SIDMAN - AVOIDANCE RESPONDING IN THE PIGEON
AS A RESULT OF CHANGES IN THE
RESPONSE - SHOCK INTERVAL

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ABSTRACT

SIDMAN-AVOIDANCE RESPONDING IN THE PIGEON AS A
RESULT OF CHANGES IN THE RESPONSE-SHOCK INTERVAL.

By

Marty Klein

Pigeons trained, with a treadle pressing response, on a Sidman-
Avoidance schedule of R-S=32, SS=10 were exposed to 10 changes in the
R-S parameter ranging from 2.5 to 150 seconds. The functions relating
response rate to R-S interval duration were found to be similar to the
ones reported by Sidman in his 1953 studies employing rats, and were
independent of the order of presentation of the R-S values. The results
suggest that decreases in response rates at short R-S values were due
to a delay of punishment gradient from increased shock frequencies.
Avoidance percentages were found to decrease, from a high asymptote, as
R-S values decreased. Effectiveness of avoidance behavior was relative-
ly independent of temporal discriminations. Examination of inter-
response times showed that, as on positive reinforcement (DRL) schedules,
the pigeon has little ability to time responses beyond 30 seconds. Ten
to twenty seconds appears to be the optimal range for the formation of
temporal discriminations.

Approved: _____
                 Committee Chairman

Date: _____

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RESULT OF CHANGES IN THE RESPONSE-SHOCK INTERVAL

By

Marty Klein

A THESIS

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To my parents

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INTRODUCTION

Non-discriminated (Sidman) avoidance was first introduced 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. Sidman-Avoidance behavior 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,b) and several
other investigators (Verhave, 1959; Clark and Hull, 1966; Scobie, 1970)
have performed parametric studies of Sidman-Avoidance behavior, varying
R-S intervals, S-S intervals, and shock intensity (Boren, Sidman,
Herrnstein, 1959). One noteable factor is common to all of these
previous experiments -- none employed pigeons as subjects.

The difficulty of conditioning escape and avoidance in pigeons is
a well documented phenomenon. The selection of the response appears to
be a crucial variable in determining the success of avoidance condition-
ing in pigeons. Hoffman and Fleshler (1959), using the head lifting
response in discriminated avoidance, reported limited success with one
bird after 3500 tone-shock pairings. Rachlin and Hineline (1967), using
the key-peck response, reported similar difficulty in training pigeons
to escape from an increasing train of shocks, Macphail (1968), after
failing to condition the key peck response in discriminated avoidance,
was successful using a running response in a one way shuttle box.
Bedford and Anger (1968), who employed a shuttle response of flying,
also reported successful discriminated avoidance conditioning. But no

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one, until recently, succeeded in conditioning Sidman-Avoidance in pigeons.

Smith and Keller (1970), using a small experimental chamber, a foot treadle response, and a moderate shock level, were the first to identify the methodological requirements for successful Sidman-Avoidance conditioning with pigeons. Foree and LoLordo (1970) also demonstrated the efficacy of the foot treadle response. Smith and Keller (1970) suggest that much of the previous dufficulty in conditioning avoidance behavior in pigeons was due to the shock-elicited response (UCR) being incompatible with 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), only avoidance responses which are species specific defense reactions can be rapidly acquired. Since jumping and wing flapping, and hence treadle pushing, are components of running and flying, which are species specific defense reactions of the pigeon, Bolles' theory appears to account quite well for Smith and Keller's observations.

The present study was conducted in order to investigate, with pigeons using a treadle response, the effects of R-S interval duration on the steady-state performance of Sidman-Avoidance behavior.

METHOD

Subjects: Four experimentally naive, white Carneax 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 lived continuously in a leather harness with an electrical

connector on the back (Azrin, 1959).

Apparatus: Following Smith and Keller (1970), the size of the experi-

mental chamber was substantially reduced in comparison with the

conventional pigeon chamber in order to increase the probability of a

treadle response. The apparatus consisted of a modified plexiglass

Skinner 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 response mechanism 2.25 in. long by

3.5 in. wide (5.7 by 8.9 cm.). The foot treadle was mounted on the

vertical mid-line of the front wall, extending 2.5 in. (6.1 cm.) into

the chamber with its forward edge 1 in. (2.54 cm.) above the floor

The rear edge of the treadle was 1.13 in. (2.86 cm.) higher than the

front edge, resulting in the treadle being at a 30° angle to the floor.

A force of 40g and a displacement of 0.50 cm. were required to operate

a microswitch connected to the treadle. The Skinner box was mounted in

a sound attenuated chamber 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 programmed the Sidman-Avoidance

contingencies, and interresponse time (IRT) distributions were recorded

on a print out counter. The response was depression, or release and

depression, of a foot treadle. A cumulative recorder was used to monitor

gross changes in day to day patterns of responding.

A coiled plug, attached to a Mercury swivel, provided the connection from the shock source to the pigeon harness. The shock source was a 7.8v a.c. transformer, adjustable from 0 to 7.8 volts via a Variac. Duration of shock was 0.25 second. The implanted electrodes were cleaned regularly to keep resistance, and thus shock intensity, within narrow limits. This 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 was used to measure internal resistance before each session.

