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The standard Sidman avoidance procedure as a temporal differentiation schedule[1]

El Procedimiento Estándar de Evitación de Sidman Como un Programa de Diferenciación Temporal

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ABSTRACT

Four rats were submitted to a standard Sidman avoidance procedure in which the response-shock interval was systematically varied from 5 to 30 sec. while the shock-shock interval was kept constant at 5 sec. The data revealed that, after extended training in the avoidance schedule, the relation between interresponse time and response-shock interval length is described by a power function, confirming previous findings and relating performance under the standard Sidman schedule to data from temporal differentiation schedules.

DESCRIPTORS: Sidman avoidance procedure, avoidance, temporal differenciation, avoidance schedules, temporal differentiation schedules, shock-shock interval, response-shock interval, inter-response time, wistar rats.

RESUMEN

Se expuso a cuatro ratas a un procedimiento estándar de evitación de Sidman, en el cual se varió sistemáticamente el intervalo respuesta-choque de 5 a 30 segundos, mientras se mantenía constante en 5 segundos el intervalo choque-choque. Los datos revelaron que después de un entrenamiento prolongado con el programa de evitación, se describe la relación entre el tiempo interrespuesta y la longitud del intervalo respuesta-choque como una función exponencial. Así, se confirmaron hallazgos previos y se relacionó la ejecución bajo el programa estándar de evitación de Sidman con datos de programas de diferenciación temporal.

DESCRIPTORES: procedimiento de evitación de Sidman, evitación, diferenciación temporal, programas de evitación, programas de diferenciación temporal,

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intervalo choque-choque, intervalo respuesta-choque, tiempo interrespuesta, ratas wistar.

In the traditional procedure for the study of avoidance behavior, the experimental session was divided in trials. A trial consisted of the presentation of a warning stimulus, followed some seconds later by a shock. A response during the warning stimulus would terminate it and cancel the delivery of shock (e.g., Warner, 1932). The measure of avoidance behavior in such conditions was the percent of trials containing a response. The inadequacy of this measure for the systematic study of individual behavior led to the development of investigations which utilized procedures providing the oportunity for the use of rate of avoidance responses as a description of behavior (cf. Sidman, 1960).

In the procedure developed by Sidman (1953a), the subject is submitted to aversive stimulation at regularly spaced time periods (shock-shock interval). A response will postpone the next shock in the sequence by a given period of time (response-shock interval). This procedure has been used in research with several species, and tne basic role of both temporal parameters —response-shock (RS) and shock-shock (SS) intervals— was shown to be similar for the different species studied (e.g., Ader and Tatum, 1961; Black and Morse, 1961; Ferrari, Todorov and Graeff, 1973; Scobie, 1970; Sidman, 1953b).

Usually, in such studies, response rate is taken as a measure of avoidance behavior. Sidman (1953b) used the equation

$$R = a(t\text{-}k)^{-b} \qquad (1)$$

to describe the relationship between response rate and RS interval, where R and t represent response rate and RS interval length, respectively, k is a constant characteristic of the organism, and a and b are non-interpreted constants. Herrnstein and Brady (1958) and Verhave (1959) described their data using a logarithmic function relating response rate and RS interval. Clark and Hull (1966) noted that when the reciprocals of response rate were plotted against the reciprocals of the RS intervals, the function relating both variables was approximately linear. Clark and Hull also noted that roughly linear plots were obtained when response rate was related to a logarithmic transformation of RS length, or when the logarithm of both response rate and RS intervals were considered. Neither Clark and Hull (1966) nor Hineline (1977), for instance, found good reasons to choose any one of such transformations as a better description of data. One problem for this decision is the theoretical interpretation of the constants in the equations. A second problem relates to how much of the avoidance behavior is being described when one plots response rate against RS length. The number of shocks delivered, for instance, depends more upon how responses are distributed in time than on response rate. Two subjects may respond at the same rate and yet avoid different numbers of shocks.

In recent years different developments concurred for the better understanding of behavior occurring in avoidance contingencies. In an attempt at classification of such developments, two major areas could be identified. The first includes studies which suggest new ways for the analysis of variables responsible for behavior in the procedure first utilized by Sidman (1953a). The second area is characterized by the development of new experimental procedures for the investigation of avoidance behavior.

The major concern of this paper is with the developments included in the first area. A view of other experimental procedures can be obtained in the literature of recent years (cf. Hineline, 1977).

Quantitative descriptions of avoidance behavior in the Sidman procedure.

