Psychology of Learning

Readings in Behavior Theory

Edited by
Barry Schwartz

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EDITED BY
Barry Schwartz
Swarthmore College

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Introduction

The discipline known as behavior theory has been at the heart of experimental psychology for most of this century. It has been concerned with exploring the determinants of certain kinds of learning and with studying the ways in which behavior can be controlled by environmental events. The principles of behavior theory have been derived primarily from laboratory experimentation with nonhuman animals; but many of these principles have been demonstrated to apply not only to animals in laboratories, but also to people in complex social environments.

This book contains a collection of articles that have contributed over the years to the development of behavior theory. The articles are organized into seven groups, each reflecting a major area of inquiry in behavior theory. Each group is further subdivided into sections and each of the sections is preceded by a brief introduction that previews the articles contained in the section and indicates why they are significant. With one exception (A Cognitive Theory of Avoidance Learning, by Seligman and Johnston), the articles have been reprinted without editing or abridgment. This decision was based on the view that an important component of one's education in psychology is in learning how to read and evaluate primary source material. In addition to their content, these articles convey the logic and subtleties of experimental design, execution, and analysis—in short, the process underlying the scientific endeavor.

Part I
Pavlovian Conditioning

At the turn of the century, Russian physiologist I. P. Pavlov (1849–1936) discovered what he called "psychic reflexes." When food was placed in a dog's mouth, the dog would salivate. This salivary response to food was wired into the dog's nervous system. It was a reflex that required no experience to be triggered by an appropriate stimulus. What Pavlov discovered was that other stimuli that bore no "wired-in" relation to salivation could also trigger the salivary response if they regularly preceded the delivery of food. These other stimuli came to be known as *conditioned stimuli* (CSs), because their ability to trigger reflexes was conditional upon the animal's experience. The CS had to be paired with an *unconditioned stimulus* (US), such as food, whose power to trigger salivation is independent of experience. The result of such pairing was the formation of an *association* between CS and US, so that the CS came to trigger a *conditioned response* (CR).

Pavlov devoted the rest of his life to the study of these "psychic reflexes," or *conditioned reflexes* as they came to be called (Pavlov, 1927).* He saw them as the building blocks of all learning by association and, indeed, perhaps all learning. In addition, he gave birth to a field of inquiry that has continued to be vigorously pursued to the present day. In the years since Pavlov's early work, the methods used to study Pavlovian conditioning, the phenomena discovered, and the accounts offered to explain these phenomena have broadened considerably. The articles included in Part I provide a glimpse of the range of concerns that occupy modern researchers.

Section A presents an article that demonstrates excitatory and inhibitory Pavlovian conditioning, using a method, quite different from Pavlov's, that has come to dominate research on Pavlovian conditioning. Section B presents an article that asks what it is an animal actually learns in Pavlovian conditioning, that is, what is conditioned. Section C explores the nature of the response conditioned to the CS, and its relation to the response triggered by the US. Section D is concerned with the kind of experience that is necessary for conditioning to occur. Is pairing of CS and US enough, as Pavlov thought, or is something more required? The evidence in Section D suggests that pairing of CS and US is not enough. This is buttressed by the article in Section E, which shows that organisms are sensitive to how informative a CS is about a coming US, and that they will learn to ignore CSs that are not informative. Finally, Section F presents an article that suggests that organisms may be pretuned to associate certain types of CSs with certain types of USs.

* For bibliographic information on all works cited in the introductions to the various sections of this book, see References to Introductions, beginning on p. 388.