Procedure: Initial training replicated Smith and Keller's (1970) procedure, with R-S=32 sec., S-S=10 sec., shock=6.2v a.c., and shock duration = 0.25 sec. As each bird satisfied the stability criteria, the R-S interval was varied according to one of several sequences used by Sidman (1953b). There were 10 values through which the R-S interval was manipulated for each bird (2.5, 4, 7, 10, 15, 20, 32, 50, 90, 150 seconds). The primary difference between this procedure and Sidman's is that each bird began on the same R-S value (32 sec.). Shock intensity (6.2v a.c.), shock duration (0.25 sec.), and S-S interval (10 sec.) were held constant throughout the experiment.

As this study was concerned with asymptotic rather than transitory behavior, two stability criteria, based upon pilot data, were used to determine when the behavior was asymptotic: (a) 5% or less variation between mean response rates of two consecutive blocks of three sessions; and (b) five percentage points or less difference in mean percentage of shock avoidance over the same two consecutive blocks of three sessions.

Comparing mean response rates and mean percent avoidance of consecutive blocks of three sessions was selected as a way of taking into account the day to day changes in the pigeons' sensitivity to shock (Rachlin and Hineline, 1967), and also allowing for the development of response trends. For example, if Block A of three sessions and Block B of three sessions were more than 5% different in mean response rates or percent avoidance, then session one of Block A was dropped from consideration and session one of Block B became session three of Block A. A new session was then used as session three 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.

The criterion of less than five percentage points difference between mean avoidance rates, used alone, would have revealed little about the spacing of responses (Hineline and Herrnstein, 1970). However, used in conjunction with a limited range of response rates, it was an indicator of similar temporal spacing of responses between sessions -- a necessary indication of stable behavior since the mean response rate of Block A could have been a product of massed responding and still equal the mean response rate of Block B, which might have been the product of spaced responding.

All data used in this study, with the exception of percent of time on the S-S interval, was obtained from the last 32 minutes of the daily one hour sessions. The first 28 minutes was not used due to the warm up effect (Sidman, 1953b; Hoffman, et al, 1961; Wertheim, 1964), and the confounding fact that the period of warm up is a product of other variables, such as amount of training, S-S interval duration, and

sensitivity to shock, in addition to duration of R-S interval (Hoffman, et al, 1961).

RESULTS AND DISCUSSION

The functions relating response rate to R-S interval duration were found to be similar to the ones reported by Sidman in his 1953 studies employing rats, and were independent of the order of presentation of R-S values. Figure 1 shows that, as the length of the R-S interval decreases, response rates increase up to a point in the vicinity of R-S = .5 (S-S). At this point, as R-S decreases, there is a drop in response rate. This peak occurs at R-S = 7 sec. for all subjects except bird 83, where the peak occurred at R-S = 4 sec. Bird 83 responded at higher rates than the other birds, at each data point, throughout the experiment.

Sidman and Anger (Sidman, 1966; Anger, 1963) call R-S = .5 (S-S) the "critical ratio". This is the point at which, assuming the responses are randomly spaced in time, the probability becomes higher than 0.5 that the animal will increase the frequency of shock by pressing the lever at certain rates -- i.e. the animal is more likely to decrease the time to the next shock than to postpone it. For example, with S-S = 10 seconds, if the animal does not press the lever it receives a shock every 10 seconds. But with R-S = 5 seconds, if the animal presses the lever once within the first half of the S-S interval, it receives the shock five seconds after the response -- earlier than if it had waited out the S-S interval.

The decreasing rates to the left of the maxima were interpreted by Sidman (1953b) 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

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experimentally verified by Baron, Kaufman, and Fazzini (1969), who varied the delay between an avoidance response and punishment. The 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.

Figure 2 shows that for R-S intervals greater than 7 seconds the probability of a shock eliciting a response is relatively constant, but as R-S duration decreases below R-S = 7 seconds, the probability of a shock-elicited response decreases. In this study, a shock-elicited response was defined as a response that occurred within 2 seconds of the shock. Only two data points are recorded for bird 83 since at all other R-S values it received fewer than the computational minimum of 15 shocks over the last three sessions (see Fig. 2 legend).

At intervals to the right of the maxima in Figure 1, a shock-elicited response postpones the next shock beyond the S-S interval. At shorter intervals however, a shock-elicited response has just the opposite effect -- i.e. it decreases the time to the next shock, and thus increases the frequency of shocks. Since the percentage of shocks which elicit a response is relatively constant for R-S intervals greater than 7 seconds (Fig. 2), the suppression of shock-elicited avoidance responses at R-S intervals less than 7 seconds can be interpreted as learned through the interaction of the aforementioned punishment contingency and increasing shock frequency.

Further evidence that the birds learned to suppress shock-elicited avoidance responses is presented in Figure 3. At longer R-S intervals, it can be seen that the S-S timer is relatively unimportant in the maintenance of stable avoidance behavior. However, as the R-S intervals

decrease, the percent of session time spent on the S-S timer increases dramatically at the same point at which shock-elicited responding (Fig. 2) drops off. This shows that the birds either waited longer into the S-S interval before responding, or failed entirely to respond before the next scheduled shock.