Scobie (1970) suggested that, rather than the absolute rate of avoidance responses, a better measure could be the relative response rate, defined as the absolute rate of responding divided by the minimum rate required to avoid all shocks. This minimum rate is given by the division of the time unit by the value of the RS interval:

$$R' = (R/t) \ / \ (t/RS) \tag{2}$$

where *R'* is the relative rate, *R* is the frequency of avoidance responses in a given period of time (*t*), and RS is the response-shock interval length.

As a measure of efficiency, Scobie's relative rate describe how response rate is relative to an ideal performance: the minimum rate required to avoid all shocks. One problem not solved by this measure is that of efficiency considered in terms of shocks avoided and/or received. Two subjects may provide equal values of R' (equation 2) and yet receive different frequencies of shock under identical conditions.

McIntire, Davis, Cohen, and French (1963) used an index of efficiency, *E*, computed as follows:

$$E = \frac{Sr}{Sp} \; \frac{R - \frac{Sp}{RS/SS}}{\frac{Sp}{RS/SS}} \tag{3}$$

where *Sr*, *Sp*, and R represent shocks delivered, shocks scheduled, and number of responses, respectively; Sp/(RS/SS) is the minimum number of responses required to avoid all shocks. When the subject's performance is so that all shocks are avoided with the minimum number of responses, the value of the efficiency index (*E*) is equal to zero. The advantage of equation 3 over Scobie's

(1970) relative response rate is the inclusion of numbers of shocks delivered and shocks scheduled, relating these variables to response rate and RS and SS intervals.

Similar characteristics are found in an equation suggested by Todorov (1972), after an examination of data from experiments on key pecking avoidance by pigeons (Ferrari *et. al.,* 1973; Todorov, Ferrari, and Souza, 1974):

$$p = (Sa/R) \ / \ (RS/SS) \qquad (4)$$

or

$$R = (Sa \ . \ SS) \ / \ (p \ . \ RS) \qquad (5)$$

where Sa and R represent numbers of shocks avoided (shocks possible minus shocks delivered) and responses, respectively. The ratio RS/SS is the maximum number of shocks that one response may avoid. Sa/R is the actual average number of shocks avoided by one response. When respondig results in the avoidance of all scheduled shocks, p is the mean interresponse time (IRT) expressed as a proportion of the value of the RS interval. It is a performance measure wich compares actual performance to the best possible performance.

A related measure of efficiency was developed by Grabowski and Thompson (1972), with efficiency defined as response rate divided by the rate required to avoid shocks that were actually avoided:

$$Effic = (R/Sa) \ / \ (RS/SS) \qquad (6)$$

or

$$Effic = (R \ . \ RS) \ / \ (Sa \ . \ SS) \qquad (7)$$

Grabowski and Thompson's measure of efficiency is the reciprocal of p (Equation 4). The disadvantage of equation 6 is that *Effic* has no defined range of variation, whereas p would be one for a perfect performance (all scheduled shocks are avoided with the minimum rate required to do so).

A common characteristic of the measures suggested by Grabowski and Thompson (1972), McIntire *et al.,* (1968), Scobie (1970) and Todorov (1972) is a basic assumption that avoidance behavior can be described in terms of an input-output relationship governed by principles of economy, in a way similar to Herrnstein's quantification of the law of effect (cf. Herrnstein, 1970; de Villiers, 1977). Of those suggestions, Todorov's Equation 5 leads to the possibility that efficiency in avoidance behavior maintained by the Sidman procedure may be interpreted in a different way, in which the association in time of responses and shocks receive special attention. Such a view has been advanced and systematically explored by Gibbon (1972).

Behavior under the Sidman avoidance procedure and animal psychophysics.

Recently de Villiers (1972; 1974) has discussed the problems of using Sidman's procedure in the study of quantitative relations between response rate and negative reinforcement variables. He indicated that responding in the standard Sidman procedure and in the adjusting avoidance schedule (Sidman, 1962) "is largely determined by regularities in the temporal relations between shocks and responses and is not free to vary widely with changes in rate of reinforcement for avoidance." (de Villiers, 1974, p. 223). Gibbon (1972) examined such temporal regularities in an interpretation of behavior under those contingencies as psychophysical judgements of time (see also Catania, 1970).

