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We, the undersigned members of the Committee appointed by you to examine the thesis submitted by Mr. A. Donald Mullin in partial fulfillment of the requirements for the degree of Master of Arts, beg to report that we consider the thesis satisfactory both in form and content.

Subject of Thesis: Delayed Termination of the Conditioned Stimulus at Different Stages of Avoidance Learning.

We also report that Mr. Mullin has successfully passed an oral examination on the general field of the subject of the thesis.

DELAYED TERMINATION OF THE CONDITIONED STIMULUS AT DIFFERENT STAGES OF AVOIDANCE LEARNING

A thesis

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1. INTRODUCTION

1.1 Avoidance Behavior and Motivation

The study of avoidance behavior is not new to psychology; it was investigated in the laboratory as early as 1913 by the Russian physiologist, Bekhterev. Recently, however, avoidance learning has attracted the interest of psychologists concerned with the motivation of behavior. This interest is related directly to the most central event in avoidance learning, the presentation of noxious or aversive stimuli. It has long been recognized that the aversiveness of an unconditioned stimulus (US) is motivating and contributes to the acquisition of escape behavior (responses that quickly terminate the aversive stimulus). More recently, however, some theorists (Solomon & Wynn, 1954; Mowrer, 1960) have also attributed motivating properties to the conditioned stimulus (CS). It is claimed that after the CS has been paired a few times with a noxious US it is no longer neutral but comes to take on fear or anxiety arousing properties that act as a drive (Miller, 1948).

Conditioned fear is considered, by the above theorists, to provide a complete motivational-reinforcement basis for avoidance learning. Briefly, the reasoning goes as follows. Early in the course of avoidance learning a process of classical conditioning occurs in which the fear response, initially elicited only by the noxious US, becomes conditioned to the CS. This renders the onset of the CS a fear-arousing event, and (by the same token) the termination of the CS a fear-reducing event. The fear reduction occurring when the CS is terminated is a drive reducing and therefore reinforcing event according to conventional drive-reduction theory of reinforcement. The concept of fear drive is an important and powerful one since it provides an explanation for the acquisition of avoidance responses. Animals learn to make avoidance responses, not because they prevent the occurrence of the US (a teleological interpretation), but because they terminate the CS and bring about fear reduction.

It can be readily seen that this conditioned fear theory makes crucial the temporal contiguity between CS termination and the occurrence of the avoidance response. If avoidance responses are to be maximally reinforced, they must be followed by prompt CS termination. Hence, the theory can specifically predict that delaying CS termination beyond the occurrence of the avoidance response (hereafter referred to as the CS delay procedure) will retard avoidance learning. Of course, terminating the CS before the occurrence of avoidance responses will also create a temporal disparity between the two events, and should likewise lead to inferior avoidance learning.

These views have led (not always directly) to several experiments for it was seen that no other theory could readily make the same specific predictions. These studies will be considered in some detail in the section to follow.

1.2 Parametric Studies of CS Termination

The first experiment to study the temporal relationship between CS termination and avoidance responses was apparently conducted by Mowrer and Lamoreaux (1942). They found that for rats in a shuttle box a CS that was terminated immediately by the avoidance response (hereafter referred to as a response-terminated CS) resulted in significantly better avoidance learning than either a 1 sec. CS or a CS that was terminated 5 sec. after avoidance responses. In a later study Mowrer and Lamoreaux (1951) compared a response-terminated CS with an "instantaneous" CS (a momentary CS occurring 5 sec. prior to scheduled shock). The results showed that the group whose responses terminated the CS made the most avoidance responses. Although Mowrer and Lamoreaux were concerned with a somewhat different question, the data can be interpreted as evidence that CS termination is a reinforcing event as conditioned fear theory predicts.

Traum and Horton (1950), in a factorially designed study, also found that rats receiving a response-terminated CS made more avoidance responses than rats receiving an invariable 5 sec. CS. These data again supported the prediction under discussion, but their statistical reliability was not clearly demonstrated.

The first really systematic and extensive effort to evaluate the effects of delaying CS termination was carried out in a series of studies conducted by Kamin. Two of his studies (Kamin, 1957a, and 1957b) are most directly relevant. In both studies he used rats in a shuttle box and delayed the termination of the CS after avoidance responses by 0.0, 2.5, 5, or 10 sec. respectively. In both studies acquisition of the avoidance response was a declining monotonic function of the amount of CS termination delay.

In the second part of his last study (1957b) Kamin conducted an even more critical test. Using similar CS delay groups he delayed the CS on only the first avoidance trial, and found that delaying the CS by as little as 2.5 sec. resulted in the animals' taking longer to make the second avoidance response. The results of this procedure gave a rather convincing indication of the reinforcing power of CS termination.

All the studies cited thus far were concerned with the role of CS termination during the acquisition of an avoidance response.Verhave (1959) attempted to determine if the effect of CS delay could also be demonstrated on an already acquired and well practiced avoidance response. He trained rats in a Skinner box to avoid shock by rotating a small drum in response to a 7-sec. CS. After about 650 trials of training, when Ss were avoiding shock efficiently, he instituted the delayed CS procedure. There was a marked decline in avoidance responding, presumably because CS-termination reinforcement was no longer contiguous with the avoidance response.

The studies cited in this section appear to comprise all the direct evidence that has been obtained on CS termination and avoidance responses. An evaluation of this evidence follows in the next section.

1.3 Evaluation of Evidence

It might be noted first that all the evidence pertaining to CS termination and avoidance responses supported the predictions of conditioned fear theory. Terminating the CS either before the occurrence of the CR, or using the CS delay procedure led to inferior avoidance responding during either acquisition or performance. However, the first of these two procedures suffers from an ambiguity of interpretation. Terminating the CS before the occurrence of the avoidance response shortens its average duration so that as a "cue" or signal it may be less effective. Hence, the inferior avoidance learning that resulted from this procedure (Mowrer &

Lamoreaux, 1942, 1951) may have been due to a less effective warning signal rather than the non-continuity between avoidance responses and CS termination. With this exception the data on acquisition of the avoidance response seem quite sound, especially Kamin's results. However, the data on the performance of the avoidance response (Verhave, 1959) is less adequate and not so convincing. To be noted first is the conditioning apparatus used by Verhave. In his modified Skinner box rats were required to rotate a small drum located in the end of the box. The data shows that only six of the eight Ss learned to use this response efficiently in order to avoid shock. This may only mean that two of the Ss were "slow learners", but it could also suggest that avoidance responding via drum-turning may not be the most stable kind of response to employ in studying the effects of CS delay. It would be more convincing if the CS delay effect were demonstrated on a response higher in the rat's response repertoire, such as running or jumping.

It is also significant to note that the design employed by Verhave was inadequate on two accounts. In using steady-state behavior to study the effects of variables, there are certain requirements that must be met (Sidman, 1960). The first requirement is to demonstrate that the behavior has achieved stability under a given set of conditions. Once stable behavior is achieved as a baseline, one variable in the conditions can be altered, but no further changes should be made before one of three eventual outcomes: (1)baseline behavior remains unaffected even after a considerable period of testing, (2) baseline behavior becomes asymptotic at a new level, or (3) baseline behavior becomes unstable and it becomes clear that stability will not be achieved. In Verhave's study the CS delay produced a considerable effect when first introduced, but the final outcome of the effect on many Ss had not been reached before regular training conditions were restored. Thus, it is uncertain whether these Ss would have eventually regained their pre-delay (baseline) performance levels, whether they would have stabilized somewhere below it, or whether they would have failed to stabilize at all.

It is also important to have some assessment of the reliability of baseline measures. With respect to the design used by Verhave there is no assurance that the stability of the baseline avoidance rate would have continued beyond the point at which CS delay was introduced, and therefore no assurance that it was the CS delay procedure that initiated the drop in performance.

The reliability of the steady state behavior must be demonstrated by including a control group in the design, or possibly by citing other data that would serve the same purpose.

In summary, the studies using CS delay during avoidance conditioning have produced considerable evidence that CS termination is an important reinforcing event for avoidance responding. The evidence on the effects of CS delay during acquisition of the avoidance response seems adequate; but as indicated above, further data are required to assess the effects of CS delay during performance. It is the purpose of the present study to obtain such data. The design followed that employed by Verhave, but with changes and modifications to provide a more adequate test of the effects of CS delay on avoidance performance. These changes required that several factors and parameters be given careful consideration, especially since statements in the literature on methods and parametric values were not always consistent. Since the details of these considerations are complex, and have only tangential interest here, a complete discussion of them is presented in Appendix A. The next section will proceed directly with a more general outline of the design of the present study.

1.4 Design and Predictions

An outline of the design used in the present study is given here to allow a more operational statement of the predictions, and to make it easier for the reader to follow the

Method section.

It will be recalled from section 1.3 that the initial purpose of the study was to get more adequate data on the effects of delayed CS termination during performance of an avoidance response. It was planned to train two groups of Ss for 660 trials on a regular avoidance conditioning programme, and then to introduce the CS delay procedure to one of the two groups. The other group of Ss was to remain on regular avoidance conditioning to ascertain if initial baseline performance levels would remain stable beyond 660 trials of regular training. After serving as a control for an adequate period of time (1610 trials) these Ss were also to be tested on the CS delay procedure so as to provide preliminary data on the effects of CS delay following extended training.

