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PARAMETERS AFFECTING THE ACQUISITION OF SIDMAN AVOIDANCE[1]

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Four studies were conducted to investigate the source of reinforcement of Sidman avoidance. First it was found that the acquisition of avoidance was seriously impaired if there was no immediate stimulus consequence of responding, *i.e.*, proprioceptive and auditory feedback. The second study showed that if the shock-shock interval was split so that only responses occurring in one half of the interval were effective in postponing shock, then learning was impaired. It made little difference which half of the interval was used. The third study demonstrated that *Ss* learn Sidman avoidance more quickly with a variable shock-shock interval than with the usual fixed-interval procedure. The results of the second and third experiments argue against the view that avoidance is reinforced by the decrease in conditioned aversiveness that occurs at long post-shock times. The final experiment indicated that *Ss* do not learn Sidman avoidance if the response-produced delay of shock is preceded by a shock, hence it seems unlikely that the crucial source of reinforcement is merely an overall reduction in shock density. All of the findings are consistent with the hypothesis that the avoidance response is reinforced by the decrease in conditioned aversiveness of stimuli at short post-response times. This seems to be the case even at the beginning of acquisition.

The importance of the warning stimulus in classical avoidance learning has been amply demonstrated by Kamin (1956) and others. Thus, whether the warning stimulus is regarded as a conditioned negative reinforcer or as an elicitor of fear, the reinforcement of the avoidance response in the classical or discriminative avoidance situation may be readily attributed to the termination of the warning stimulus. But Sidman (1953) showed that rats could learn to press a bar to avoid (postpone) an electric shock even though there was no environmental warning stimulus, the termination of which could be said to reinforce the response. Moreover with Sidman's procedure it is not possible for the avoidance response merely to be a generalization of a previously acquired escape response; the bar press is never permitted to terminate shock but only to postpone the next scheduled shock. The question then is what reinforces bar pressing in Sidman's situation?

Sidman's own first proposal (1953) followed the general lines of the argument Schoenfeld (1950) had advanced to account for classical avoidance learning. According to Schoenfeld and Sidman (and subsequently Dinsmoor, 1954), any response other than the avoidance response is likely sooner or later to occur in the presence of shock, at which time the proprioceptive, tactile and external stimuli resulting from such non-avoidance behavior will become conditioned negative reinforcers. Their termination will reinforce any response which interrupts them. As alternative responses become punished they become gradually suppressed until *S* has no response available except bar pressing. One serious difficulty with this interpretation is that it would seem to require that the avoidance response be acquired rather gradually; in fact, it is commonly found that the response increases in strength precipitously, and frequently quite early in acquisition training. Moreover, once the behavior is established it is usually found to be exceedingly resistant to extinction.

More recently, Sidman (1962) has argued that the avoidance response may be reinforced by the reduction in shock density that it effects (*S* receives fewer shocks per unit time when it presses the bar than when it does not). Although a reinforcement mechanism based upon shock density may be effective early in

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acquisition, when a few responses can materially reduce shock density, Anger (1963) has pointed out that it cannot account for the continued improvement in performance long after the shock density has been reduced to values lower than the rat can be reasonably assumed to discriminate. Some other source of reinforcement must be sought.

The most recent and promising interpretation of Sidman avoidance has been made by Anger (1963). He argues that the aversive stimuli, termination of which reinforces the avoidance response, are temporal in character. And just as there are two temporal parameters in a Sidman schedule so there are two classes of temporal stimuli that can be involved. One is the set of stimulus changes that follow a shock. The subject is safe immediately after a shock but whatever temporal stimuli *S* has should increase in conditioned aversiveness during the interval (the S-S interval) as the time for the next shock approaches. When the avoidance response occurs *S* encounters novel post-shock-time stimuli (PST stimuli) which can only be aversive by generalization since they have never been paired with shock. The avoidance response is reinforced by the reduction in aversiveness it produces.

However, Anger (1963) stresses the importance of the second class of temporal stimuli and a reinforcement mechanism originally suggested by Mowrer and Keehn (1958). Stripped of Mowrer and Keehn's concepts of fear, drive and perseverative traces it is this: whatever stimuli follow the avoidance response, they are aversive only by generalization from those present at the time of shock. Stimuli that come later, toward the end of the postponement interval (the R-S interval), are more like those present at the time of shock and hence are more aversive. Making the avoidance response removes the stimuli of long post-response-time (PRT) and reintroduces those of short PRT. The reduction in conditioned aversiveness reinforces the response. This hypothetical reinforcement mechanism makes it possible to account for the more or less regular pacing of avoidance responses that occurs when the behavior is so well established that few shocks are received.