The data presented here relate to an interpretation of stable behavior maintained under the standard Sidman avoidance procedure as sequences of psychophysical judgements of time. It is not the purpose of this work to discuss what reinforces avoidance behavior, nor to examine the necessary and/or sufficient conditions for the acquisition of avoidance responding. A recent presentation of such issues can be found in Hineline (1977). What follows is a view of the variables which control avoidance behavior in the Sidman procedure after acquisition, i. e., when avoidance behavior is stable.

One might argue against an arbitrary separation of the acquisition and the performance phases in avoidance conditioning. In the case of behavior under the Sidman avoidance contingency, however, this separation seems reasonable on the following grounds:

a) Variables which are important to determine the speed of acquisition of avoidance responding have little or no effect on response rate once stability in responding and in received shocks is reached, as is the case with the SS interval (e.g., Sidman, 1953b; Todorov *et. al.*, 1974) and shock intensity (Souza, 1976).

b) The Sidman procedure combines three factors which alone could be responsible for the acquisition of avoidance behavior: responding results in shock frequency reduction (Herrnstein and Hineline, 1966), a period free from shock (Lewis, Gardner, and Hutton, 1976), and no shocks closely following a response (Hineline, 1970; Hineline and Herrnstein, 1970). After stability in responding, only the changes in the temporal relationship between responses and shock clearly affect response rate (see *a* above).

c) Because it confounds the influence of those three factors (in *b*, above), the standard Sidman procedure is inadequate for an analysis of acquisition of avoidance behavior. However, the fixed temporal relationship between responses and shocks makes the procedure a convenient tool for the study of time as a discriminative stimulus in the control of behavior after stability in responding (e.g., Libby and Church, 1974; Catania, 1970).

d) Stable performance has been shown to be independent of the conditions of acquisition in a large number of situations. As examples, all the studies in which subjects with varied experiences under schedules of reinforcement were used; in avoidance conditioning, the data from Foree and LoLordo (1974) and Todorov *et. al.* (1974).

Thus, the purpose of the present investigation was to explore the possibility that steady state responding maintained under the Sidman avoidance procedure might be described as sequences of psychophysical judgements of the fixed tem poral relation between responses and shocks.

METHOD

Subjetcs. Four male, experimentally naive Wistar rats, with 120 days of age, were used. Subjects had free access to food and water in their home cages.

Apparatus. A standard operant conditioning chamber for rats, originally with two response-levers, was used (Grason-Stadler. Model E 3125B 100). The original levers were removed, and on the left side an aluminium bar was inserted, measuring 5.5 cm (width) by 6.5 cm (length). The opening in the intelligence panel was located at 9.0 cm from the floor, and from there the bar was angled to the floor, making a 40 degrees angle with the lateral wall. A press with minimum force of 0.15 N and a displacement of 2.5 mm was required to operate a microswitch and register a response. This modified lever was introduced to increase the initial probability of a lever press. Pressing the lever produced an audible sound inside the experimental chamber. Shocks of 1.3 mA and 0.2 sec duration were produced with a Grason-Stadler shock generator Model E 1064 GS (with scrambler) and delivered through the grid floor. A white houselight was on during session time. Standard electromechanical equipment was used to schedule and record events.

Procedure. No shaping of the lever press response was made. Subjects were placed inside the experimental chamber and a 4-hr session began. The shock-shock interval was 5 sec and each response (pressing and releasing the bar) postponed the next shock for 25 sec. Subjects were run on alternate days, with session time always set at four hours. Throughout the experiment, the SS interval was kept at 5 sec, while the RS interval varied from 5 to 30 sec in different experimental conditions, in the following order: 25, 10, 20, 5, 30 and 15 sec (first determination), and 10, 20, 5, 30, 15 and 25 sec (replication).

Changes in RS value were made only after a minimum of seven sessions in any given experimental condition. Response rate was considered stable when the data from the last hour of each session met the following criterion: taking the last six sessions, the average response rate computed from the first three sessions should not differ from the average response rate from the last three sessions by more than 10% of the average of all six sessions.

RESULTS

Only the data from the last hour of each session, and from the last six sessions in each experimental condition, were used in the analysis of results.

The data here presented refer to the replication series of RS intervals. At the beginning of replication, each subject had at least 168 hours of training in the avoidance schedule.

Table 1 shows that, except when the RS interval was 5 sec, all subjects avoided more than 90% of the scheduled shocks, for all other values of RS length. Of all 24 percentages shown, 16 are over the 95% level.