The results obtained from the first six Ss indicated that the effect of CS delay was small in magnitude and not permanent. These results seemed to be related to the procedures used; and it was, therefore, decided to expand the original design and incorporate a third group which would receive CS delay from the onset of training. This modification allowed for a test of the effects of CS delay on the acquisition of the avoidance response, and also permitted a comparison of the effect of CS delay on acquisition (Kamin, 1957b) as opposed to its effect on performance (Verhave, 1959).

To summarize, the final design employed three experimental groups: group I received 0, group II 660, and group III 1610 trials of regular avoidance training prior to the introduction of the CS delay procedure. Testing for the effect of CS delay on acquisition employed an inter-subject comparison (group I versus group II + group III), while the effect of CS delay on performance after 660 and 1610 trials of regular training employed intra-subject comparisons (comparison of the avoidance rates preceding CS delay with those during CS delay).

It was predicted on the basis of the effects of CS termination reinforcement and the results of previous studies that: (1) the avoidance rates of group I Ss would be inferior to the rates of group II and group III Ss, (2) the avoidance rates of group II and group III Ss would decline when the CS delay was introduced after the appropriate amount of regular avoidance training.

2. METHOD

2.1 Subjects

This study employed 18 experimentally naive albino rats of Wistar strain obtained from the Saskatoon Cancer and Medical Research Institute. At the start of testing the animals ranged in age from four to seven months, and in weight from 300 to 505 grams. During testing they were housed in individual cages with continual access to food and water. They were prehandled prior to the beginning of testing. One animal from group III was eliminated from the results due to both behavioral and physical abnormalities (see Appendix B).

2.2 Apparatus

The apparatus consisted of four basic units: a rotor, a four-channel recorder, a stimulator, and a programmer. (Pictures of rotor, and a wiring diagram are given in Appendices C and D).

The rotor consisted of a drum 20 in. in diameter and 6 in. wide. It was constructed of two 3/8 in. lucite sides joined by 3/16 in. aluminum rods. The ends of the aluminum rods were set in the lucite sides at a 19 in. diameter and centered 5/8 in. apart. A 13 in. circular door was cut in the center of the one side leaving a 3 1/2 in. rim. This door was hinged to open outward, but otherwise remained stationary while the rim was free to rotate around it. The other side was one solid piece, and was bolted against three rigid spokes that radiated from the end of a 3/4 in. shaft. This shaft was in turn mounted to the chassis on two self-centering ball bearings so that the rotor was free to turn with a minimum of friction. A hinged brake shoe rode lightly on the top edge of the inside rim of the drum, and permitted rotation in one direction only.

To turn the rotor the animal had only to move forward past the vertical center line. To stop rotating the animal had to stop running and remain stationary with respect to the rotor. When the animal did this, it was carried back past the vertical center line in a pendulum-like arc. At the top of this backward swing, the rotor came to a smooth silent halt, and was kept stationary by the brake until the animal again moved forward.

At the rear of the main axle was a 4 5/8 in. wheel or disc having a hard rubber band on the circumference. This disc turned a small (approx. 3/8 in. diameter) wheel mounted with an eccentric axle to the end of a set of electrical contacts. By virtue of its eccentric mounting, the rotation of this small wheel opened and closed the contacts. One cycle of opening and closing was completed for every 30 degrees of rotor rotation. The electrical contacts controlled an electrical circuit that operated one recording pen of the recorder. In this manner, rotation of the rotor was recorded as a square wave with the pen deflecting after every 15 degrees of rotation.

Avoidance and escape responses in the rotor were defined as 30 degrees of rotation after CS onset. This was accomplished by means of a special mechanical switching mechanism. This mechanism had three electrical contacts that controlled the operation of a holding circuit. The contacts were operated by a 2 5/16 in. disc. At CS onset this disc was engaged next to the 4 5/8 in. disc by the action of a 110 v. DC solenoid. Following CS onset the switching mechanism would be tripped by a minimum of 30 degrees of rotor rotation. Activating the switching mechanism initiated a series of events: the holding circuit was discharged, a relay was opened, and the power supply to the CS, US and solenoid were discontinued. The holding circuit had capacitance to operate for about 11 seconds, and hence allowed sufficient time for the normally programmed CS and US to expire.

Alternate bars of the shock grid were wired together to form two single circuits. The constant current output from an Applegate, model 228, stimulator was transferred to the bars by means of two sliprings and brushes, in the same manner as current is collected from the armature of an electrical AC power generator. The grid was cleaned periodically to remove minor accumulation of faeces and urine.

A Gerbrands two-channel programmer was used in connection with relays and electrical circuits to programme the administration of the buzzer and shock. As a convenience, the circuit was designed with a switch that when turned on, changed the regular programme to the CS delay programme.

During training a model B-200 four-channel event recorder (Pharmaceutical Research & Development Co.) was used to record the occurrence and durations of the CS, US, and rotor turning.

All aspects of the apparatus except the recorder were located in a small test chamber about 6 ft. square. The rotor sat on a table adjacent to one wall. The buzzer was mounted on the same wall at a spot 12 in. above the rotor. The Gerbrand's programmer was mounted on a second wall.

All relays were housed in a sound-reducing box made of four layers of insulating material and a dead-air space. The recorder could not be silenced in the same manner, as it required ventilation for cooling. To minimize the clicking sound of the pens, the recorder was located at a distance from the test chamber and housed in a less efficient but ventilated sound-reducing box.

With this arrangement, apparatus noise was restricted to the constant but very mild hum of the Gerbrand's programmer, the very faint clicking of its microswitches, and the faint and distant clicking of the recorder. One recorder pen operated whenever the rotor was turning, but all other events producing any noncontinuous sounds occurred in conjunction with CS onset, CS termination, or during a short interval after the occurrence of each trial. The test chamber itself, however, was not soundproof, and it was not possible to control a wide and random variety of noises originating from outside the chamber.

2.3 Procedure

In reading this rather detailed section the reader should keep in mind the outline of the experimental design that was given in section 1.4. The stimulus conditions used in regular avoidance training consisted of a buzzer as the CS and a shock as the US. The intensity of the buzzer was about 60 decibels, and its frequency was approximately 170 cps. At the beginning of testing, the shock intensity was set at 0.5 milli-amperes for all _Ss_. But after a few hundred trials three group I _Ss_ stopped responding to this intensity, and for these animals it was increased to 1.0 ma.

Each trial of standard avoidance training began with the onset of the CS. Following CS onset either of two things happened. The S could make a rotor turning response (turning the rotor a minimum of 30 degrees after CS onset) sometime before 5 sec. had expired, and by doing this immediately terminate the CS and prevent the otherwise scheduled shock from occurring for that trial. Since responses of this kind were instrumental in averting shock, they were termed avoidance responses or avoidances. If S failed to respond before 5 sec. had elapsed, the shock came on and could only be terminated (together with the CS) by a rotor turning response. Responses of this kind were instrumental in escaping the shock and buzzer, and were termed escape responses or escapes.

Delayed-CS avoidance training differed in only one respect; instead of the CS being immediately terminated by the S's responses, it lasted a full 7 sec. as programmed. This meant that after avoidance responses, the termination of the CS was delayed anywhere from two to just under 7 sec. depending upon when the response occurred during the CS-US interval. This made for a variable CS delay. It was also possible for the CS termination to be delayed slightly on escape trials, but for this to happen the animal had to make an escape response in less than two secs. after shock onset. The amount of CS-termination delay after escape responses also tended to be further minimized by the S's tendency to respond longer than necessary in escaping shock.

Subjects were permitted to respond at any time during either the regular or delayed CS procedure.

During testing each S received one session of 50 trials per day. On the first day of testing all Ss received an adaptation session in which each trial consisted of a 10 sec. non-terminable CS presentation without shock. Regular avoidance training for group II and III Ss, and delayed-CS avoidance training for group I Ss was begun the second day. Group I Ss were trained on the CS delay procedure for a varying number of sessions depending upon each S's individual performance. Group II Ss remained on the regular training procedure till the 13th session when they were switched over to the CS delay procedure. Group III Ss were switched over during the 33rd session. In both cases this switching over was done after the first ten trials of the session provided that S avoided consistently. This happened with all but two Ss in group III, in which case they were switched over after they had avoided on all trials from 10 to 20. This procedure was adopted to rule out possible influences occurring between test sessions.

The intertrial interval (ITI) was randomized, and its average duration reduced from 60 to 30 sec. over the first 400 trials. During the first 250 trials (first five sessions) ITIs of 40, 50, 60, 70, and 80 sec. were used. For the next 150 trials (sessions 6 to 8) the average ITI was reduced from

60 to 45 sec. by using ITIs of 25, 35, 45, 55, and 65 sec. Thereafter the intervals were 20, 25, 30, 35 and 40 sec.

The 18 _Ss_ were run in three sets of six each. Testing for the first, second, and third sets was started on February 11th, April 20th, and May 25th respectively. Because of the addition to the design part-way through the study (see section 1.4), _Ss_ in each of the three sets were not evenly assigned to all three conditions. The first set of _Ss_ was divided randomly between groups II and III. After the results from the first set were collected, group I was added, and from the second set of _Ss_ four were picked at random for group I and one each for group II and group III. This made a combined total of four for each of the three groups. But the results of the second set of _Ss_ indicated an interesting variability in the performance rates of group I _Ss_, and to get more data, a third set of animals was tested. From this third set four _Ss_ were picked at random for group I and the other two were assigned to group II.