The purpose of the present study is to demonstrate that the temporal stimuli contingent upon responding also account for the early acquisition of the behavior. We will show that it is PRT stimuli rather than PST stimuli that are crucial in the initial acquisition of Sidman avoidance.

EXPERIMENT I

In proposing that it is the conditioned aversiveness of response-produced stimuli that are involved in reinforcing the avoidance response, Anger (1963) has not speculated about the locus or nature of such response-produced stimuli. They might be internal or external. The response time hypothesis requires only that there be some stimulus consequence of the response. The precise specification of the stimulus is not crucial so long as it can be assumed that there are some stimulus consequences of responding and that these stimulus consequences change with PRT. The purpose of Experiment I is to show that if the experimental situation is arranged so as to minimize the stimulus consequences of the avoidance response then it is not likely to be learned.

Subjects. Twenty naive male albino rats of the Sprague-Dawley strain, approximately 3 months old, were used.

Apparatus. A Foringer 1102 test chamber was equipped with a modified operandum. The bar was 2½ in. long, ½ in. in diameter, and protruded 2 in. into the box. Approximately 10 g of force were required to move it. A bar depression of 1/16 in. closed a silent wiping switch; the action of the bar was damped so that there was no "feel" or sound when it was pressed or released. It was located 4 in. above the grid. Recording and programming apparatus was located in another room. Thus, the sensory consequences of responding could be reduced to a minimum. Shocks were delivered from a high voltage dc constant-current source of 1.1 ma through a Lehigh Valley grid scrambler.

Procedure. Shocks of .30-sec duration were presented at 5-sec intervals (the S-S interval) unless a bar press occurred, in which case the next shock came 15 sec after the last response (the R-S interval). A response during the R-S interval initiated a new R-S interval.

Half of the *S*s were run under "silent" conditions, *i.e.*, those just described. The other half were run under the usual conditions where immediate sensory feedback of responding was provided; for these *S*s an empty Davis pellet dispenser was activated with each response. Subjects were run for 2 hr sessions, generally on successive days.

Results

Preliminary Considerations. Typically, the operant rate of bar pressing is initially relatively high and then drops off as the session continues. There is individual variation in operant rate which reflects primarily variation in gross body activity under conditions of periodic shock. Animals that flinch, freeze or develop stereotyped running reactions to the shock generally do not learn the avoidance response; those that explore, rear and attempt to climb the walls do learn. These gross activities raise the operant level of bar pressing.[3]

Effective avoidance does not, however, emerge gradually from the operant level; almost invariably there is a clearly specifiable point at which the rate of responding suddenly increases and the shock density suddenly decreases. The local rate of responding in this "acquisition burst" is usually at least as high as is found in well-established avoidance responding. It represents a sharp transition from rates near 25 per hr to rates in the order of 1000 per hr. Thus, there is rarely any question about whether *S* learns the avoidance response or at what point the learning becomes effective. Since the present studies are concerned with the parameters that reinforce avoidance early in acquisition, the primary concern will be with the effect of various experimental conditions upon the location of this acquisition burst, both in terms of the number of responses that precede it and how soon it occurs. The acquisition burst usually occurs either in the first or second hour of training or not at all; of the 27 *S*s that learned the avoidance response in the four present experiments 26 showed the acquisition burst in the first 2-hr session, and only one in the second session. The occurrence of the acquisition burst seems to require a relatively high operant rate of bar pressing, although, as Fig. 1 indicates, there are exceptions to this rule. It is as though *S* must make a number of responses in the "operant phase" so that long PRT's can become aversive. This is what the PRT hypothesis requires, and generally this is the way it seems to be. But there are some cases where the acquisition burst occurs before this can happen.

Some *S*s learn to freeze while holding on to the bar. This behavior occurs under normal conditions rather frequently; it is a phase that may last from a few up to 30 min, although it may be passed over entirely. This pseudo-avoidance phase occurs when *S* freezes on the bar so that no responses occur during the R-S interval. When the shock comes on *S* is jolted and a bar press is registered. Such pseudo-avoidance behavior is also easy to detect in the cumulative records since it results in a somewhat lower rate of pressing than that found in effective avoidance, and a shock density that is much higher and much more locally stable than that achieved by *S*s that learn to respond during the R-S interval. This sort of behavior may be reinforced by the mechanism Sidman (1962) has suggested, *i.e.*, by the reduction in shock density it produces. But more likely it is an artifact of the particular time intervals that were used here. Thus, *S*s will freeze on the bar when shocks recur every 15 or 20 sec but not when they recur every 5 sec; all too frequently they freeze crouched in the corner when shocks are presented at 5-sec intervals, but not standing by the bar. The more rapid shocks elicit too much competing behavior.