TABLE 1

Percentage of shocks avoided, for all subjects in all values of the response-shock interval

RS length (sec)	Subjects				
	33	34	35	36	Group
5	76	91	74	89	82
10	91	97	97	97	96
15	95	97	98	96	96
20	97	98	96	96	97
25	95	99	98	99	98
30	93	97	95	98	96

TABLE 2

Constants and coefficients of determination for the best fitting power function relating averaged interresponse time and response-shock interval length, for each subject and for averaged data from all four subjects of the present experiment. Data from rat 41 are from Sidman (1953b)

Subjects	$IRT = a(RS)^b$		
	a	b	r^2
33	1.08	0.35	0.98
34	0.99	0.73	0.97
35	0.97	0.86	0.99
36	0.89	0.73	0.99
41	1.02	0.70	0.99
Group	0.97	0.81	0.99

Table 2 shows the relationship between average interresponse time (IRT) and RS length described as a power function. Also shown are data from rat

41, from Sidman (1953b). The equation accounts for more than 97% of the variability for all subjects, and more than 99% for three of them.

Average interresponse times at each value of the RS interval, for all subjects, are shown in Table 3.

TABLE 3

Average interresponse times in all values of the RS interval

RS length (sec)	Subjects 33	34	35	36	Group
5	4.44	3.28	3.79	2.77	3.57
10	7.20	4.80	7.50	5.14	6.16
15	10.91	7.16	9.47	6.54	8.52
20	12.86	9.86	12.86	8.00	10.89
25	18.95	9.57	14.40	10.00	13.23
30	18.95	11.58	18.95	10.00	14.87

DISCUSSION

A power funtion fitted well as a description of the relationship between average interresponse time and the response-shock interval for data obtained under a standard Sidman avoidance procedure (Sidman, 1953a). Good fits between response rate and RS interval have been obtained utilizing other equations (e.g., Sidman, 1953b; Verhave, 1959; Clark and Hull, 1966), however. The advantage of working with average interresponse time (the reciprocal of response rate) and the power function resides on the opportunity to relate the data obtained under the Sidman avoidance procedure to data generated under other schedule conditions.

The standard Sidman procedure can be described as an example of temporal differentiation schedules. Under such schedules, the presentation of a consequence depends on the duration of behavior (DeCasper and Zeiler, 1974). Behavior duration can be measured as the latency, duration, or interresponse time (e. g., Skinner, 1938) of one event or of a sequence of events (e. g., Zeiler, 1970). Temporal differentiation schedules may require maximum or minimum durations of behavioral events. The standard Sidman schedule qualifies as a temporal differentiation schedule because it specifies that a given consequence, an aversive event, will occur when interresponse time exceeds t seconds; in this sense, it specifies a maximum duration for a behavioral event (e. g., Catania, 1970).

Examining data from experiments with minimum requirements for response duration, interresponse time, the total time for completing a fixed-ratio, DeCasper and Zeiler (1974) indicated that the power function, $T = kt^n$, described behavior under these different conditions. T is the obtained duration of the behavioral event, t is the required duration; the constants k and n are empirically determined. These empirical constants were similar accross different experiments, suggesting that "the effects of temporal differentiation schedules were independent of the particular response units or temporal properties." (DeCasper and Zeiler, 1977, p. 235).

The experiments reviewed by DeCasper and Zeiler had in common the use of positive reinforcement as the consequence of behavior meeting the scheduled requirements. The present investigation extends the application of the power function to temporal differentiation schedules which involve aversive consequences. If one considers T as the average interresponse time and t as the response-shock interval, the values of the constants k and n from the present data (a and b, respectively, in Table 2) are very close to those obtained by DeCasper and Zeiler (1974; 1977).

The present data suggest that the value of a in the power function shown in Table 2 may depend on the frequency of occurrence of response bursts, while b would reflect the sensitivity of behavior to changes in the RS interval. This hypothesis may be tested by a redefinition of the response as one or more lever presses followed by one second without a lever press, for instance.

REFERENCES

Ader, R. and Tatum, R. Free-operant avoidance conditioning in human subjects. *Journal of the Experimental Analysis of Behavior,* 1961, *4,* 275-276.

Black, A. H. and Morse, P. Avoidance learning in dogs without a warning stimulus. *Journal of the Experimental Analysis of Behavior,* 1961, *4,* 17-23.

Catania, A. C. Reinforcement schedules and psychophysical judgments. In W. N. Schoenfeld (Ed.), *The Theory of Reinforcement Schedules.* N. York; Appleton-Century-Crofts, 1970. Pp. 1-42.