The criterion used in terminating testing followed Sidman's (1960) suggestions. Testing was continued until each _S's_ avoidance rate had become stable and asymptotic (or remained unstable) over a considerable period of testing. One _S_ in group I was discontinued after 900 trials of testing when it had failed to make any avoidances after the first 250 trials. All other Ss in group I were tested for a minimum of 1400 trials and some of them for as many as 2400 trials. The Ss in group II were tested on the CS delay procedure for a minimum of 950 trials (max. 1500 trials). The Ss in group III were tested for 550 or 600 trials on the CS delay procedure.

For each S a daily record was kept of weight, time at which testing began, and the temperature of the test chamber. Starting times unavoidably varied somewhat during the shortening of the ITI. However, Ss were always tested in the same order, and testing was always started in the morning between 9:00 a.m. and 10:00 a.m., with only three exceptions in which testing was started as late as 10:30 a.m.

The temperature generally varied from 70° - 80°F. with only a few exceptions -- 66° and 84°F. being the extremes. However, no one animal experienced this full range of temperature variation.

Data scoring was facilitated by a special data scoring apparatus. A description and picture of this apparatus are given in Appendix E. An escape response, avoidance response, or an anticipatory response was scored for each trial. If shock had been delivered, the trial was scored as an escape response. If no shock had been delivered, and the CS duration exceeded 0.5 sec., an avoidance response and its latency (to the nearest 0.5 sec.) was scored. If the CS duration for the trial was 0.5 sec. or less, an anticipatory response was scored. Pilot tests had indicated that rats seldom, if ever, executed an avoidance response in less than one sec. unless the rotor was in motion at CS onset. When the rotor was in motion at CS onset, response latencies were almost always less than 0.5 sec. The criterion for anticipatory responses was based on these two observations.

The data were continuously scored from day to day for each S, and plotted on profiles so as to be able to continuously observe the performance of individual Ss. Included were daily avoidance rates, average avoidance latencies, animal weight, and number of anticipatory responses.

3. RESULTS AND DISCUSSION

The results can be most conveniently considered in three parts; (1) the characteristics and stability of avoidance responding, (2) evidence pertaining to pseudoconditioning, and (3) the effect of CS delay on the acquisition and performance of the avoidance response. For the first two sections the results will be discussed as they are presented, while for the third and main section the discussion will follow the presentation of results.

3.1 Avoidance Behavior

The acquisition of the avoidance response in the rotor appeared to correspond to the typical pattern reported for other more widely used training conditions. The nine Ss on the regular training procedure (group II and III) demonstrated a typical learning curve over the course of the first training session (see Figure 1). The most significant feature of this learning curve appears to be its marked negative acceleration indicating a rapid initial acquisition rate. As early as the first 10 trials the mean avoidance rate for Ss was 50 percent, and over the next 10 trials their avoidance rate reached 78 percent. This left little opportunity for further improvement over the last 30 trials. In order to determine how this

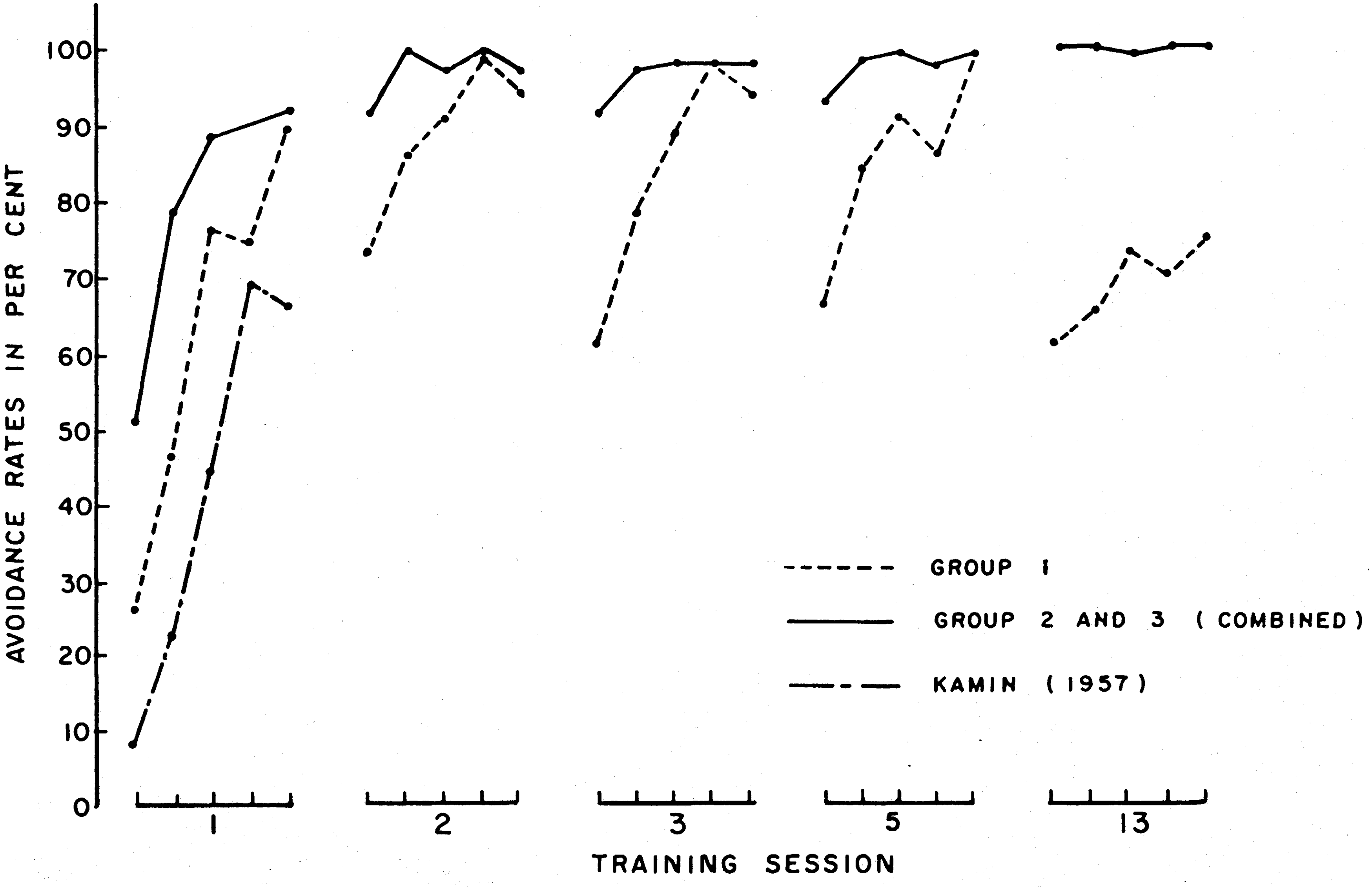

Fig. 1. Group avoidance rates during training sessions 1, 2, 3, 5, and 13 (blocks of 10 trials).

acquisition rate compared with avoidance learning in the frequently used shuttle-box, the data from the first 50 trials of Kamin's (1957a) control group were also plotted in Figure 1. This comparison suggests that avoidance acquisition in the rotor is more efficient than in the shuttle-box; however, no statistical evaluation was possible, because the scores of Kamin's individual Ss were not available. To obtain a statistical comparison of avoidance learning between rotor and shuttle-box, the data from Mullin and Mogenson (1963) were utilized, and a Mann-Whitney U test comparison was made for five indices of acquisition: the trial of the first avoidance response (U = 13.5), the trial of the second avoidance response (U = 13.5), the trial of the first two consecutive avoidance responses (U = 6.5), the first trial of the first 10 consecutive avoidance responses (U = 18.0), and the number of avoidances made during the first 25 trials (U = 15.5). It will be noted that each U value was highly significant ($p < .01$), and confirms the observation by Keehn (1959) that avoidance learning in a rotor is more efficient than in a shuttle-box.

Avoidance performance became relatively stable during the first 50 trials, and remained remarkably constant over the course of the next 600 trials (see

Figure 2). During each session, 9 to 13 inclusive, all Ss in groups II and III avoided consistently at a rate above 92 percent. The performance of group III Ss became even more stable during sessions 14 to 32, with no S responding below 98 percent. These data suggest behavior stability, and indicate that the avoidance responding obtained in the present study was suitable as steady-state behavior. The high stability of this behavior permitted a sensitive test of the effects of CS delay.

The average rate of anticipatory responding was low, occurring on only 2.5 percent of either the regular or CS delay trials.

3.2 Pseudoconditioning

It will be recalled that certain procedures were adopted in an attempt to minimize pseudoconditioning (Appendix 1). In order to determine whether these procedures had been successful, the data were analysed for specific pseudoconditioning effects. However, because there is no adequate criterion by which to determine the presence of pseudoconditioning and because it is a minor issue, the analyses is presented in Appendix F. The results of this analysis failed to indicate any clear evidence of pseudoconditioning. In particular, there is no evidence that the CS elicited rotor turning until it had been paired with grid shock.

3.3 Effects of CS Delay

The overall results are illustrated in Figure 2. The raw data which it serves to summarize is given in Appendix G. The results of CS delay is seen by comparing the mean curve for group I (N = 8) with the curves for groups II (N = 6) and III (N = 3). For statistical analyses the data covering groups II and III were combined and compared with group I. Between-group performance was analysed using the Mann-Whitney U test on the following four criteria of response acquisition: the number of trials preceding the first two consecutive avoidance responses ($U = 22.5$), the number of trials preceding the first ten consecutive avoidance responses ($U = 15.5$), the number of avoidance responses during the first 25 trials ($U = 20.5$), and the number of escape responses between the first and second avoidance response ($U = 34.5$). None of the differences between the two groups on any of the four criteria were significant ($p > .05$) in all cases). It can be assumed, therefore, that there were no differences between the groups in initial learning.