The percentage of shocks avoided (Figure 4), equals $100 \ (1 - \frac{\text{shocks received}}{\text{S-S shocks scheduled}})$. This measure is negative when the bird receives more shocks than are scheduled by the S-S timer, i.e. when the bird receives more shocks than would be received in the absence of responding. This occurrance is only possible when the R-S interval is shorter than the S-S interval, since, at these short R-S intervals, a response earlier than (SS-RS) seconds in the S-S interval decreases the time to the next scheduled shock rather than postponing it.

Figure 4 shows that as R-S duration decreases, percent avoidance decreases, with no apparent minimum, from a high asymptote. At longer R-S intervals, avoidance responding is quite effective, while at R-S intervals below 7 seconds, three of four birds (#5, #21, #88) show poor avoidance behavior. Only #83, with it's high response rate (Figure 1) was able to maintain effective avoidance behavior until R-S = 2.5.

As noted earlier, at short R-S intervals a response occurring earlier than (SS-RS) seconds in the S-S interval decreases the time to the next scheduled shock rather than postponing it. Thus, in order to minimize shock at short intervals, the bird must respond continually at a high rate, or not respond at all. Figures 1 and 2 show that the birds, with the exception of #83, did neither. With continued exposure to a short interval there was a tendency to cease responding; but imperfect

suppression of shock-elicited responses resulted in shock densities of the same order of magnitude, and sometimes greater, than the S-S scheduled baseline. This appears as low, or negative avoidance percentages in Figure 4.

During acquisition of the avoidance response, all of the birds responded in a "burst" pattern (Ellen and Wilson, 1964; Sidman, 1966) in which the response occurred immediately after the shock and was followed by a shock at the end of the R-S interval. Ellen and Wilson reported that 13 of 15 rats responded in a burst pattern, and, even after several weeks exposure to the avoidance contingency, failed to shift to the "continual" pattern in which the responses are spaced in such a manner as to result in efficient avoidance behavior. In the present experiment however, three of four birds (#21, #83, #88) shifted to the continual pattern during exposure to the first or second R-S value. The differences in response pattern are reflected in Figure 4, which shows that bird #5, with a burst pattern at all but the two longest intervals, has the poorest avoidance percentages. Bird #21 shows relativly poor avoidance performance at R-S = 32, the first R-S value encountered, where it responded in a burst pattern. It switched to the continual pattern before stabalizing at the second R-S value. Bird #88 responded in a burst pattern at R-S = 10.

Further enlightenment regarding the relationship between R-S interval duration and response rate may be found through examination of the relative rate of responding. The

$$\text{relative rate} = \frac{\text{response rate}}{\dfrac{1}{\text{R-S interval (minutes)}}} \text{ ,}$$

the response rate, at an R-S interval, relative to the minimum rate

necessary for 100% avoidance at that interval. The relative rate is 1.0 if the number of responses emitted is equal to the minimum number necessary for 100% avoidance. If the number of responses is greater than the minimum necessary, the relative rate is greater than 1.0. Fewer than the minimum necessary responses results in relative rates below 1.0.

Figure 5 shows that, as the R-S interval increases, relative rates tend to increase. For three of the four birds (#5, #21, #88), most of the increase in relative rates takes place between R-S=2.5 and R-S=15. Relative rates below 1.0 are evident only for the two shortest R-S values. For bird #83, due to its high response rates, the increase in relative rates remains high throughout the range of R-S values.

In general, as the R-S interval increases, increasingly more responses than necessary were emitted. Similar results with other species were reported by Clark and Hull (1966), Verhave (1969), and Scobie (1970). Since this increase in relative rates occurred independently of the order of presentation of the R-S intervals, it cannot be interpreted as a carryover of high rates from short R-S intervals to longer ones -- particularly in light of the fact that the two shortest R-S intervals generally had lower response rates than the next several longer ones. While response rates increased over a short range, and then decreased, relative rates increased throughout the range of R-S values.

Table 1 presents the IRT/OP data (Anger, 1963). This statistic was computed for each 2 sec. class interval by dividing the number of IRT's within a class interval by the number of IRT's exceeding the lower limit of that class interval. Although in some cases temporal discriminations were evident, the probability of a response burst, i.e. a

response in the 0-2 sec. category, was high for all R-S values. All four birds had some degree of temporal discrimination on R-S values in the ten to twenty second range. For R-S values that show no evidence of temporal discriminations, the tendency was to respond early in the R-S interval.

As reported by Hineline and Herrnstein (1970), temporal discriminations were relativly independent of the effectiveness of avoidance behavior. Although there were no apparent temporal discriminations at long R-S intervals (Table 1), all birds had effective avoidance behavior, as evidenced by high avoidance percentages (Fig. 4). This was a result of continual response patterns. In most cases when there was a temporal discrimination, the birds avoided effectivly. But when a burst pattern of responding accompanied a temporal discrimination, avoidance efficiency fell. For example, bird #5 had burst response patterns and some degree of temporal discriminations at R-S values between ten and twenty seconds (Table 1), but avoidance percentages were relativly poor for these same R-S values (Fig. 4). Typically, the bird emitted a rapid sequence of responses immediately after shock, and then waited for the next shock at the end of the R-S interval. The predominance of this type of responding resulted in a high 0-2 second IRT/OP value, and poor avoidance performance. When a response did occur before the end of the R-S interval, it tended to occur late in the interval. The occurrence of this type of response resulted in evidence of a temporal discrimination. Bird #88 showed the same behavior pattern at R-S = 10.

