*EFFECTS OF RESPONSE-SHOCK INTERVAL AND SHOCK
INTENSITY ON FREE-OPERANT AVOIDANCE
RESPONDING IN THE PIGEON¹*

MARTY KLEIN AND MARK RILLING

MICHIGAN STATE UNIVERSITY

Two experiments investigated free-operant avoidance responding with pigeons using a treadle-pressing response. In Experiment I, pigeons were initially trained on a free-operant avoidance schedule with a response-shock interval of 32 sec and a shock-shock interval of 10 sec, and were subsequently exposed to 10 values of the response-shock parameter ranging from 2.5 to 150 sec. The functions relating response rate to response-shock interval were similar to the ones reported by Sidman in his 1953 studies employing rats, and were independent of the order of presentation of the response-shock values. Shock rates decreased as response-shock duration increased. In Experiment II, a free-operant avoidance schedule with a response-shock interval of 20 sec and a shock-shock interval of 5 sec was used, and shock intensities were varied over five values ranging from 2 to 32 mA. Response rates increased markedly as shock intensity increased from 2 to 8 mA, but rates changed little with further increases in shock intensity. Shock rates decreased as intensity increased from 2 to 8 mA, and showed little change as intensity increased from 8 to 32 mA.

Non-discriminated or free-operant avoidance was first studied by Sidman (1953a) in an attempt to bring avoidance behavior from the discrete trial to the free-operant paradigm, and to disentangle escape and avoidance. The free-operant avoidance schedule is defined by two temporal parameters; the response-shock (R-S) interval, the period of time that each response postpones the shock, and the shock-shock (S-S) interval, the period of time between shocks in the absence of a response. Since his original experiments, Sidman (1953a, 1953b) and several other investigators (Verhave, 1959; Clark and Hull, 1966; Scobie, 1970) have performed parametric studies of free-operant avoidance behavior, varying R-S intervals, S-S intervals, and shock intensity (Boren, Sidman, and Herrnstein, 1959; Riess, 1970). Most of these studies employed rats or monkeys as subjects. Recently however, Smith and Keller (1970), Foree and LoLordo (1970), and Rossi and Rilling (1971) reported avoidance in the pigeon using a foot-treadle response.

The present studies were conducted in order to investigate, with pigeons using a treadle re-

sponse, the effects of R-S interval duration and shock intensity on free-operant avoidance of electric shock.

GENERAL METHOD

Subjects

Eight experimentally naive, White Carneau pigeons were housed in individual home cages with free access to food and water. The subjects had stainless steel electrodes implanted through the pubic arch, and wore a leather harness with an electrical connector on the back (Azrin, 1959).

Apparatus

Following Smith and Keller (1970), the size of the experimental chamber was substantially reduced in comparison with the conventional pigeon chamber in order to increase the probability of a treadle response. The chamber was a Plexiglas box 11.5 in. high by 8 in. wide by 8.5 in. deep (29.2 by 20.3 by 21.6 cm), with a foot treadle 2.25 in. long by 3.5 in. wide (5.7 by 8.9 cm). The treadle was centered on the front wall, extending 2.5 in. (6.1 cm) into the chamber, with the edge nearer the pigeon 1 in. (2.54 cm) lower than the distant edge, resulting in the treadle being at a 30° angle to the floor. A force of 40g (0.40N) and a downward displacement of 0.50 cm were required to operate

¹This investigation was supported in part by PHS Research Grant 1 R01 MH 18342 from the National Institute of Mental Health. Reprints may be obtained from Marty Klein, Department of Psychology, Michigan State University, East Lansing, Michigan 48823.

a microswitch connected to the treadle. The box was mounted in a sound attenuating enclosure with an exhaust fan providing masking noise. A 5-w houselight mounted on the ceiling of the chamber was on throughout the session. Electromechanical equipment arranged the avoidance schedule, and interresponse time (IRT) distributions for Experiment I were recorded on a printout counter. A cumulative recorder was used to monitor changes in day-to-day patterns of responding.

A coiled cable, attached to a mercury swivel, provided the connection from the shock source to the pigeon harness. The shock source for Experiment I was a 7.8-v ac transformer, adjustable from 0 to 7.8 v via a Variac. The shock source for Experiment II was a 64-v ac transformer, adjustable from 0 to 64 v. Duration of shock was 0.25 sec in both experiments. The implanted electrodes were cleaned regularly to reduce changes in resistance. Cleaning was accomplished by rotating the implanted portion of the stainless steel loops into an exposed position, and scraping the deposits with a small knife blade. A Wheatstone bridge measured internal resistance before each session, and the shock transformer voltage output was adjusted accordingly.