A further test of the effects of CS delay was made by comparing the two groups using two other criteria:

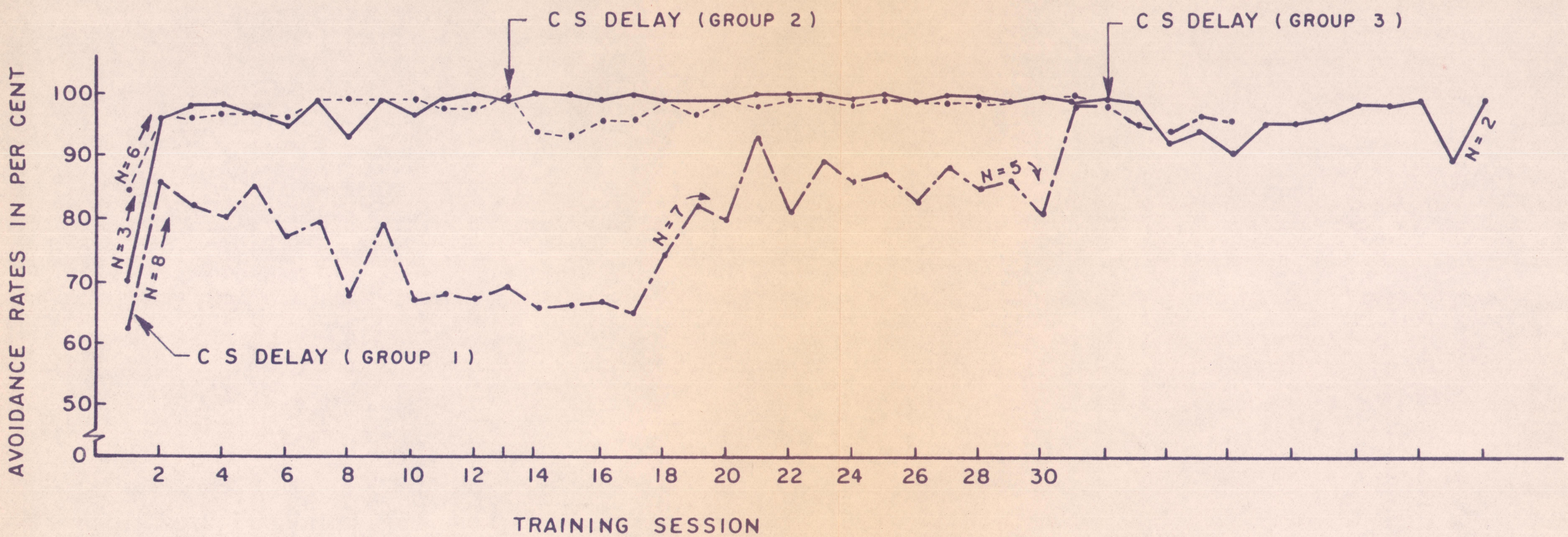

Fig. 2. Group avoidance rates by daily session for groups I, II, and III. (CS delay was introduced for each group at the indicated points).

the total number of avoidances that occurred during the first 50 trials of training, and during the first 100 trials of training (cf. Kamin; 1957a, 1957b). Differences were significant in both cases ($U = 11$, $p < .02$; and $U = 4.5$, $p < .002$). To test for the permanence of this effect, the two groups were compared on combined sessions 3 to 7, and on combined sessions 8 to 13. Differences remained significant ($U = 11.5$, $p < .05$; $U = 7$, $p < .02$).

The effects of CS delay on the avoidance performance of group II and III Ss involved within-group comparisons of avoidance rates just preceding and just after the introduction of CS delay. For group II Ss (CS delay after 660 trials), a randomization test for matched pairs (Siegel, 1956) was used to compare performance during the 200 trials preceding introduction of the CS delay (baseline performance) with the first 200 trials of performance on delayed CS. The CS delay produced a significant decline in performance ($p < .02$). To test the permanence of this effect, the randomization test was used to compare the 200 trials of baseline performance with the second 200 trials of performance under CS delay. The effect of CS delay was no longer significant ($p > .05$), indicating that the Ss had returned to their predelay baseline performance level.

The effects of CS delay on group III Ss (delay after 1610 trials) was examined using a Friedman two-way analysis of variance (Siegel, 1956). The avoidance performance just preceding the introduction of CS delay was compared with performance during the first, second, and third 100 trials of delayed CS. The effect of CS delay was found to be non-significant ($X^2_r = 6.1$, $p > .10$).

It appeared that another of the effects of CS delay was to increase within-group variability. To assess this the F ratio was used to test independent variances (McNemar, 1949, p. 244-247). In comparing the within-group variance of group I versus groups II and III (combined) over successive sessions 1 to 13, it was found that there was no significant difference on sessions 1 and 2, but that on sessions 3 to 13 inclusive, the within-group variance of group I was significantly greater($p < .02$).

It was further noticed that the introduction of the CS delay procedure to groups II and III initiated a change in response pattern. When termination of the CS was delayed, _Ss_ continued to run until the end of the 7-sec. CS duration. An attempt was made to measure this change in response pattern by recording for each trial the occurrence of running during four successive intervals of the 7-sec. CS (0 - 1 sec., 1 - 3 sec., 3 - 5 sec., and 5 - 7 sec.). The percentage of trials on which _Ss_ responded during each of these four intervals was plotted for each _S_ on separate profiles. To illustrate the effect of CS delay on the response pattern, three typical sets of profiles for group II Ss are presented in Figure 3. Each of the three sets contains four successive profiles: the training session just preceding introduction of CS delay, and the first, seventh, and seventeenth sessions under CS delay training. These profiles clearly demonstrate the change in the response pattern that was initiated by the delayed CS. Ss in groups I and III that were making a high percentage of avoidance responses also continued to run throughout the seven-sec. delay period. However, Ss that performed poorly in the rotor during CS delay did not display this continuous responding.

3.4 Discussion

The results demonstrate that delay in the termination of a CS can produce a decrement in avoidance behavior. When initial training was under conditions of CS delay (group I), there was a significant and permanent decrement in avoidance responding. However, it is important to note that this effect did not appear until after the completion of 25 training trials. This indicates that there was no significant between-group difference initially, and that the data of the present study were therefore adequate to test for the effects of CS delay upon acquisition.

The acquisition data were entirely consistent with those of Kamin (1957a, 1957b), in that Ss under CS delay training made fewer avoidances during the first 100 trials of training than did Ss under regular training. Kamin did not analyse his data to determine the specific effects of CS delay on early acquisition, but his group data suggest that the effects of CS delay did not begin to appear until after the completion of some 20 to 30 training trials.

The data for group II show that the CS delay procedure likewise produced a significant decline in the performance of a well established (stable) avoidance response. However, the effect is considerably smaller, as indicated by the mean performance curves given in Figure 2. No S in group II performed below 84 percent while on the CS delay procedure. In addition, the effect was neither permanent, nor significant beyond the first 200 trials of CS delay training.

Both the small magnitude and transitory nature of the effect in the present data appear to differ from the results reported by Verhave. Although Verhave's data are limited, there are indications that his Ss declined to avoidance levels between 0 and 60 percent (over 60-trial blocks) at sometime during the CS delay training.

This is in contrast to the effects of the delay in the present study where no group II S responded below 84 percent at any time under conditions of CS delay. Verhave's data also show that, even for Ss that did return to their predelay performance rates, more than 200 trials were required.

There are three factors that may have contributed to the differences between the results of the present study and that of Verhave. First, the duration of CS delay in the present study was considerably shorter. The duration of CS delay after avoidance responses (30 degrees rotor rotation) could vary from 2 sec. up to a maximum of approximately 4 sec., whereas for the Verhave Ss, the degree of delay varied from 4 sec. to approximately 10 sec. A second factor was that in the present study there was little chance of the CS being delayed appreciably on escape trials, whereas for Verhave's Ss it could be delayed by almost 5 sec. after the escape response. Since Church and Solomon (1956) and Kamin (1957b) have demonstrated that delaying the CS on escape responses has a detrimental effect on acquisition of a shuttle box avoidance response, it is reasonable to ascribe the decrement in the Verhave study, in part at least, to CS delay on escape trials. Finally, it might be suggested that avoidance responding in a rotor is more stable and is disrupted to a lesser degree by a change in stimulus conditions than is true for a shuttle box situation.

The effect of CS delay on group III Ss did not reach statistical significance. Since it is well documented that over-learned habits or responses are relatively invulnerable to disruption, it seems reasonable to suggest that the efficacy of CS termination delay on response disruption will be reduced following over-training. However, further data is required to test this hypothesis adequately.

The data also reveal that the stage of learning at which the CS termination delay is introduced affects the permanency of the CS delay decrement. For group I Ss the effect was shown to persist over at least the first 650 training trials, whereas for group II Ss the effect was demonstrated for only the first 200 trials of the CS delay procedure. And, as mentioned in the previous paragraph, there was no avoidance responding decrement when the delay was introduced after 1610 trials (group III). Although the decrements in avoidance responding produced by the CS delay procedure were significant for groups I and II, it is remarkable, in the light of previous investigations (Kamin, 1957a, 1957b; Verhave, 1959), that the magnitude of the effect was small and temporary (i.e. group II). According to the view that CS termination is an important source of reinforcement for avoidance learning (Mowrer, 1960; Solomon & Wynn, 1954), manipulation of the interval between the avoidance response and CS termination should (and has been found to) impair acquisition and performance of the avoidance response. How delayed CS termination in the present study continued to reinforce the avoidance response is a problem of considerable theoretical interest. Superficially, it appears to be a case of learning under conditions of delayed reinforcement. Rats have been shown to learn under brief delays of food reinforcement (Grice, 1948), but there does not appear to be any good evidence that delayed secondary reinforcers are effective. Certainly, it is clear from the earlier studies that a delayed negative secondary reinforcer (delayed CS termination for avoidance responding) is not conducive to learning (Kamin, 1957b).