The typically high probability of a burst of responses shown in Table 1, also resulted in high relative rates. This was probably 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 Sidman-Avoidance (R-S = 20), that IRT's longer than 16 seconds were likely to be followed by very short IRT's. Scobie (1970), using goldfish on Sidman-Avoidance, noted that high relative rates 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 in difficult. However, Table 1 shows that, when a temporal discrimination was absent, the tendency was to respond early in the R-S interval. Staddon (1965) reported that pigeons fail to adjust to DRL (differential reinforcement of low response rates) values of longer than 30 seconds -- i.e. the median IRT's fell short of the DRL value. Apparently, similar results hold for Sidman-Avoidance with pigeons. Ten to twenty seconds seems to be the optimal range for formation of a temporal discrimination, since, as Table 1 shows, all four birds showed some evidence of temporal discriminations in this range. Longer R-S values resulted in erratically spaced, continual response patterns, with most responses coming early in the interval. On short R-S intervals, bursting seemed to account for most responding. Sidman (1966, p. 464) suggests 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 develope long before the temporal discrimination ...." As noted earlier, Hineline and Herrnstein (1970) experimentally verified this.

Sidman (1966, p. 486) reported that rats were able to rapidly adjust their temporal discriminations to changes in R-S values. In the present experiment, some of the ten to twenty second 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 Sidman-Avoidance behavior, they had relativly little trouble adjusting to new R-S values in the ten to twenty second range. These results suggest the presence of some sort of learning set, operating under the restrictions imposed by the organism's timing abilities.

Figure 1. Response rate as a function of R-S interval duration.

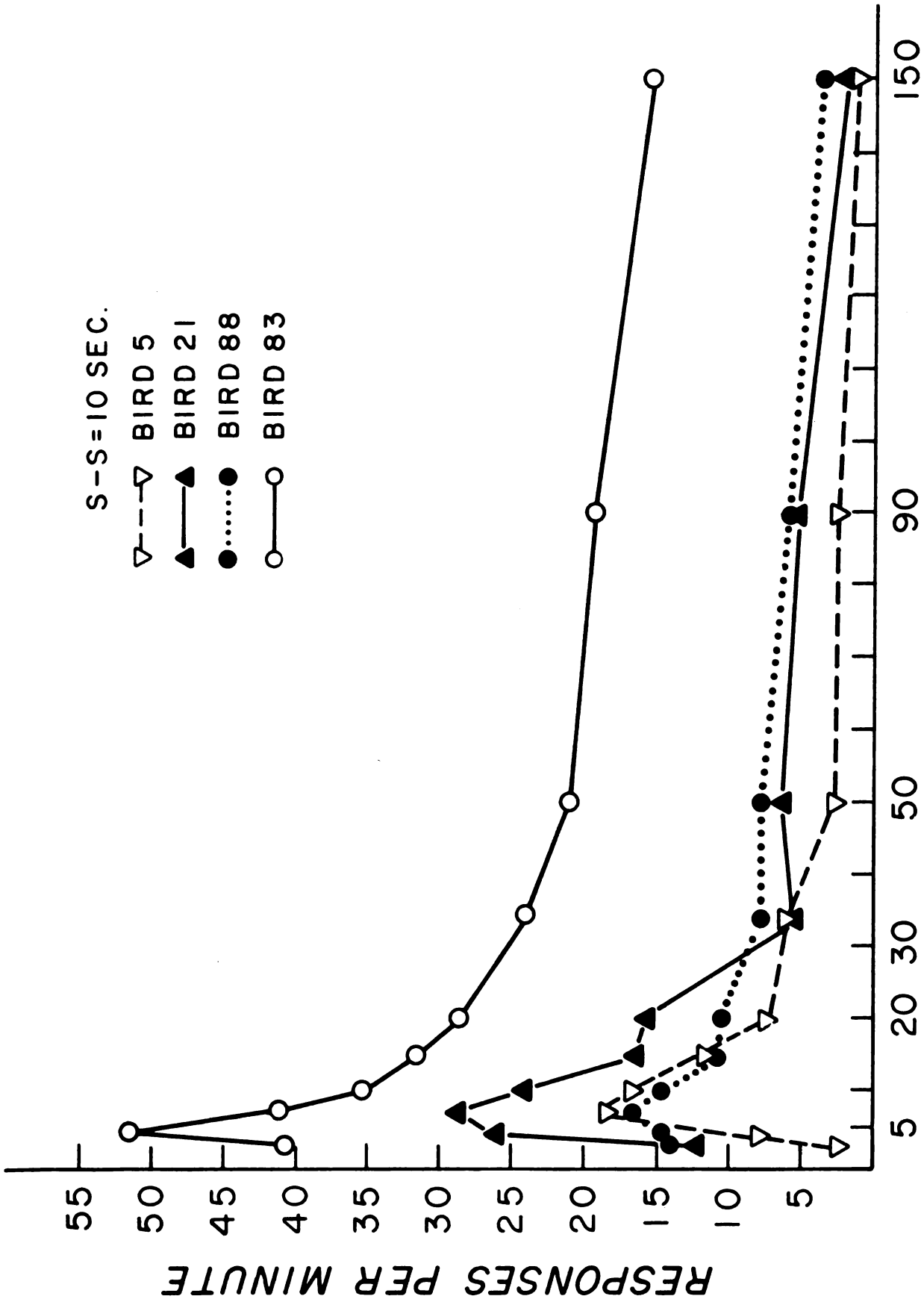Data points are the mean of the last six sessions at each interval.