EXPERIMENT I: THE EFFECTS OF
CHANGES IN THE RESPONSE-
SHOCK INTERVAL

Procedure

Four pigeons were initially studied with an R-S interval of 32 sec, an S-S interval of 10 sec, and an 8-mA shock of 0.25-sec duration. As each pigeon satisfied the stability criteria (described below), the R-S interval was varied according to one of several random sequences. Ten values of the R-S interval were studied in

each bird (2.5, 4, 7, 10, 15, 20, 32, 50, 90, 150 sec). Shock intensity, shock duration, and S-S interval were not changed during the experiment.

Two criteria were used to determine when the behavior was stable: (1) 5% or less difference between the mean response rate during one block of three sessions and the mean response rate during the next block of three sessions; and (2) five percentage points or less difference in the mean percentage of S-S shocks avoided over the same two consecutive blocks of three sessions. Table 1 shows the order of presentation of the R-S intervals and the number of sessions to criterion at each interval.

Grouping successive sessions into blocks of three was selected as a way of taking into account the day-to-day changes in the pigeon's sensitivity to shock (Rachlin and Hineline, 1967), and of allowing for the development of response trends. For example, if Block A and Block B were more than 5% different in mean response rates or per cent avoidance, then Session 1 of Block A was dropped from consideration and Session 1 of Block B became Session 3 of Block A. A new session was then added as Session 3 of Block B. The data point recorded for a particular R-S interval was computed as the average of these two means, and is thus based upon data from the last six sessions on an R-S interval.

All data reported here were obtained from the last 32 min of the daily 1-hr sessions. The first 28 min were not used, due to a warm-up effect (Sidman, 1953*b*; Hoffman, Fleshler, and Chorny, 1961; Wertheim, 1964), and the complicating fact that the period of warm-up was a product of several variables, including amount of training, S-S interval duration, sensitivity to shock, and duration of R-S interval (Hoffman, *et al.*, 1961).

Table 1

Order of presentation of R-S values and number of sessions to criterion at each value for four pigeons. The R-S value (seconds) is given to the left of the slash mark; the number of sessions to criterion at each R-S value is given to the right of the slash mark.

Pigeon	Order of Presentation									
	1	2	3	4	5	6	7	8	9	10
# 5	32/51	15/7	2.5/8	90/11	4/27	7/11	20/6	150/6	50/11	10/13
#21	32/54	10/20	7/6	50/10	20/6	15/7	90/6	4/15	150/7	2.5/13
#83	32/59	90/23	150/20	20/6	2.5/8	15/8	10/6	7/6	4/30	50/11
#88	32/47	50/16	20/6	10/10	15/8	90/7	7/6	4/15	2.5/12	150/10

RESULTS

The functions relating response rate to R-S interval duration were similar to those reported by Sidman (1953b) in rats, and were independent of the order of presentation of R-S values. Figure 1 (upper frame) shows that, as duration of the R-S interval increased, response rates increased and reached a maximum at an R-S interval of 7 sec for all subjects except Bird 83. Bird 83, which responded at higher rates than the other birds throughout the experiment, had a maximum rate at an R-S interval of 4 sec. Response rates for all birds decreased as R-S interval duration increased beyond 7 sec.

The heavy dashed line in the upper frame of Figure 1 represents the minimum response rate necessary to postpone all shocks at each R-S value. At R-S values greater than 4 sec, all birds responded at rates higher than necessary for avoiding all shocks. At R-S values of 2.5 and 4 sec, only Bird 83 responded at a high enough rate to avoid all shocks.

Fig. 1. Response rate (upper frame) and shock rate (lower frame) as a function of R-S interval duration in four pigeons. Each data point is the mean of the last six sessions at each duration. There were 192 S-S shocks scheduled (S-S = 10 sec).

The lower frame of Figure 1 shows shock rate as a function of R-S interval duration. The heavy dashed horizontal line indicates the shock rate in the absence of responding, *i.e.*, the shock rate scheduled by the S-S timer. It was possible for the birds to receive higher shock rates than scheduled by the S-S timer only when the R-S interval was less than the S-S interval, since, at these brief intervals, a response before S-S minus R-S sec in the S-S interval decreased the time to the next scheduled shock rather than postponing it.