Since avoidance learning was relatively efficient under the conditions of the present investigation, the question is raised as to whether there was really a phenomenological delay between the response and CS termination. There was, of course, a delay of several seconds between the 30 degree rotation of the rotor and

CS termination; however it was observed that some Ss tended to continue running during the full CS delay interval. All responding beyond 30 degrees of rotation might be considered superstitious (Skinner, 1948) or perseverative behavior. Although this perseverative running did not alter the duration of the CS it served to bridge, or even eliminate, the interval of CS termination delay, so that the running response was still reinforced by CS termination. As indicated in section 3.3, an attempt was made to measure this response perseveration, and the results (illustrated in Figure 3) indicated the group II Ss, all of whom avoided efficiently during CS delay, exhibited a high degree of perseverative responding. This was also the case for Ss in the other two groups whenever they performed at high levels during CS delay. In contrast, Ss who did not avoid well on CS delay had low perseverative responding scores. In short, the results showed that regardless of when the CS delay procedure was introduced, Ss were able to attain consistently high avoidance rates, but only if they bridged or eliminated the CS delay interval with perseverative responding.

Besides serving a time-spanning function, it is also probable that the perseverative responding reduces the likelihood of other responses being reinforced by CS termination. Responses such as sitting or crouching, if they occur contiguously with CS termination, are reinforced and compete with the avoidance response. The reduction or elimination of response competition by perseverative responding may have been a significant factor contributing to the high avoidance rates under conditions of CS delay.

It is also less likely that perseverative responding occurs in the drum-turning apparatus used by Verhave, and even more improbable that it occurs in the shuttle box. Without the beneficial effects of perseverative responding, it is not surprising that Kamin (1957b) and Verhave (1959) observed greater avoidance responding decrements under CS delay.

A perseverative hypothesis offers a parsimonious interpretation of the data, and focuses attention upon observable behavior. Such an explanation suggests that new research should be conducted into the factors associated with perseveration, utilizing the CS delay procedure.

If the perseverative interpretation is correct, then the theoretical implications for behavior pathology are important. It may be possible, for example, not only to re-evaluate the work of Mays (1934) and Shipley (1934), who attributed enhanced conditioning effects on the part of catatonic Ss to 'perseverative tendencies'; but also to design a study to provide a more direct test of their conclusions. Following these authors, the perseveration hypothesis suggests that instead of merely examining a patient's response acquisition or extinction performance (Howe, 1958; Pfaffman & Schlosberg, 1936; Spence & Taylor, 1953; Lindsley & Skinner, 1954; and Krasner, 1958), attention should be paid to the determination of <u>how</u> behavior is maintained.

4. SUMMARY

The purpose of the present study was to investigate the effect of delayed termination of the CS upon avoidance learning in rats. When the delayed CS termination procedure was used throughout training, it was found to have a significant and permanent effect upon the acquisition of the avoidance response. This effect was consistent with other published data, and was readily explained in terms of current learning theory. When CS delay was introduced after 660 trials of regular avoidance training, the effect on avoidance performance, although significant, was small, and dissipated after 200 trials. Associated with this finding was the fact that the delayed CS produced a marked and consistent increase in the duration of the running response. It was hypothesized that the animals' perseverative running enabled them to span or bridge the interval between avoidance responses and delayed CS termination. The implications of this hypothesis for further research and for behavior pathology were discussed.

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APPENDIX A

FACTORS IN THE DESIGN RECEIVING SPECIAL ATTENTION

In evaluating Verhave's study in section 1.3 it was questioned whether a drum-turning apparatus was the best avoidance learning situation currently available. Meyer, Cho and Wesemann (1960) have suggested that the rotor used some time ago by Brogden, Lipman and Culler (1938) is probably the most efficient avoidance conditioning apparatus. The rotor has been rarely used, but two studies by Keehn (1959a, 1959b) give some support for the expectations of Wesemann et al. Another advantage of the rotor for the present study is that it requires the very simple response of walking or running, behavior that is highly suited to a rat.

The procedure used in delaying the CS required special attention. It will be recalled that Kamin (1957a, 1957b) delayed the CS by a constant amount after each avoidance response. Verhave, on the other hand, used a variable CS delay procedure in which the CS duration was an invariable 11 sec., and the amount of CS delay was dependant upon how soon the animal responded after CS onset. These variations in method probably reflect the two training situations used. Shuttle-box avoidance responses provide a rather discrete point in time from which to start timing a delayed CS termination, whereas this is more difficult with drum turning. Pilot studies indicated that the nature of rotor-turning responses also required the variable-delay procedure, since in many cases it proved difficult to know when to start timing a delayed CS. The use of the variable-delay procedure has one other advantage in that the duration of the CS is constant for all Ss.

The quality, intensity and duration characteristics of the CS were considered. With respect to the quality of CS used in conditioning experiments, the most frequently employed stimulus has been a buzzer. Myers (1962), however, has demonstrated that in an avoidance situation similar to that of Verhave, the effectiveness of a buzzer may be partially due to some effect similar to, or identical with, pseudoconditioning, and especially at higher intensities. He suggested that it may well be that a buzzer of moderate to low intensity will still produce good conditioning effects and mitigate the pseudoconditioning components. Myers also found that a tone tends to produce poor conditioning, but no pseudoconditioning. These data suggested that a buzzer be used; but that as control measures over the pseudoconditioning, the buzzer intensity be moderate, and its frequency be increased somewhat so as to minimize its harsh buzzerlike qualities.

The duration of the interval between CS and US onsets (CS-US or interstimulus interval) used in conditioning experiments with animals has varied considerably. Solomon and Brush (1956) and Kimble (1961) have reviewed the relevant literature, and have not been able to arrive at any very definite conclusions concerning an optimal CS-US interval. The data that they review suggests that five sec. is a satisfactory if not optimal interval; but the two reviewers also suggest that the time required to make the response should be considered. The S should be given ample time to execute the required response; but at the same time, the CS should not be so unnecessarily long that it loses its discriminative or "cue" properties as a warning signal. Preliminary pilot testing showed that rats generally took from one to two sec. to make avoidance responses in the rotor, and it was felt that a five-sec. interval should give ample time for responding, and yet not be too long by conventional standards.

Pilot testing also indicated that intertrial responding is sometimes frequent in the rotor. This creates a difficulty on trials that are immediately terminated by the S's responding at the time of CS onset. These occasions, resulting from intertrial activity, are best considered anticipatory responses rather than avoidance responses. To circumvent this difficulty some experimenters simply prevent the animal from responding between trials. However, in the writer's opinion, this technique probably introduces more difficulty than it eliminates. First of all, it restricts the animal's behavior and renders the conditions of learning even more dissimilar to those under natural conditions. A much more serious objection to this technique is the possible interpretation of any resulting avoidance behavior as a form of pseudoconditioning. It might be argued that the animal responds during each trial only because it can respond at no other time. The technique also allows no way of comparing the responding that occurs during the CS with responding that may normally occur during the intertrial interval. The method adopted in the present study was to allow intertrial responding to occur, but to discount anticipatory responses.

The qualities of the CS in connection with pseudoconditioning have already been considered, but another control measure was also considered. Some experimenters administer a few "control trials" of CS alone prior to regular avoidance conditioning, and then eliminate those animals that respond to more than a very small percentage of the CS presentations. However, this technique does not constitute a control measure beyond the first few trials of the avoidance conditioning; and in most conditioning situations, the avoidance conditioning takes place beyond the number of control trials used. It might be asked further if the CS and US have necessarily to be paired to produce conditioning; and to check for this, a control condition would have to be set up involving nonpaired CS and US. As this discussion indicates the question of pseudoconditioning can become an involved one. Nothing short of deliberate studies can give final answers to the questions involved. Most studies do not concern themselves with the problem at all, and prefer to accept the conventional view that true conditioning does occur in the typical avoidance conditioning apparatus. The policy followed in the present study was: (1) to take any known precautions to prevent pseudoconditioning (e.g. to use mild buzzer and to discount anticipatory responses), and (2) to analyse the data in a way that might give evidence indicating the presence or absence of pseudoconditioning.

Age changes in the Ss was considered another relevant factor, since the conditioning was to be carried out over a considerable period of time. Kirby (1962) has investigated this variable in a runway avoidance situation, and found that there was no significant difference between three age groups (25, 50, and 100 days) on acquisition or extinction. The only other data that seemed of some relevance to this question was that of Reed (1947). Reed found that the spontaneous running activity of rats in activity cages increases with age until the animals are about 80 days old. After 80 days it remains relatively constant until about 120 days when it begins a long and very gradual decline until death. These data on age suggest that it would be best not to use animals until they reach maturity (70-80 days).

The diminished intertrial technique used by Miller and Murphy (1958) and Murphy and Miller (1956) appeared to be a practical way of reducing testing time. This technique was seen to have another advantage in that it is claimed to produce avoidance responding that is highly stable and resistant to extinction.