A. EXCITATION AND INHIBITION

In studying conditioned salivation in dogs, Pavlov discovered two types of conditioning. One type, conditioned excitation, *resulted when a CS was presented in conjunction with a US; the other type,* conditioned inhibition, *resulted when a CS was presented in the absence of a US. Pavlov showed that when, for example, a tone was presented in the absence of food, in a situation in which food was being delivered at other times, the tone did not remain neutral with respect to salivation; it actually inhibited the occurrence of salivation. Much of Pavlov's own research actually focused on the phenomenon of conditioned inhibition.*

The article in this section, by Rescorla and LoLordo, demonstrates both conditioned inhibition and conditioned excitation using methods quite different from Pavlov's. Animals are first trained to avoid electric shock by running back and forth across a barrier. It is assumed that their continued avoidance responding is motivated by their fear of being shocked (see Part III). Then Pavlovian conditioning is introduced. One CS (the CS+) is followed by shock with the expectation that it will eventually trigger conditioned fear. Another CS (the CS−) is not followed by shock, with the expectation that it will eventually inhibit fear. Now what should happen when these two CSs are presented while the animal is responding to avoid shock? The CS+, if it makes the animal more afraid, should increase the rate of avoidance responding. The CS−, if it makes the animal less afraid, should decrease the rate of avoidance responding. Thus changes in the rate of avoidance responding are used to measure excitatory and inhibitory Pavlovian conditioning.

1 Inhibition of Avoidance Behavior

ROBERT A. RESCORLA AND VINCENT M. LOLORDO

Conditions for establishing stimuli which inhibit conditioned fear reactions are demonstrated in 3 experiments. Dogs, trained in a shuttle box to avoid shock on a Sidman avoidance schedule, received Pavlovian fear conditioning involving the presentation of tones and shock in various temporal relations. Subsequently, these tones were presented while *S* performed the avoidance response. Stimuli preceding shock in conditioning increased rate of avoidance; Pavlovian conditioned and discriminative inhibitors depressed it. Furthermore, a stimulus whose presentation was "contrasted" with that of shock depressed the avoidance rate. These findings imply that inhibitory as well as excitatory Pavlovian processes are involved in fear conditioning. Implications for pseudoconditioning control procedures and reinforcement of avoidance behavior are discussed.[1]

Although the establishment of conditioned fear by excitatory Pavlovian processes has been well accepted, the diminution of fear by inhibitory Pavlovian processes has received little attention. In salivary conditioning, some contingencies between a neutral stimulus and an US produce excitatory Pavlovian processes; other contingencies yield inhibitory processes (Pavlov, 1927). If the fear reaction follows the laws of Pavlovian conditioning, both excitatory and inhibitory processes should occur for it as well.

The three experiments reported here are based upon this reasoning: If avoidance behavior is maintained in part by a conditioned fear reaction, then any stimulus that increases this reaction should enhance the avoidance response and any stimulus which inhibits fear should weaken the avoidance response. Using avoidance responding as the index of fear, these experiments demonstrate that certain Pavlovian conditioning procedures produce elicitors of fear while others yield inhibitors of the fear reaction.

Experiment 1: Conditioned Inhibition

This experiment was designed to explore the possibility of inhibiting avoidance behavior by means of a Pavlovian conditioned inhibitor. We used a modification of one of Pavlov's (1927) conditioning procedures, employing two CSs, one of which warned *S* of the onset of shock and one of which informed *S* that no shock would follow.

Method

Subjects and Apparatus The *Ss* were 10 mongrel dogs obtained from a local supplier. They were maintained in individual cages on ad-lib food and water throughout the course of the experiment. Short exercise periods were given before and after the daily 1-hr. sessions.

The apparatus was a two-compartment shuttle box for dogs described

"Inhibition of Avoidance Behavior" by Robert A. Rescorla and Vincent M. LoLordo. *Journal of Comparative and Physiological Psychology*, 1965, *59*, 406-412.

in detail by Solomon and Wynne (1953). The two compartments were separated by a barrier of adjustable height and by a drop gate which, when lowered, prevented *S* from crossing from one compartment into the other. The floor was composed of stainless-steel grids which could be electrified through a scrambler. Speakers mounted above the hardware-cloth ceiling provided a continuous white noise background and permitted the presentation of tonal stimuli. The general noise level in the box, with the white noise and ventilating fans on, was about 80 db. re. .0002 dyne/sq cm; the tones added 10 db. to this level. Events were recorded on an Esterline-Angus operations recorder.

