-218.
- Gorayeb, R., & Todorov, J. C. Key pecking maintained by negative reinforcement: Multiple schedules. *Mexican Journal of Behavior Analysis*, 1977, **3**, 161-168.
- Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, **13**, 243-266.
- Hutton, L., Gardner, E. T., & Lewis, P. Matching with a key-peck response in concurrent negative reinforcement schedules. *Journal of the Experimental Analysis of Behavior*, 1978, **30**, 225-230.
- Lewis, P., Moon, L., & Hutton, L. Choice between shock-free times in concurrent avoidance schedules. *Bulletin of the Psychonomic Society*, 1976, **8**, 395-398.
- Logue, A. W., & de Villiers, P. A. Matching in concurrent variable-interval avoidance schedules. *Journal of the Experimental Analysis of Behavior*, 1978, **29**, 61-66.
- Poling, A. Performance of rats under concurrent variable-interval schedules of negative reinforcement. *Journal of the Experimental Analysis of Behavior*, 1978, **30**, 31-36.
- Rachlin, H. Contrast and matching. *Psychological Review*, 1973, **80**, 217-234.
- Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 57-71.
- Sidman, M. Two temporal parameters of the maintenance of avoidance behavior by the white rat. *Journal of Comparative and Physiological Psychology*, 1953, **46**, 253-261.
- Sidman, M. Reduction of shock frequency as reinforcement for avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 247-257.
- Todorov, J. C., Ferrari, E. A. M., & Souza, D. G. Key pecking as a function of response-shock and shock-shock intervals in unsignalled avoidance. *Journal of the Experimental Analysis of Behavior*, 1974, **22**, 215-218.
- Verhave, T. Some observations concerning prepotency and probability of postponing shock with a two-lever avoidance procedure. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 187-192.

Received September 6, 1977

Final acceptance May 27, 1980