APPENDIX B

DETAILS OF REJECTED RAT

During testing Rat no. 23 of group III maintained an avoidance rate that continually varied between 74 and 96 percent. This rate was 10 to 15 percent below the avoidance rate of the other three members of the group. The animal was quite lethargic, even when handled. About midway through testing it was noticed to excrete blood periodically. Upon examination at the completion of testing, it was found to have an abnormally large (60 gram) left kidney. This mass, along with the right kidney (< one gram) and spleen, were taken to the Pathology Department for tissue study. A copy of the pathology report is given below.

Gross Description: Gross specimen consists of: (1) an oval shaped mass of grossly unidentifiable tissue, grey and blue black in color and measuring 6.0 x 4.5 x 3.5 cm. (2) a spleen (rat) measuring 6.2 x 1.5 x 0.4 cm. (3) the right kidney measuring 2.0 x 1.4 x 0.6 cm.

Microscopic Description: The right kidney and the spleen are not remarkable. The left renal tumour is a nephroblastoma and is very similar in appearance to the human nephroblastoma (Wilm's tumour). The most differentiated structures are epithelial tubules composed of cuboidal and columnar cells. However, the bulk of the lesion is connective tissue in various stages of differentiation including primitive mesenchymal appearances, myxomatous areas, fibrous connective tissue and fatty tissue. In some areas the epithelial tubules are lined by cells producing mucus.

APPENDIX E

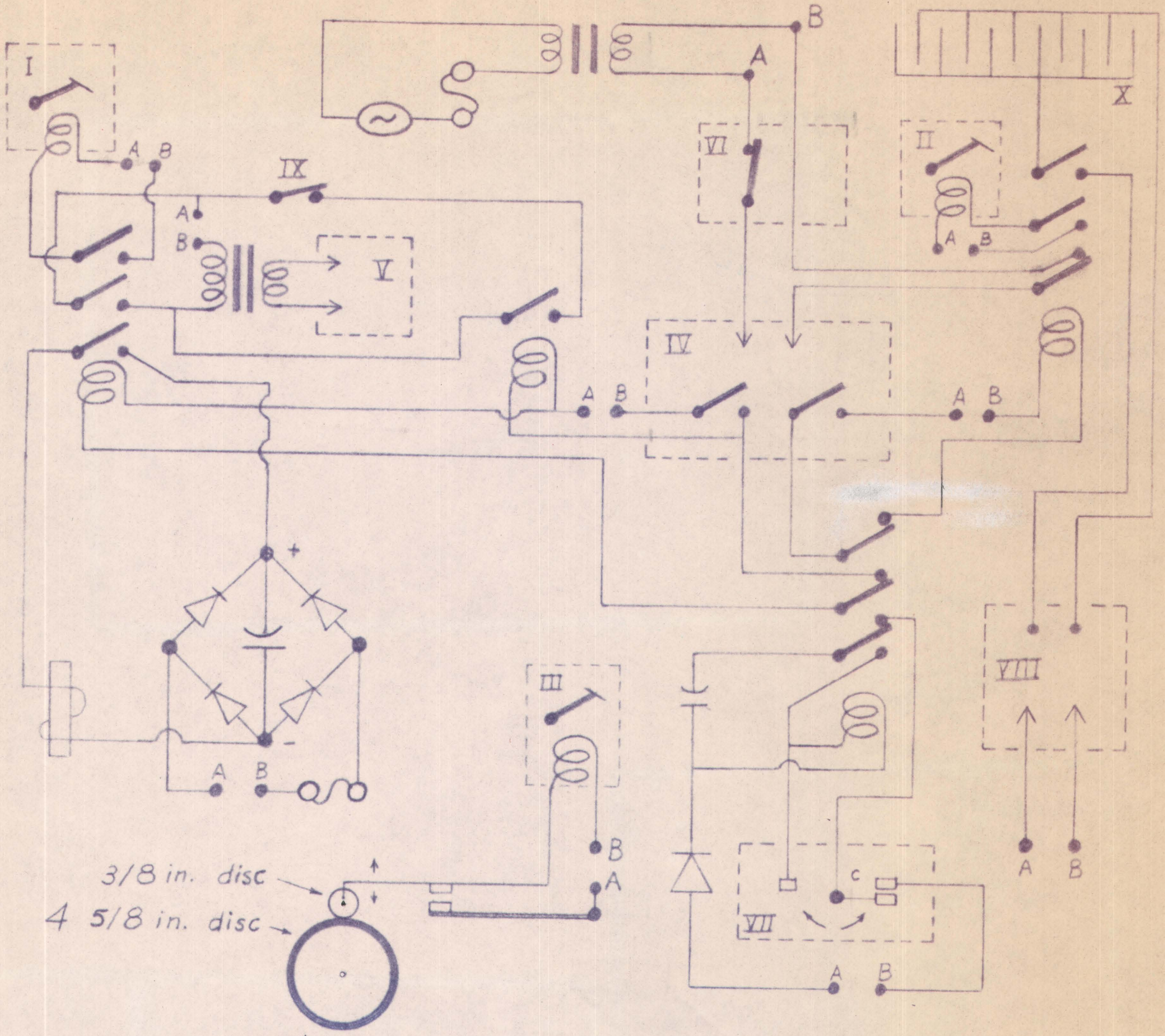
DATA SCORING APPARATUS

The apparatus used to score the data consisted of three parts: a track, a transparent template, and a slender drum. The main body of the apparatus served as a track which guided the waxed paper recording tape onto the crank-operated drum. The tape was rolled onto the drum during the scoring process. After the tape had been rolled onto the drum, the drum was extracted leaving the tape rolled for storage. The data was rolled separately for each session and S. The removable transparent template fitted in a stationary manner over the tape. On this template was engraved a scale such that its units in length corresponded to sec. of time. This scale served to measure the response latency (CS duration) on each trial.

Data scoring apparatus mounted on edge of table (top view).

APPENDIX D

WIRING DIAGRAM



I CS recording pen
II US recording pen
III pen for recording rotor turning
IV Gerbrand's programmer
V 6 v. buzzer
VI timer
VII "special switching mechanism"
VIII stimulator
IX "CS switch"
X rotor grid

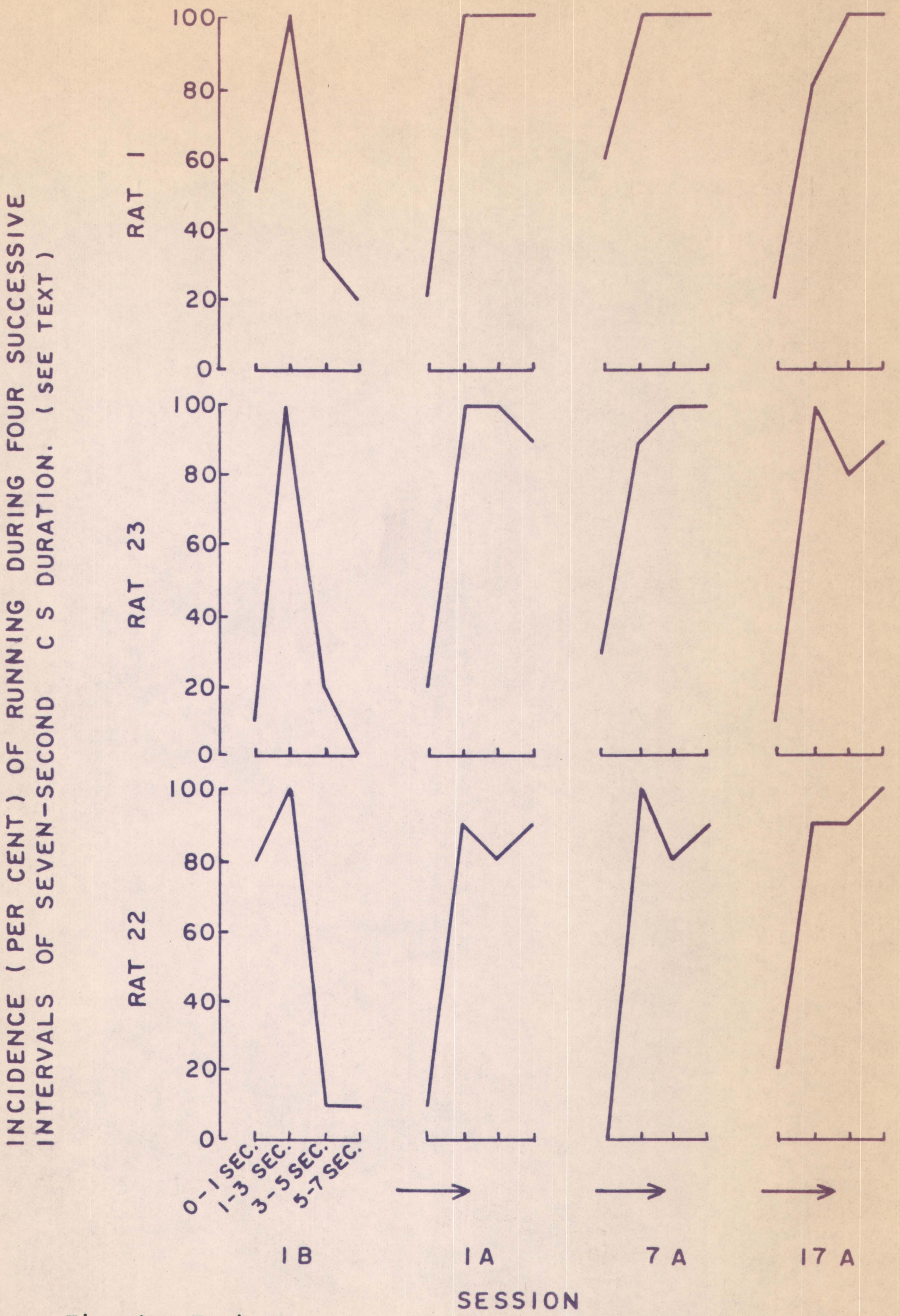
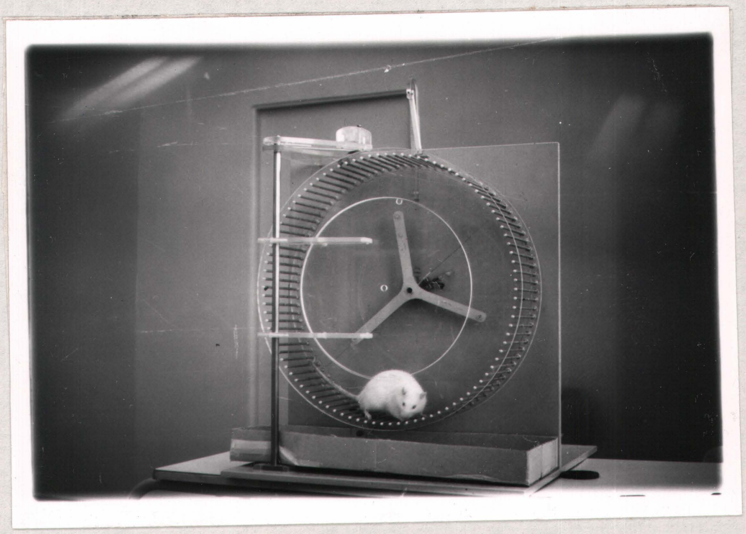