FIGURE 1

Figure 2. Probability of a shock-elicited (0-2 sec.) response as a function of R-S interval duration. Data points were computed from the last three sessions at a given interval, by dividing the number of shocks followed within 2 seconds by a response, by the total number of shocks. Points where fewer than 15 shocks were received (over the three sessions) are omitted.
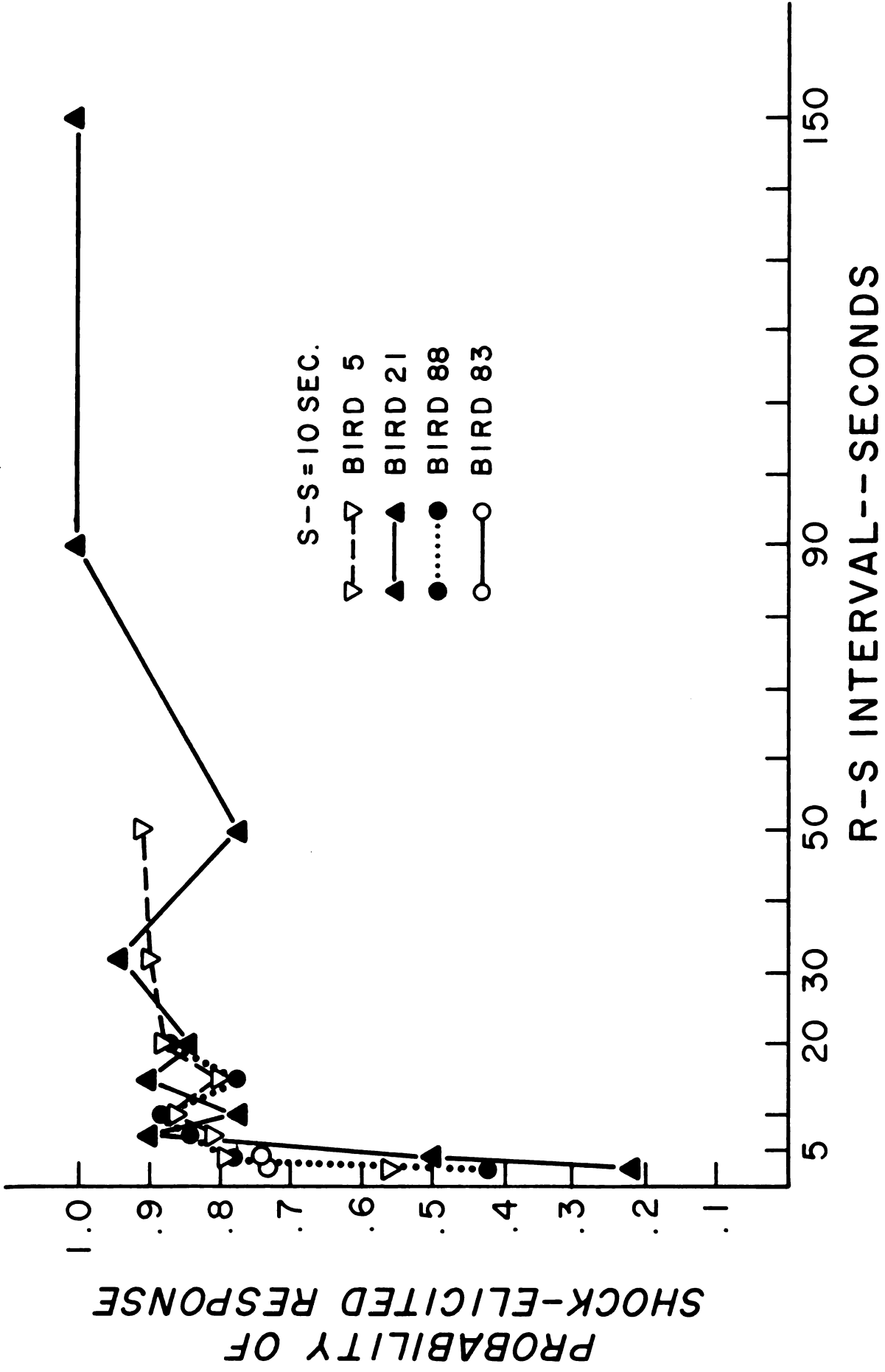
FIGURE 2