Procedure. Each *S* was trained to jump a barrier, separating the two sides of the shuttle box, to avoid electric shock. An unsignaled avoidance schedule similar to that described by Sidman (1953) was used. If *S* did not jump the barrier, a shock was delivered to the grid every 10 sec.; each jump postponed the next shock for 30 sec. Thus the shock–shock interval was 10 sec. and the response–shock interval was 30 sec. Shock duration was 0.25 sec.; the intensity was 6 ma. from a 550-v. ac source.

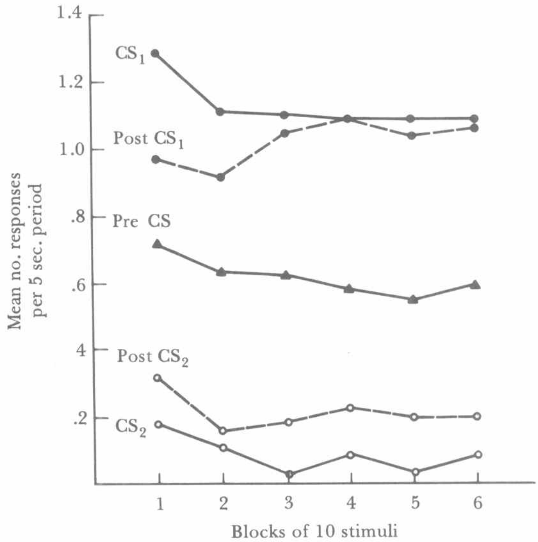
The *S* received 3 days of avoidance training. The height of the barrier separating the compartments of the shuttle box was 9, 12, and 15 in. on successive days. Beginning with the fourth experimental day, *S* was confined to one-half of the shuttle box and given five 1-hr. Pavlovian conditioning sessions on alternate days. On the days between Pavlovian conditioning sessions, *S* continued to receive 1-hr. sessions of avoidance training, with the barrier at 15 in. This particular order of events was adopted to prevent adventitious reinforcement of the avoidance response during Pavlovian conditioning. In preliminary experimentation, dogs given inescapable shock in the shuttle box had tended to have some difficulty in subsequent avoidance training; therefore, we established the avoidance behavior prior to Pavlovian conditioning and maintained the response by alternating avoidance training and conditioning sessions.

During the Pavlovian conditioning sessions, *S* received two kinds of conditioning trials: *(a)* CS_1 was presented for 5 sec.; either 2, 5, or 8 sec. following the termination of CS_1, a 5-sec. 3-ma. shock was presented; *(b)* CS_1 was presented for 5 sec.; either 2, 5, or 8 sec. following its termination, CS_2 was presented for 5 sec. but no shock was presented. Thus CS_1 was a trace CS with a variable gap between CS and US; the gaps of 2, 5, and 8 sec. were presented equally often for each kind of trial. In addition, CS_1 was followed by shock on only some trials, with CS_2 replacing shock on the remaining trials. Following CS_1, the onset of CS_2 was the only event which informed *S* that the particular presentation of CS_1 would not be followed by shock.

On each conditioning day, 18 of each of the two kinds of trials were presented in random order. The intertrial intervals were 1, 1.5, and 2 min., with a mean of 1.5 min. For five *Ss*, CS_1 was a 400-cps tone and CS_2 a 1,200-cps tone; for the other five *Ss*, the tones were interchanged.

After *S* had completed the sequence of five Pavlovian conditioning and seven avoidance sessions, a single test session was given. During this 1-hr. session, *S* performed the avoidance response under extinction conditions, i.e., no shocks were delivered. The 400- and 1,200-cps tones were presented in random order without respect to *S*'s behavior. Sixty 5-sec. pre-

FIG. 1. *Mean number of responses during 5-sec. periods before, during, and following stimulus presentations in the test session (Experiment 1).*



sentations of each tone were given with a mean intertone interval of 25 sec. (range: 10–40 sec.).