The effect of sensory feedback. Seven of the 10 *S*s trained under normal conditions, *i.e.*, with the click of the feeder mechanism occurring with every response, learned the avoidance response. Only two of the 10 *S*s trained under the silent conditions, *i.e.*, with a minimum of response feedback, learned in the two sessions. The cumulative response records for all *S*s are given in Fig. 1.

The four non-learners with the highest operant rates of pressing were run additional sessions; their rates dropped to 1 per hr or less. Subjects with response feedback achieved the acquisition burst sooner and on the basis of fewer prior responses than *S*s with no feedback. The medians under the normal conditions were 12 min and 20 responses as against indeterminant medians larger than 240 min and 35 responses under the silent condition. Counting just learners, the differences are still in favor of more rapid onset of the acquisition burst for the normal, *i.e.*, click, *S*s. The two *S*s that did learn with minimal feedback, as well

[3]The "operant rate" referred to here is something of a misnomer since, presumably, the avoidance response is reinforced whenever it occurs. The phrase here refers to the rate of responding in the absence of any behavioral evidence of reinforcement.

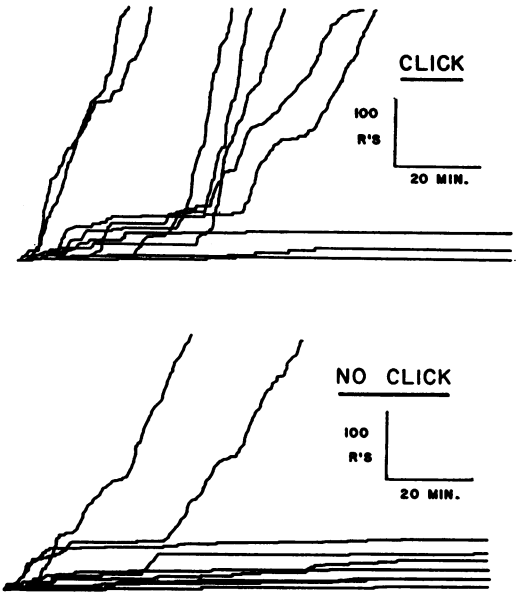

Fig. 1. Cumulative response records during the first training session of rats given a click for response feedback (upper records) or no click to minimize response feedback (lower records).

as other animals observed under these conditions, went through a prolonged pseudo-avoidance phase of freezing at the bar. Those learning with feedback showed shock density curves which, by the end of the 2-hr session, were still dropping. It would seem then that the introduction of a novel stimulus, such as the feeder click, which is contingent upon the avoidance response, markedly facilitates the acquisition of the response.

EXPERIMENT II

Anger (1963) has proposed that as time elapses after the last shock, the total stimulus situation becomes more aversive, more like that which exists at the time of shock. The conditioned aversiveness should be a monotonic increasing function of elapsed time in the S-S interval, since stimuli following shortly after a shock have themselves never been paired with shock and so can be aversive only by generalization. When a response occurs in the S-S interval, the animal soon encounters novel temporal stimuli which, because of their novelty, can only have generalized aversiveness. It is, according to the PST hypothesis, the transition from the relatively highly aversive preshock stimuli to these stimuli at novel post-shock times that provides the initial reinforcement of the avoidance response.

Responses made early in the S-S interval should not be so effectively reinforced as those made late in the interval. This follows partly from the continued increase in conditioned aversiveness that continues through the S-S interval, and partly because they are more removed in time from the eventual drop in aversiveness. This implication was tested in the present experiment by running two groups of *Ss*. For one, only responses made in the first half of the S-S interval were effective in postponing shock; for the second, only responses made in the second half were effective. It would be predicted on the basis of the PST hypothesis the second-half group should learn Sidman avoidance more readily than the first-half group.

Subjects. Seventeen naive male Sprague-Dawley rats, 3 to 4 months old, were used.

Apparatus. The same as in Experiment I.