Figure 1 (lower frame) shows that as R-S interval duration increased, shock rate decreased for all birds. At longer R-S intervals, shock rates were quite low, while at R-S values below 7 sec, three of four birds (5, 21, 88) received shocks at a rate nearly as high, or higher, than the rate scheduled in the absence of responding. Only Bird 83, with its high response rate (upper frame) maintained low shock rates at brief R-S intervals.

During acquisition of the avoidance response, all birds responded in a "burst" pattern (Ellen and Wilson, 1964; Sidman, 1966) in which responses occurred immediately after the shock and were followed by a shock at the end of the R-S interval. During exposure to the first or second R-S value, three of four birds (21, 83, 88) shifted to the "continual" pattern (Ellen and Wilson, 1964), in which responses were spaced in such a manner as to result in low shock rates. The differences in response patterns are reflected in Figure 1 (lower frame), which shows that Bird 5, which responded in a burst pattern at all but the two longest intervals, had the highest shock rates. Bird 21 received a relatively high shock rate at R-S = 32 sec, the first R-S value studied, where it responded in a burst pattern. It switched to the continual pattern before stabilizing at the second R-S value. Bird 88 responded in a burst pattern at R-S = 10 sec.

Figure 2 shows IRT/OP data (Anger, 1963). This statistic was computed for each 2-sec class interval by dividing the number of IRTs within a class interval by the number of IRTs exceeding the lower limit of that class interval, *i.e.*, by the number of opportunities (OP) for that IRT to occur. Although temporal discriminations were evident within some R-S intervals (arrows in Figure 2), the probability of a response burst, *i.e.*, a response in the 0 to 2-sec category, was high for all R-S values. All

four birds had some degree of temporal discrimination at R-S values in the 10- to 20-sec range. At long R-S values, where there were no apparent temporal discriminations, the tendency was to respond early in the R-S interval. However, all birds had quite low shock rates at these long R-S values (lower frame, Figure 1).

EXPERIMENT II: THE EFFECTS OF CHANGES IN SHOCK INTENSITY

Procedure

Each of four birds (98, 553, 803, 952) acquired free-operant avoidance behavior on a schedule with an R-S interval of 20 sec, an S-S interval of 5 sec, and an 8-mA shock of 0.25-sec duration. As each bird satisfied the stability criteria, which were the same as in Experiment I, the shock intensity was varied according to one of several random sequences. There were five values through which the shock intensity was manipulated for each bird (2, 4, 8, 16, 32 mA). Bird 952, however, died after exposure to only three values (2, 4, 8 mA). R-S interval duration, S-S interval duration, and shock duration were constant throughout the experiment. Table 2 shows the order of presentation of the intensities and the number of sessions to criterion at each intensity.

As in Experiment I, all data were obtained from the last 32 min of daily 1-hr sessions.

RESULTS

Figure 3 (upper frame) shows that, as the shock intensity increased from 2 to 8 mA, the response rates increased for all birds, but as

Table 2

Order of presentation of shock intensities and number of sessions to criterion at each intensity for three pigeons. The shock intensity (mA) is given to the left of the slash mark; the number of sessions to criterion at each intensity is given to the right of the slash mark.

Pigeon	Order of Presentation				
	1	2	3	4	5
# 98	8/16	4/7	16/6	2/6	32/9
#553	8/16	16/6	4/7	32/7	2/6
#803	8/24	16/10	32/6	2/9	4/22
#952	8/20	2/8	4/8	—	—

shock intensity continued to increase from 8 to 32 mA, only Bird 803 showed continued increases in response rates, while Birds 98 and 553 showed slight decreases in response rates. The heavy dashed horizontal line in the upper frame represents the minimum response rate necessary to postpone all shocks.

The lower frame of Figure 3 shows that as shock intensity increased from 2 to 8 mA, shock rates decreased sharply, but as intensity continued to increase from 8 to 32 mA, shock rates levelled off for Bird 803, and increased slightly for Birds 98 and 553. The heavy dashed horizontal line in the lower frame indicates the shock rate in the absence of responding.