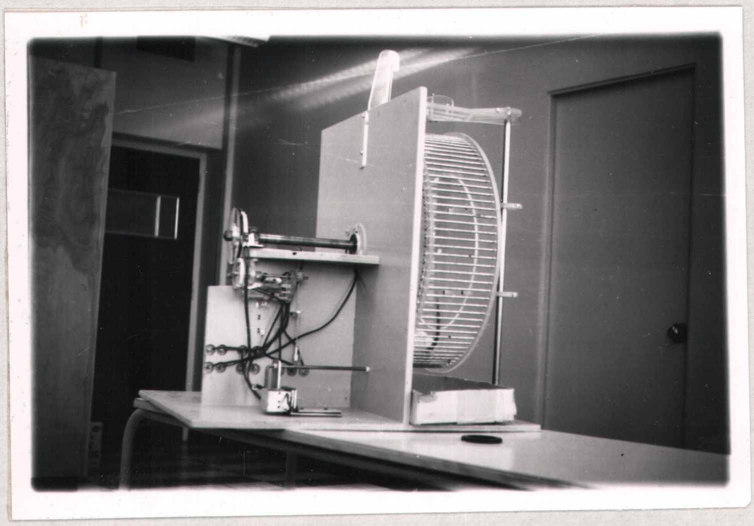
Fig. 3. Typical response patterns of 3 Ss; during the last session before (LB), and during the first (1A), seventh (7A), and seventeenth (17A) sessions during the CS delay.

APPENDIX C

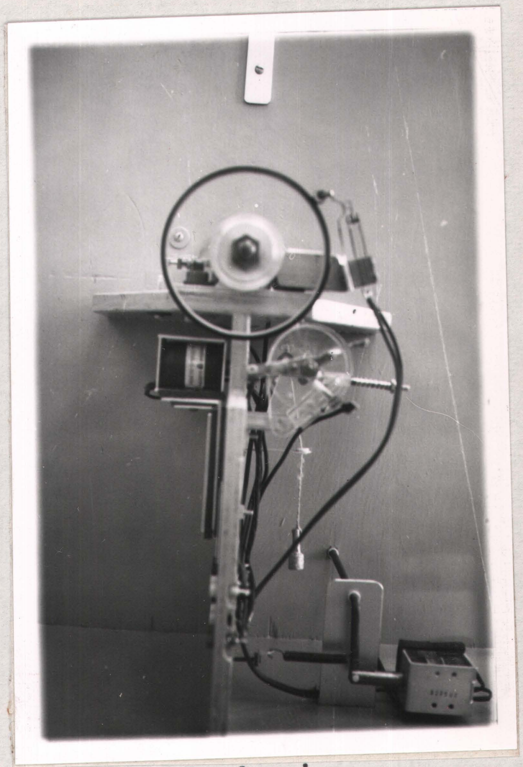
PICTURES OF ROTOR



Front view



Side view



Back view

APPENDIX F

PSEUDOCONDITIONING

Examination of the data for the Ss on the regular conditioning procedure (groups II and III) during adaptation and during the first two training sessions was the first test for pseudoconditioning. The 50 adaptation trials were classified into three categories (see Figure 1) according to the percentage of CS presentations during which Ss: (1) ran after CS onset, (2) remained stationary throughout the 10 sec. CS, or (3) were running at the time of CS onset. The same analysis and classification were also carried out for the first two training sessions, except that only the first five sec. of CS were considered in scoring. The data show that Ss tended to remain still during the CS (see Figure 1). The behavior of 'sitting through' the CS presentations increased over the session, and apparently indicates adaptation to the buzzer and to the apparatus. However, during the first training session a clear reversal in behavior is observed. Running decreased in the absence of the CS and increased sharply in the presence of the CS. During the second training session Ss rarely remained sitting in the presence of the CS (i.e. almost always made avoidance responses). Thus, it is clear that the CS was ineffective in eliciting rotor turning until CS and grid shock were paired during

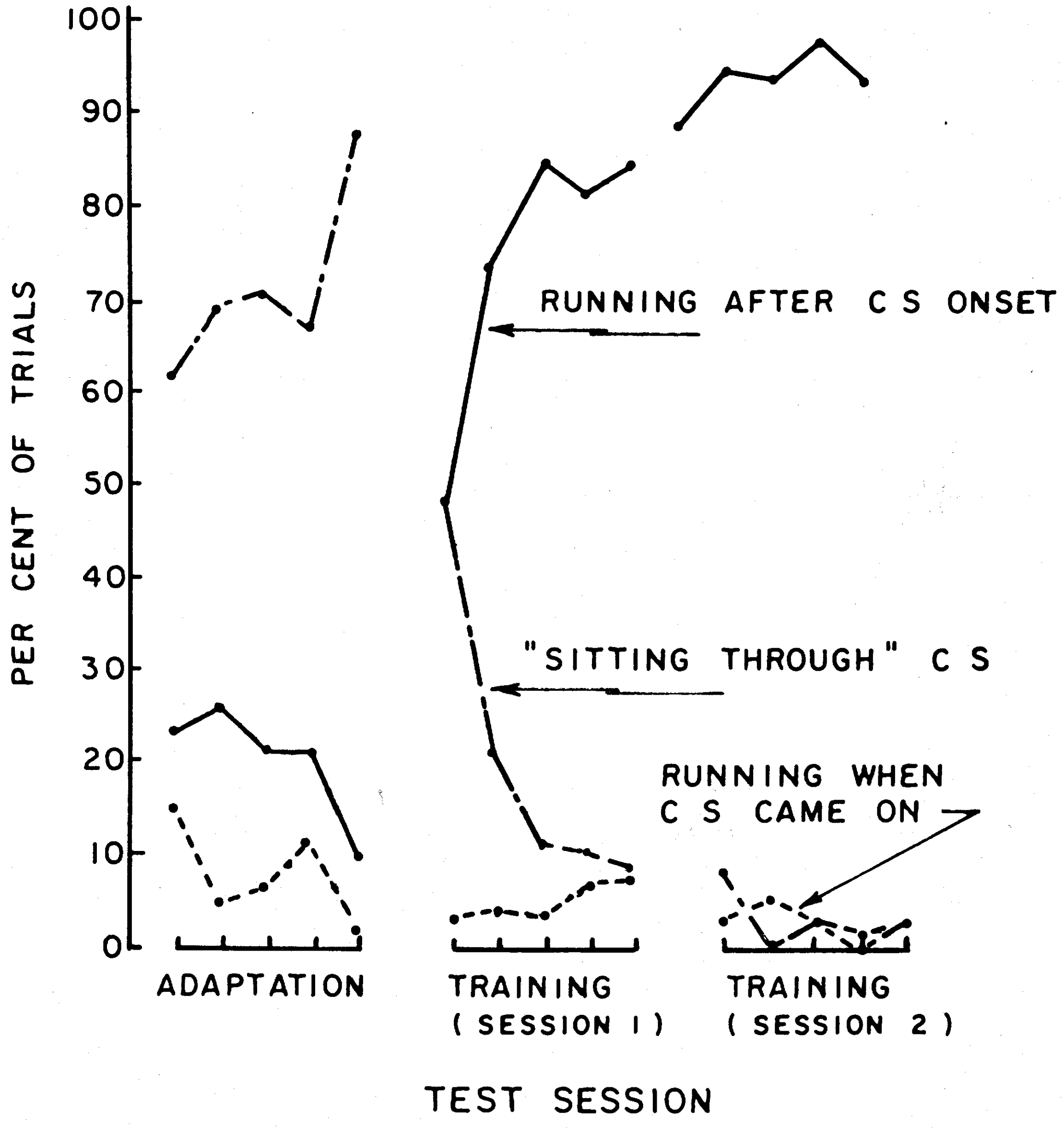


Fig. 1. Behavior elicited by the CS during adaptation and first two training sessions (blocks of 10 trials).

the first training session.