Procedure. For the nine *Ss* in group 1, only responses made in the first half of the 5-sec S-S interval were effective in postponing the shock and only those responses produced the feedback click. Responses in the second half were recorded but were of no consequence to *S*; they neither produced the feedback click nor postponed shock. For the eight *Ss* in group 2 only bar presses made in the second half of the S-S interval were effective in producing feedback and in postponing shocks, and those in the first half were of no consequence to the animal. For both groups, however, all responses outside the S-S interval, *i.e.*, all those made in the R-S interval, were effective in providing further postponement of shock, and all such responses produced the feedback click. Hence, under these conditions, once avoidance became established it occurred under conditions that approached normal for both groups, but the conditions under which the initial acquisition burst occurred differed markedly between groups.

Results

Two of the nine *Ss* in group 1 learned the avoidance response, although in one of these (Rat #1-8) the behavior was of the pseudo-avoidance variety which lasted through three sessions. Two of the eight *Ss* in group 2 also learned the bar press response, and neither of them went through a pseudo-avoidance phase (because responses immediately after a shock were not effective).

The distribution of responses in the two halves of the S-S interval and the R-S interval is shown in Table 1 for each *S* for the first session. Subjects are ranked in the table according to the total number of responses. Note that there is very little difference in distribution of responses between the two groups, and that for all non-learners the preponderance of responses occurred shortly after a shock when gross body activity was high. This is also true of the majority of responses in the R-S interval; they occurred as infrequent bursts of responses that initiated an R-S interval). The only difference in pattern of responses is found in *S*s that learn. There the distribution of responses follows the reinforcement contingencies. Rat #1-9, cumulative records for which are shown in Fig. 2, displayed the most gradual acquisition of genuine avoidance of any *S*. There was no well-defined acquisition burst, although there is a sharp drop in shock density at point A, after 400 responses had been cumulated.

The conjectures regarding the importance of temporal discrimination within the S-S interval are not substantiated by these results. There is no overall increment in responding in group 2 that the hypothetical greater reinforcement from second-half responding is supposed to provide. Actually, the total number of responses in the first session was somewhat higher among non-learners than it was among non-learners in Experiment I where all responses in S-S were supposedly reinforced. On the other hand, it could be argued that a comparable number of responses were generated by far fewer reinforcements in group 2 than in group 1 (median of 13 as against 38). There remains the puzzle of why acquisition in both groups was so poor.

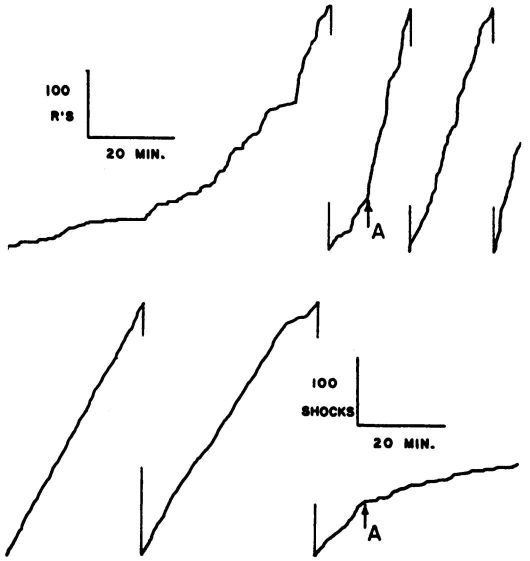

Fig. 2. Cumulative responses (upper record) and cumulative shocks (lower record) during the first training session of rat #1-9 which displayed unusually gradual acquisition of Sidman avoidance.

EXPERIMENT III

The results of the previous experiment suggest that discrimination of temporal stimuli in the S-S interval are relatively unimportant in Sidman avoidance. It is conceivable that the PRT hypothesis is applicable to the acquisition of avoidance right at the outset. To test

Table 1

The Distribution of Responses in the First and Second Half of the S-S Interval and in the R-S Interval by Rats for which Responding only in the First Half or the Second Half is Reinforced.

Group 1				*Group 2*			
	R's in S-S				*R's in S-S*		
Rat #	*First Half*	*Second Half*	*R's in R-S*	*Rat #*	*First Half*	*Second Half*	*R's in R-S*
1-1	22	4	0	2-1	25	6	0
1-2	21	2	4	2-2	20	9	5
1-3	27	1	5	2-3	31	3	1
1-4	24	6	4	2-4	31	8	4
1-5	34	2	4	2-5	37	8	2
1-6	37	3	1	2-6	64	17	7
1-7	39	4	3	2-7	523	637	451
1-8	689	30	333	2-8	407	922	714
1-9	664	63	498				
Medians	34	4	4		34	8.5	4.5

this possibility two groups of Ss were run, one under the usual conditions with S-S interval fixed, and the other with a variable S-S interval. Under the variable S-S condition there should be little or no opportunity for the hypothesized PST mechanism to be effective. If PST discrimination does in fact play a part in the initial acquisition of avoidance behavior, then learning should be impaired. On the other hand, any learning which results in this situation should be the result of differential aversiveness of early and late PRT stimuli.