Figure 3. Percent of time on the S-S timer as a function of R-S interval duration. (computed over the last three sessions at an interval)
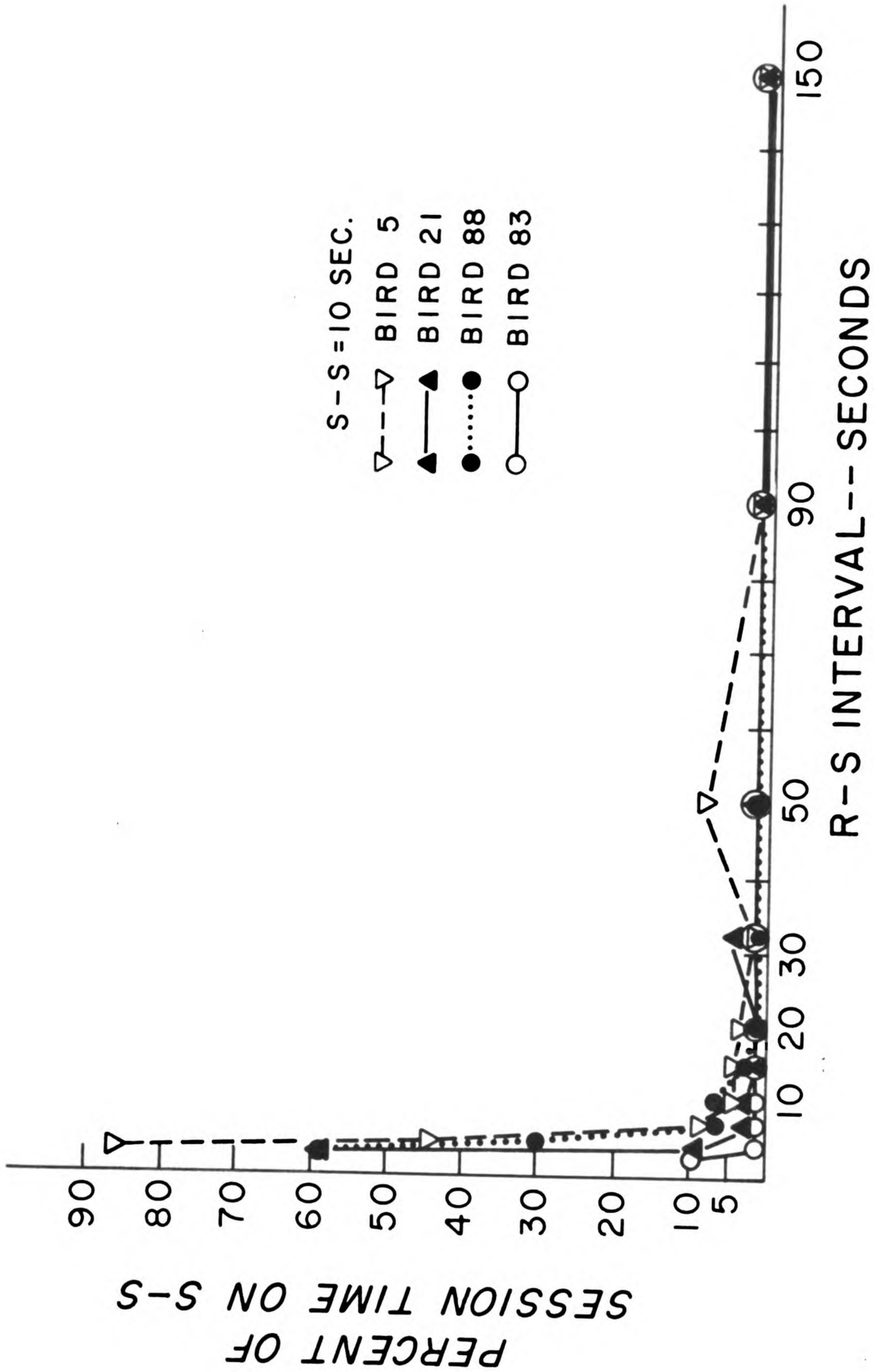
FIGURE 3