DISCUSSION

In Experiment I, the decreasing response rates to the left of the maxima in Figure 1 (upper frame) were interpreted by Sidman (1953*b*) as a delay of punishment gradient. As the R-S interval decreases, the probability that an avoidance response will be closely followed by a shock increases, which decreases the probability of an avoidance response. The delay of punishment interpretation was experimentally verified by Baron, Kaufman, and Fazzini (1969), who varied the delay between an avoidance response and punishment. Their general finding was that response-produced shock suppressed avoidance responding under most of the delay conditions studied. Suppression increased as a function of decreases in the delay.

At brief R-S intervals, a response occurring before S-S minus R-S sec in the S-S interval decreases the time to the next scheduled shock, rather than postponing it. Thus, in order to minimize shock at brief R-S intervals, the bird must respond continually at a high rate, or not respond at all. Figure 1 shows that the birds, with the exception of Bird 83, did neither. With continued exposure to a brief R-S interval there was a tendency to cease responding, which is shown by response rates below the heavy dashed line (upper frame). However, at these brief R-S intervals, shock-elicited responses (responses occurring within 2 sec of shock) occurred before S-S minus R-S sec in the S-S interval. This resulted in shock densities of the same order of magnitude, and sometimes greater, than the S-S scheduled base-

Fig. 2. Interresponse time per opportunity as a function of R-S interval duration for four pigeons. Data are based upon the IRT distributions pooled over the last three sessions at each R-S interval. Each data point is the conditional probability of a response occurring in that 2-sec interval, given that the bird did not respond in an earlier interval. Categories with fewer than 20 opportunities are excluded. Arrows indicate apparent temporal discriminations.

Fig. 3. Response rate (upper frame) and shock rate (lower frame) as a function of shock intensity in four pigeons. Each data point was computed from the mean of the last six sessions at a given intensity. There were 384 S-S shocks scheduled (R-S = 20 sec, S-S = 5 sec).

line. This appears as shock rates higher than the heavy dashed line in the lower frame of Figure 1.

The typically high probability of a burst of responses shown in Figure 2 was due, at least in part, to the response topography. Unsystematic observation of the birds revealed that many of the responses were emitted in rapid sequence, rather than as single responses. Wertheim (1964) found, with rats on free-operant avoidance (R-S = 20 sec), that IRTs longer than 16 sec were likely to be followed by very short IRTs. Scobie (1970), using gold-

fish on free-operant avoidance, noted that high response rates, relative to the minimum rate necessary for avoiding all shocks, were a result of responding much earlier in the R-S interval than required by the avoidance schedule. Since, due to longer response execution times, it was not possible for the goldfish to respond in a burst, comparison of the results is difficult. However, Figure 2 shows that, when a temporal discrimination was absent, the tendency was to respond early in the R-S interval.

Staddon (1965) reported that pigeons failed to adjust to DRL (differential-reinforcement-of-low-response-rates) values of longer than 30 sec—i.e., the median of the IRTs was less than the DRL value. Apparently, similar results hold for free-operant avoidance with pigeons. Ten to 20 sec seems to be the optimal range for formation of a temporal discrimination, since all four birds showed some evidence of temporal discriminations in this range. Longer R-S values resulted in erratic responding, with most responses coming early in the interval. On short R-S intervals, bursting seemed to account for most responding. Sidman (1966, p. 464) suggested that temporal processes are secondary in the acquisition of avoidance behavior, but may play an important role in maintaining the behavior once it is learned. "Efficient avoidance behavior, in terms of the number of shocks an animal avoids successfully, may develop long before the temporal discrimination. . . ." Hineline and Herrnstein (1970) also reported that temporal discriminations were relatively independent of avoidance performance.

Sidman (1966) reported that rats were able to adjust rapidly their temporal discriminations to changes in R-S values. In the present experiment, some of the 10- to 20-sec temporal discriminations were formed in as few as six sessions regardless of the order of exposure to the R-S intervals, so it seems reasonable to assert that once the birds learned efficient free-operant avoidance behavior, they had relatively little trouble adjusting to new R-S values in the 10- to 20-sec range.