Subjects. Fifteen naive albino female rats of the Dublin Disease Resistant (DDR) strain, 2 to 3 months old, were used.

Apparatus. The same used in the preceding experiments except that the S-S interval was governed by a tape programmer.

Procedure. The seven Ss under the FI condition were presented with shocks every 5 sec as long as no bar press occurred. A bar press stopped the S-S programmer and delayed the next shock for 15 sec; a response during the R-S interval initiated a new R-S interval. Eight Ss of the VI group were presented shocks on a 5-sec VI schedule (6, 8, 2, 7, 2, 5, 7, 1, 9, 6, 3, 1, 9, 8, 4, 3, 5, 4 sec). All responses produced the feedback click.

Results

Five of the 8 Ss in the FI group learned the response in the first test session. This proportion is comparable to the 7 out of 10 Ss that learned under the same conditions in Experiment I. The striking finding here is that all Ss in the VI group learned the avoidance response. Comparing Ss in this group with just the learners of the FI group, their performance is still superior. They made more responses during the first session, received fewer shocks, showed a shorter latency to the acquisition burst and achieved this burst on the basis of fewer responses.

It would seem that the regular pacing of shocks under the FI S-S condition interferes with avoidance learning rather than providing the basis for it. Direct observation of Ss reveals that they are considerably more active under the VI condition than under the FI condition. Evidently the regular pacing of shocks at a fixed S-S interval permits S to learn postural adjustments such as freezing and perhaps other unauthorized avoidant behaviors which compete with bar pressing. Whatever the details of this competing behavior, it is clear that the avoidance response is not principally reinforced, if at all, by the interruption of a temporal pattern of shocks.

EXPERIMENT IV

Sidman (1962) has suggested that an important variable in avoidance is the reduction of shock density. The animal is supposed to learn to discriminate the difference between shock and no shock, and the reduction of the density of shock provides reinforcement of the response that produces it. In the present experiment this interpretation was tested against the PRT hypothesis. The experimental situation was arranged so that after an avoidance response in the S-S interval that S-S interval was completed, the scheduled shock was presented, and then the R-S interval was interposed. Responses made during the R-S interval were then effective in providing further postponement of shock. This procedure permits a decrease in the shock density but isolates the change in density from the response by a shock delivered on schedule. According to the shock density hypothesis, learning should occur under these conditions. However, if the PRT hypothesis provides the correct interpretation, then learning should be virtually impossible under these conditions.

Subjects. Fourteen naive albino female rats of the DDR strain, 3 months old, were used.

Apparatus. The same apparatus was used.

Procedure. As before, the shock was presented at 5-sec intervals in the absence of a bar pressing. When a response occurred the next scheduled shock was delivered but the appearance of the following shock was delayed for the R-S interval. Responses in the R-S interval provided further postponements of shock. Two groups were run, one with a 15-sec R-S interval and the other with a 45-sec R-S interval.

Results

With the 15-sec delay condition no S learned the avoidance response. With the 45-sec delay, one S learned. The behavior in this one case, it should be noted, was exceedingly persistent and precise pseudo-avoidance.

In conclusion it would seem that the stimuli that follow a response and increase in aversiveness with the passage of time since the response (PRT stimuli) not only play a crucial role in the ultimate form Sidman avoidance behavior takes after prolonged training, but are also important in the initial acquisition of this behavior. There seems to be little or no avoidance learning unless the response results in some immediate stimulus consequence for the animal (Experiment I). The generalized components of this stimulation (or its traces) increase progressively in aversiveness during the R-S interval so that *S* is reinforced for abolishing these aversive components (or resetting the trace). If low aversiveness of short PRT stimuli is precluded by the experimental conditions (Experiment IV), then learning to respond during the R-S interval does not occur. The analogous temporal gradient of aversiveness arising from the stimulus consequences of the shock itself (PST stimuli) seems to play a minor role in the acquisition of the behavior (Experiments II and III).

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