Figure 4. Percent avoidance as a function of R-S interval duration.
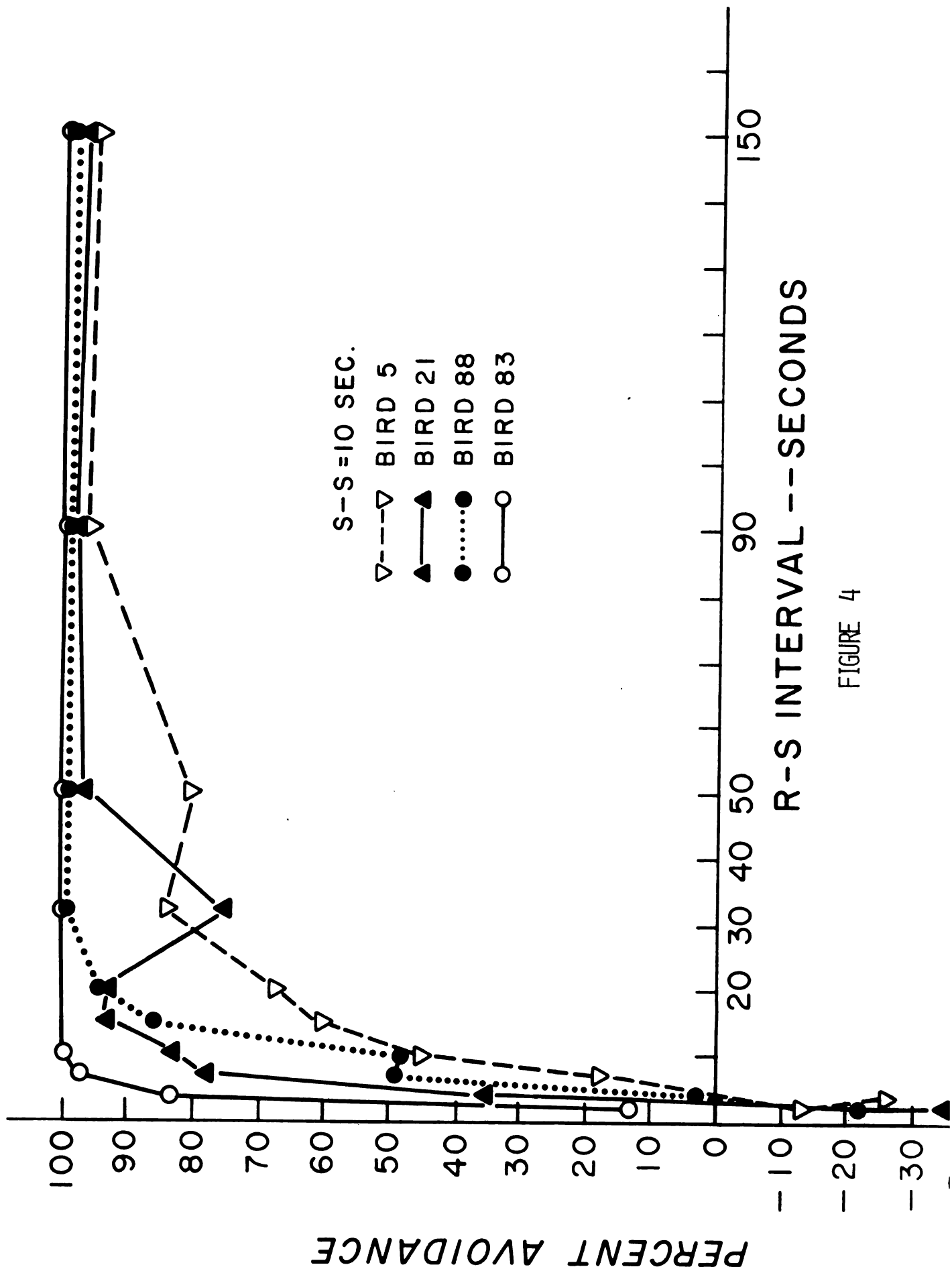Data points were computed from the mean of the last six sessions at
a given interval.

FIGURE 4

Figure 5. Relative response rates, based on the mean response rate of the last six sessions at a given interval. Each point is the response rate at a given interval, divided by the minimum number of responses necessary for 100% shock avoidance at that interval.
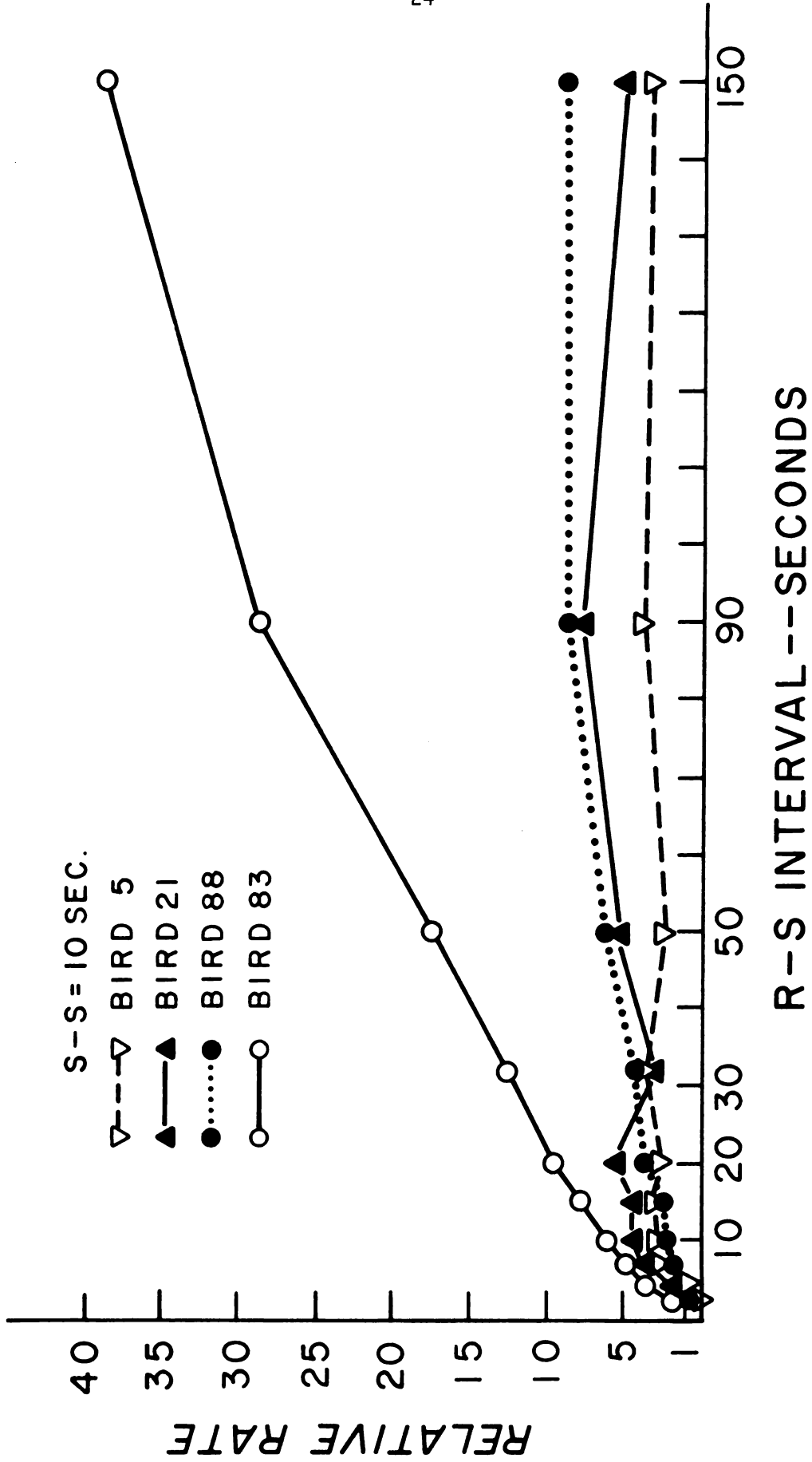
FIGURE 5