In Experiment II, the functions relating shock intensity to response rates (Figure 3, upper frame) are strikingly similar to those reported by Boren, *et al.*, (1959) and Riess (1970), both of whom employed rats as subjects. The generally positive relationship be-

tween response rate and shock intensity, when studied during maintenance of performance, has been shown to hold for unsignalled escape-avoidance (Boren, *et al.*, 1959), signalled escape-avoidance (D'Amato, Fazzaro, and Etkin, 1967), unsignalled escape (Dinsmoor and Winograd, 1958), and unsignalled avoidance (Riess, 1970). On the other hand, during acquisition of these behaviors, intensity has frequently been found to be inversely related to performance (Moyer and Korn, 1964; Levine, 1966; D'Amato and Fazzaro, 1966; Bolles and Warren, 1965). D'Amato *et al.*, (1967) proposed that higher shock levels lead to poorer avoidance acquisition because they result in the conditioning of competing responses, which suppress a wide range of instrumental behaviors. By training at a moderate intensity, the avoidance response becomes dominant in the animal's repertoire, so that when strong shock is introduced after the avoidance response is acquired, the competing responses either no longer occur, or occur to a much reduced degree. Bolles (1970, 1971) extends this interpretation by arguing that an avoidance response is rapidly acquired only by the suppression of other species-specific defense reactions (SSDRs). He proposes that the primary effect of avoidance training is to get rid of competing behavior, and that this is accomplished mainly by the avoidance schedule. Observation of the birds in this experiment lends support to this interpretation. Initially, the birds exhibited much undifferentiated behavior, reacting to shock by jumping and wing flapping. However, as the treadle response increased in frequency, these other responses were reduced, and finally almost disappeared. Each time shock intensities were increased beyond the highest previous level encountered, these behaviors reappeared for a short time, and then disappeared again. When shock intensities were decreased to below the highest previous level encountered, these behaviors did not reappear.

Huff, Piantanida, and Morris (1967) showed that the intensity of the training stimulus may be an important variable. In that study, changes in shock intensity produced shifts in response rates, with the amount and direction of the shift dependent upon both the training intensity and the previous shock level. In the present study, the response rates increased sharply and shock rates decreased sharply

(Figure 3) as shock intensity increased from 2 to 8 mA, where 8 mA was the training stimulus. Further increase in shock intensity produced relatively small changes in response and shock rates. In contrast to these results, Riess (1970) trained rats on free-operant avoidance at 2.5 mA, but the avoidance behavior became asymptotic at 1 mA rather than at 2.5 mA. Thus, the present results may be partially dependent upon the particular value selected as the training stimulus.

Perhaps the most important implication of avoidance studies with pigeons using a treadle response is the support given to Bolles' theory of SSDRs (1970, 1971). It was 17 yr after Sidman's original free-operant avoidance studies with rats (1953a, 1953b) before Smith and Keller (1970), using a small experimental chamber, a moderate shock level, and a foot-treadle response, finally determined the methodological requirements for successful free-operant avoidance conditioning with pigeons. The selection of the proper avoidance response appears to be the crucial variable in determining the success of avoidance conditioning in pigeons. Smith and Keller (1970) suggested that much of the previous difficulty in conditioning avoidance behavior in pigeons was due to the incompatibility of the shock-elicited response (UCR) and the avoidance response. They observed that shock, administered through the pubic arch (Azrin, 1959) results in an upward tilting of the head, a response incompatible with the key-pecking response. In contrast, a treadle response (Smith and Keller, 1970, p. 212) "appears to be quite compatible with other aspects of the UCR, such as jumping and wing flapping." According to Bolles (1970, 1971), only avoidance responses that are SSDRs can be readily acquired. The more similar a response is to a SSDR, the more rapid will be acquisition in an avoidance situation. Since jumping and wing flapping, and hence treadle pushing, are components of running and flying, which are SSDRs of the pigeon (Levi, 1963, p. 373), Bolles' theory appears to account for Smith and Keller's observations.

Bolles' theory also raises an important question about the results of the present, and other similar, studies (Sidman, 1953b; Boren, *et al.*, 1959; Riess, 1970; Scobie, 1970). If selection of the proper avoidance response is so crucial as to make acquisition of an "improper" avoidance response difficult or impossible (Hoffman

and Fleshler, 1959; Rachlin and Hineline, 1967; Macphail, 1968), then response selection may also play a part in determining what behaviors are exhibited once the avoidance response has been acquired. Bolles (1970) compared avoidance behavior in rats using different avoidance responses and showed that the avoidance behavior improved as the responses became more effective, in the functional sense of removing the animal from the situation.

Bolles (1970) also showed that when the avoidance response is not an SSDR, acquisition depends upon a response-produced safety signal (either through response-contingent feedback or signal termination). In the present experiments, there was much response-produced intrinsic and extrinsic feedback. The treadle travel ended with a jarring thump. This feedback may have facilitated the acquisition of the avoidance behavior.