Since the CS was accompanied by running some of the time during adaptation (on about 20 percent of the trials) this may be interpreted as pseudoconditioning. However, as indicated above, running during the CS did not increase over the adaptation session, but in fact, decreased. Furthermore, as shown below, the amount of running during the CS was no greater than the spontaneous activity of Ss.

Spontaneous activity during adaptation and training is shown in Figure 2. Only the data for group I Ss are presented here, because only with these Ss were the CS durations during training consistently long enough to allow a legitimate comparison to be made with the constant 10 sec. CS used for adaptation. During the two training sessions, responding was scored only if it occurred during the first 5 sec. of the CS presentation, since later responding was often in response to grid shock. The first three sec. of the ITI following CS termination were also eliminated in order to exclude running that was initiated by the US. As shown in Figure 2, the running rates during the ITI and during the CS are very similar for the adaptation period. Thus the CS had no appreciable effect on spontaneous running during this phase of testing. The decline in activity is presumably the result of habituation to the

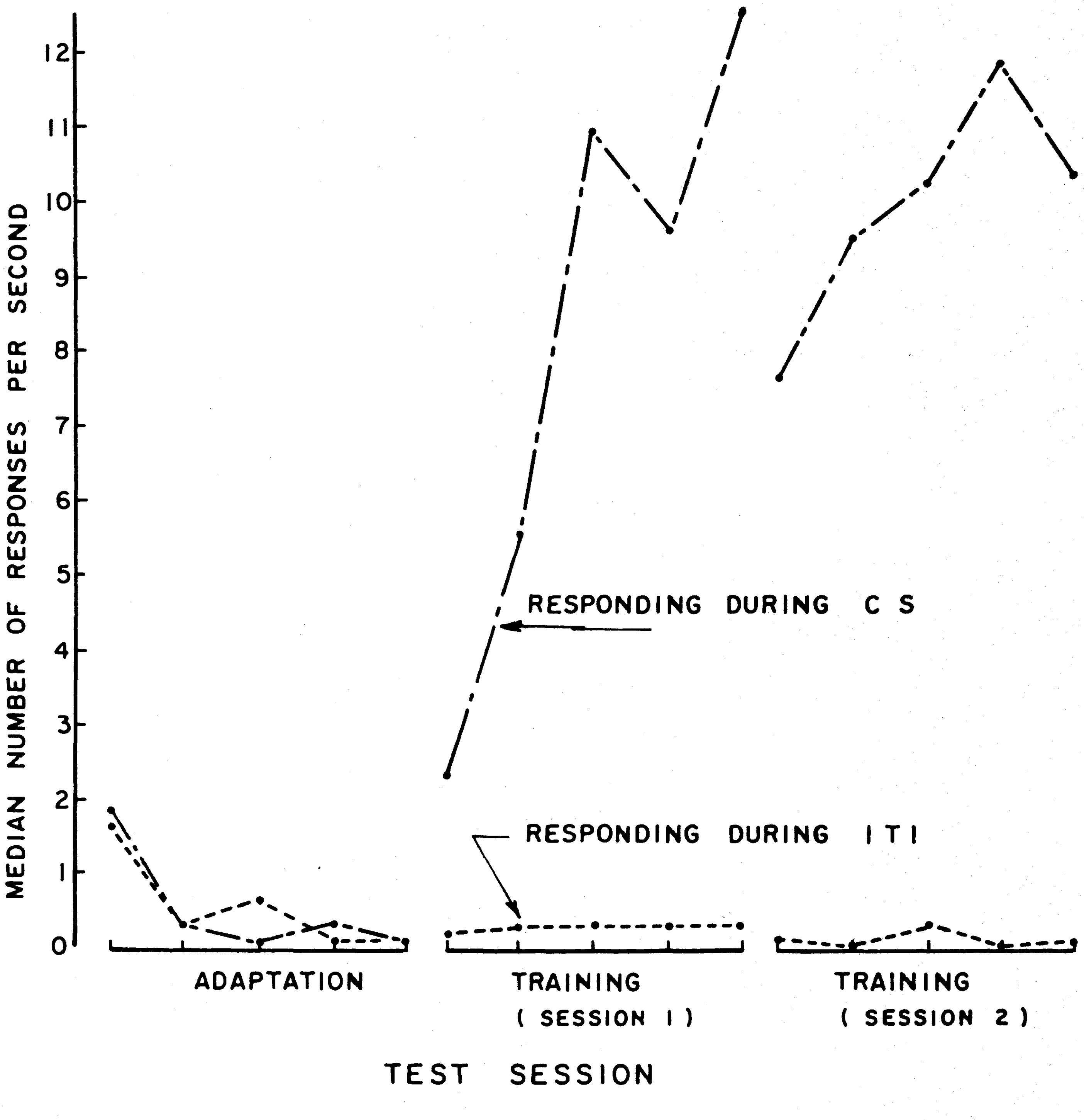


Fig. 2. Amount of differential responding in the presence of the CS during the adaptation and first two training sessions (blocks of 10 trials).

apparatus.

The pairing of buzzer and grid shock in the first training session caused a striking change in the S's reaction to the buzzer. Running in the presence of the CS increased while running during the ITI remained at a low level. During the second training session there was an even greater difference between CS and ITI running. It seems clear that running becomes highly correlated with the CS only after paired presentations of CS-UCS, and that we are dealing, not with pseudoconditioning, but with the true conditioning, or "S-R bias".

APPENDIX G

AVOIDANCE RATES BY SESSION

Session Number	Group I Ss								Group II Ss						Group III Ss		
	1	2	21	30	2	3	21	23	1	3	21	23	1	22	2	22	3
1	63	66	57	83	64	66	30	72	82	90	84	89	86	76	58	82	71
2	96	84	85	82	84	94	82	84	100	98	92	96	98	94	96	98	98
3	98	56	94	86	96	96	58	76	94	94	92	98	98	98	100	96	98
4	96	56	?	64	94	96	76	80	98	98	94	98	100	96	98	98	98
5	94	62	91	74	96	96	72	96	98	100	98	98	98	92	100	98	94
6	100	0	100	86	98	96	46	90	96	98	88	100	98	98	98	96	92
7	98	0	100	72	98	100	70	96	98	100	100	98	100	100	100	98	98
8	100	0	100	58	94	98	2	96	98	98	96	100	100	100	98	96	84
9	98	0	98	90	94	100	50	100	100	100	98	98	98	100	100	100	98
10	96	0	98	68	92	100	0	84	100	98	100	96	100	100	98	92	100
11	98	0	98	70	88	96	0	98	100	100	100	98	98	96	100	100	98
12	96	0	98	60	98	96	0	90	98	100	96	100	98	98	100	100	100
13	94	0	100	66	98	100	0	92	100	100	100	100	100	100	98	100	100
14	100	0	100	68	94	98	0	70	98	98	88	90	92	98	100	100	100
15	98	0	100	68	94	98	0	72	100	98	92	92	92	84	100	100	100
16	98	0	98	72	96	98	0	78	100	96	96	96	96	94	98	100	98
17	94	0	100	70	94	100	0	64	100	100	98	94	92	94	100	100	100
18	98	0	98	62	90	100	52	88	100	98	100	98	98	100	100	100	98
19	100		100	80	100	100	0	94	96	98	100	92	98	100	100	100	98
20	100		98	86	90	100	12	76	100	100	100	100	98	98	100	98	100
21	98		100	96	94	100	66	96	100	100	100	98	100	98	100	100	100
22	96		95	94	96	98	0	86	100	100	98	100	98	98	100	100	100
23	100		100	98	98	100	30	94	100	98	98	100	98	100	100	100	100
24	98		100	100	90	100	28	84	100	98	100	96	98	98	100	100	98

Session Number	Group I Ss								Group II Ss						Group III Ss		
	1	2	21	30	2	3	21	23	1	3	21	23	1	22	2	22	3
25	96		98	98	96	100	46	78	100	98	100	98	96	100	100	100	100
26	100		98	98	92	100	28	66	100	100	100	98	98	98	98	100	100
27	98		100	100	92	100	40	86	98	100	100	100	98	100	100	100	100
28	94		100	100	94	98	6	100	100	98	100	98	98	100	100	100	100
29				100	96	100	36	98	100	100	98	98	100	100	100	100	98
30				100	90	100	14	100	100	100	100	100	98	100	100	100	100
31				100	98	100	94	100	100	100	100	100	98	100	100	100	98
32				100	98	100	94	96	98	98	100	98	100	100	100	100	100
33				100	100	100	82	94				100	98	100	100	100	97
34				100	80	98	96	94				98	100	100	100	98	80
35				100	96	98	90	100				100	100	98	98	98	88
36				100	88	100	92	98				98	100	100	96	98	80
37				100	90		92	100				98			98	100	90
38				100	82		88	100				98			100	100	88
39				100	84		98	98				98			100	100	90
40				98	60		96	92				100			100	100	98
41				100	86		96	96				100			100	100	96
42				100	90		94	96				98			100	100	100
43				98	94		100	76				100			100	100	70
44					90		96	56							100	100	
45					90		96	60									
46					94		94	52									
47					96		100	50									
48					96		96	52									