Clark, F. C. and Hull, L. D. Free-operant avoidance as a function of the response-shock = shock-shock interval. *Journal of the Experimental Analysis of Behavior.* 1966, *9,* 641-647.

DeCasper, A. J. and Zeiler, M. D. Time limits for completing fixed ratios. III. Stimulus variables. *Journal of the Experimental Analysis of Behavior,* 1974, *22,* 285-300.

DeCasper, A. J. and Zeiler, M. D. Time limits for completing fixed ratios. IV. Components of the ratio. *Journal of the Experimental Analysis of Behavior,* 1977, *27,* 235-244.

de Villiers, P. A. Reinforcement and response rate interaction in multiple random-interval avoidance schedules. *Journal of the Experimental Analysis of Behavior,* 1972, *18,* 499-507.

de Villiers, P. A. The law of effect and avoidance: a quantitative relationship between response rate and shock-frequency reduction. *Journal of the Experimental Analysis of Behavior.* 1974, *21,* 223-235.

de Villiers, P. A. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig and J. E. R. Staddon (Eds.), *Handbook of Operant Behavior.* Englewood Cliffs, N. Jersey: Prentice-Hall, 1977. Pp. 233-287.

Ferrari, E. A., Todorov, J. C., and Graeff, F. G. Nondiscriminated avoidance of shock by pigeons pecking a key. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 211-218.

Foree, D. D., and LoLordo, V. M. Transfer of control of the pigeon's key-peck from food reinforcement to avoidance of shock. *Journal of the Experimental Analysis of Behavior*, 1974, *22*, 251-259.

Gibbon, J. Timing and discrimination of shock density in avoidance. *Psychological Review*, 1972, *79*, 68-92.

Grabowski, J. and Thompson, T. Response patterning on an avoidance schedule as a function of time-correlated stimuli. *Journal of the Experimental Analysis of Behavior*, 1972, *18*, 525-534.

Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, *13*, 243-266.

Herrnstein, R. J. and Brady, J. V. Interaction among components of a multiple schedule. *Journal of the Experimental Analysis of Behavior*, 1958, *1*, 293-300.

Herrnstein, R. J. and Hineline, P. N. Negative reinforcement as shock frequency reduction. *Journal of the Experimental Analysis of Behavior*, 1966, *9*, 421-430.

Hineline, P. N. Negative reinforcement without shock reduction. *Journal of the Experimental Analysis of Behavior*, 1970, *14*, 259-268.

Hineline, P. N. Negative reinforcement and avoidance. In W. K. Honig and J. E. R. Staddon, (Eds.), *Handbook of Operant Behavior*. Englewood Cliffs, N. Jersey: Prentice-Hall, 1977. Pp. 364-414.

Hineline, P. N. and Herrnstein, R. J. Timing in free-operant and discrete trial avoidance. *Journal of the Experimental Analysis of Behavior*, 1970, *13*, 113-126.

Lewis, P., Gardner, E. T., and Hutton, L. Integrated delays to shock as negative reinforcement. *Journal of the Experimental Analysis of Behavior*, 1976, *26*, 379-386.

Libby, M. E. and Church, R. M. Timing of avoidance responses by rats. *Journal of the Experimental Analysis of Behavior*, 1974, *22*, 513-517.

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. *Tactics of Scientific Research*. N. York: Basic Books, 1960.

Sidman, M. An adjusting avoidance schedule. *Journal of the Experimental Analysis of Behavior*, 1962, *5*, 271-277.

Skinner, B. F. *The Behavior of Organisms*. N. York: Appleton-Century-Crofts, 1938.

Souza, D. G. *Esquiva livre sinalizada em ratos: efeitos da intensidade do choque elétrico*. Unpublished Master's thesis, Universidade de Sao Paulo, 1976.

Todorov, J. C. *Proporcao de estímulos aversivos evitados por resposta: uma nova medida no comportamento de esquiva*. Paper read at the II Reuniao Anual de Psicologia. Ribeirao Preto, S. P., Brazil, october of 1972.

Todorov, J. C., Fèrrari, E. A., and 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. Avoidance responding as a function of simultaneous and equal changes in two temporal parameters. *Journal of the Experimental Analysis of Behavior*, 1959, *2*, 185-190.

Warner, L. H. The association span of the white rat. *Journal of Genetic Psychology*, 1932, *41*, 57-90.

Zeiler, M. D. Time limits for completing fixed rations. *Journal of the Experimental Analysis of Behavior*, 1970, *14*, 275-286.