Thus, while the importance of cross-species comparisons is acknowledged, within-species comparisons of different responses are equally important because changes in either feedback conditions or response requirements may lead to changes in the observed behavior.

REFERENCES

- Anger, D. The role of temporal discriminations in the reinforcement of Sidman-Avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 477-506.
- Azrin, N. H. A technique for delivering shock to pigeons. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 161-163.
- Baron, A., Kaufman, A., and Fazzini, D. Density and delay of punishment of free-operant avoidance. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 1029-1037.
- Bolles, R. Species specific defense reactions and avoidance learning. *Psychological Review*, 1970, 77, 32-48.
- Bolles, R. Species-specific defense reactions. In F. R. Brush (Ed.), *Aversive conditioning and learning*. Academic Press, 1971. Ch. 3.
- Bolles, R. and Warren, J. Acquisition of bar press avoidance as a function of shock intensity. *Psychonomic Science*, 1965, 3, 297-298.
- Boren, J., Sidman, M., and Herrnstein, R. Avoidance, escape, and extinction as functions of shock intensity. *Journal of Comparative and Physiological Psychology*, 1959, 52, 420-425.
- Clark, F. and Hull, L. Free operant avoidance as a function of the response-shock = shock-shock interval. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 641-647.
- D'Amato, M. R. and Fazzaro, J. Discriminated lever press avoidance learning as a function of type and intensity of shock. *Journal of Comparative and Physiological Psychology*, 1966, 61, 313-315.
- D'Amato, M. R., Fazzaro, J., and Etkin, M. Discriminated bar-press avoidance maintenance and extinction in rats as a function of shock intensity. *Journal of Comparative and Physiological Psychology*, 1967, 63, 351-354.
- Dinsmoor, J. A. and Winograd, E. Shock intensity in variable-interval escape schedules. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 145-148.
- Ellen, P. and Wilson, A. Two patterns of avoidance responding. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 97-98.
- Foree, D. and LoLordo, V. Signalled and unsignalled free-operant avoidance in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 283-290.
- Hineline, P. and Herrnstein, R. Timing in free-operant and discrete trial avoidance. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 113-126.
- Hoffman, H. and Fleshler, M. Aversive control with the pigeon. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 213-218.
- Hoffman, H., Fleshler, M., and Chorny, H. Discriminated bar-press avoidance. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 309-316.
- Huff, F. W., Piantanida, T. P., and Morris, G. L. Free operant avoidance responding as a function of serially presented variations of UCS intensity. *Psychonomic Science*, 1967, 8, 111-112.
- Levi, W. M. *The pigeon*. Sumpter, S. Carolina: Levi Publishing Co., 1963.
- Levine, S. UCS intensity and avoidance learning. *Journal of Experimental Psychology*, 1966, 71, 163-164.
- Macphail, E. Avoidance responding in pigeons. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 629-632.
- Moyer, D. E. and Korn, J. H. Effects of UCS intensity on the acquisition and extinction of an avoidance response. *Journal of Experimental Psychology*, 1964, 67, 352-359.
- Rachlin, H. and Hineline, P. Training and maintenance of key-pecking in the pigeon by negative reinforcement. *Science*, 1967, 157, 954-955.
- Riess, D. Sidman-Avoidance in rats as a function of shock intensity and duration. *Journal of Comparative and Physiological Psychology*, 1970, 73, 481-485.
- Rossi, R. and Rilling, M. Effects of shock frequency reduction on avoidance responding in the pigeon. *Psychonomic Science*, 1971, 25, 267-268.
- Scobie, S. R. The response-shock—shock-shock interval and unsignalled avoidance in goldfish. *Journal of the Experimental Analysis of Behavior*, 1970, 14, 219-224.
- Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 1953, 118, 157-158. (a)
- 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. (b)
- Sidman, M. Avoidance behavior. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. Appleton-Century-Crofts, 1966. Pp. 448-498.

- Smith, R. and Keller, F. Free-operant avoidance in the pigeon using a treadle response. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 211-214.
- Staddon, J. R. Some properties of spaced responding in pigeons. *Journal of the Experimental Analysis of Behavior*, 1965, 8, 19-27.
- Verhave, T. Avoidance responding as a result of simultaneous and equal changes in two temporal parameters. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 185-190.
- Wertheim, G. Sequential properties of Sidman-Avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 170.

Received: 29 April 1971

(Final acceptance: 21 April 1972)