Table 1. Interresponse times per opportunity as a function of

R-S interval duration. Data are based upon the IRT distributions

pooled over the last three sessions at each R-S interval. Numbers

across the top are times, in 2 second categories, since the pre-

ceeding response. Numbers at the left are R-S interval durations.

Each table entry is the conditional probability of a response

occurring in that 2 second interval, given that the bird did not

respond in an earlier interval. Categories with fewer than 20

opportunities are excluded. The arrows at the left indicate

apparent temporal discriminations.

SECONDS SINCE PRECEDING RESPONSE

BIRD 5

R-S INTERVAL — SECONDS	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56
2.5	.74																											
4	.51																											
7	.63	.42	.40																									
10	.75	.41	.37	.52																								
15	.83	.39	.23	.30	.38	.41																						
20	.69	.25	.20	.18	.18	.29	.48	.37																				
32	.61	.24	.16	.09	.10	.10	.12	.14	.22	.14	.30	.27	.27															
50	.58	.11	.13	.13	.06	.02	.13	.12	.12	.17	.12	.14																
90	.47	.13	.07	.01	.04	.01	.02	.03	.08	.05	.07	.03	.04	.03	.05	.03	.05	.05	.06	.10	.02	.05	.05	.08	.05	.14	.10	
150	.54	.09	.17	.05	.11	.06	.13	.03	.00	.04	.00	.08	.00	.04	.09													

BIRD 21

R-S INTERVAL — SECONDS	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56
2.5	.88																											
4	.53																											
7	.71	.49	.70																									
10	.73	.40	.38	.62																								
15	.63	.25	.10	.24	.41	.57	.71																					
20	.67	.31	.14	.17	.25	.34	.37	.49	.72																			
32	.82	.34	.29	.17	.07	.18	.09	.14	.11	.39	.16	.07	.17	.21	.12	.22	.09	.26	.16	.12	.14	.17						
50	.46	.32	.11	.06	.08	.09	.18	.21	.09	.07	.10	.13	.09	.13	.10	.15	.01	.09	.04	.04	.08	.07						
90	.49	.16	.08	.03	.04	.05	.07	.07	.09	.07	.07	.03	.01	.01	.05	.01	.01	.01	.04	.04	.05	.07						
150	.37	.20	.04	.04	.03	.03	.04	.01	.04	.04	.07	.03	.01	.01	.05	.01	.01	.01	.04	.04	.08	.07	.05	.02	.02	.00	.00	.02

TABLE 1

SECONDS SINCE PRECEDING RESPONSE

BIRD 83

R-S INTERVAL — SECONDS	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56
2.5	.85																											
4	.87																											
7	.80	.70	.86																									
10	.71	.65	.67	.73																								
15	.74	.52	.58	.70																								
20	.69	.48	.53	.64	.75																							
32	.65	.47	.40	.51	.45	.51	.51																					
50	.65	.54	.50	.45	.21	.17	.24	.37	.28																			
90	.65	.40	.38	.35	.31	.28	.33	.32	.14	.16	.27																	
150	.61	.38	.29	.29	.27	.18	.20	.19	.20	.32	.26	.29																

BIRD 88

R-S INTERVAL — SECONDS	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56
2.5	.78																											
4	.72																											
7	.61	.32	.38																									
10	.75	.48	.35	.57																								
15	.52	.18	.08	.11	.22	.31	.63		.80																			
20	.54	.20	.13	.12	.15	.27	.43	.57	.29	.31	.36	.40	.43															
32	.50	.21	.04	.02	.06	.11	.13	.28	.06	.17	.12	.13	.23	.23	.22	.31	.30											
50	.53	.25	.10	.09	.11	.08	.10	.09	.08	.08	.08	.08	.09															
90	.54	.24	.08	.09	.08	.09	.08	.03	.08	.08	.08	.08	.10	.10	.13	.09	.07	.09	.08	.09	.18	.09	.17	.04	.13			
150	.47	.30	.22	.18	.18	.14	.09	.01	.14	.06	.08	.07	.10	.05	.00	.06	.03	.03	.06	.07	.04	.08	.00	.13				

TABLE 1 — CONTINUED

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