Results

Nine *S*s acquired the avoidance response, with distinct signs of learning appearing in the first 1-hr. session. One *S* was eliminated for failure to avoid one-half of the shocks programmed on Day 2. By the seventh day of avoidance training, the behavior of the nine *S*s was stable. The mean number of shocks received on this day was 1.2; however, the response rate varied considerably among *S*s. During the seventh avoidance training day, rates ranged from 6.5 to 12.7 jumps per minute, with a mean of 8.1. Even *S* with the lowest rate was responding at approximately three times the minimum rate necessary to avoid all shocks.

In order to evaluate the effects of the two CSs upon jumping during the test session, comparison was made with a base-line jumping rate. The rate of jumping during the 5-sec. periods immediately preceding the onset of the tones was taken as a base rate. Since the mean values of 0.61 and 0.63 jumps for the pre-CS_1 and pre-CS_2 periods did not differ significantly ($T = 18$, $p > .20$), a single base-rate score was computed by averaging the scores for these two periods. Figure 1 shows this base rate (pre-CS) together with the jumping rates both during and after the tones, all plotted in terms of the mean number of responses per presentation of each stimulus over blocks of 10 presentations.

The response rate was higher during the presentations of CS_1 than during the prestimulus periods for all *S*s, yielding a $p < .01$ by the Wilcoxon signed-ranks test. In addition, the rate of responding in the 5-sec. period immediately following CS_1 was considerably higher than the base rate ($p < .01$). For some *S*s, this period had a higher rate than the during-CS_1 period. But for every *S* the relation between response rates during CS_1 and during the 5 sec. following CS_1 was consistent throughout the session. Approximately 5–10 sec. after the termination of CS_1 (not shown), responding had returned to the base rate.

In striking contrast to the effects of CS_1, the response rate during CS_2 was well below the base rate for each *S* ($p < .01$). As in the case of CS_1, the effects of CS_2 continued after its termination. For both the period 0–5 sec. after CS_2 and the period 5–10 sec. after CS_2, the rate of responding was below the prestimulus rate ($p < .01$). However, response rate was higher during the 5 sec. following CS_2 than during CS_2 ($p < 05$). Even though these conclusions are based upon responding for the test session as a whole, the same relations obtain within each block of 10 stimulus presentations. Though Fig. 1 indicates a slight decline in responding during the test session, this was not statistically significant (Friedman two-way analysis of variance by ranks; $p > .20$).

To summarize, response rate suddenly increased upon presentation of the CS_1, remained high for the next few seconds, and then slowly returned to the prestimulus level. Upon presentation of CS_2, there was a sharp drop in response rate lasting about 15 sec., then responding returned to the base rate.

Discussion

The novel finding of this experiment was the capacity of CS_2 to depress avoidance responding. Observation of *S* during Pavlovian conditioning sessions confirmed the inference that CS_2 inhibited fear. Upon the onset of CS_1 *S* typically showed signs of fear and agitation—barking, crouching, running around with its ears back and its tail between its legs, etc. However, by the last conditioning session, CS_2 clearly produced termination of this behavior; during CS_2 *S* seemed to relax, cocking its head at the sound of the stimulus.

It is interesting to note that CS_2 had the same relation to shock in the present experiment that stimuli associated with the avoidance response have in the traditional signaled avoidance training procedure. In a (trace) avoidance situation, the CS occurs briefly; if *S* responds following the CS, shock does not occur, while failure to respond leads to the delivery of shock. In our Pavlovian conditioning procedure, CS_1 occurred briefly; if it was followed by CS_2, no shock occurred. The failure of CS_2 to occur led to the delivery of shock. Thus stimuli associated with an avoidance response might be expected to acquire properties similar to those of CS_2. The capacity of such stimuli to inhibit the fear previously aroused by the warning stimulus would mean rapid reinforcement for the avoidance response and might provide a mechanism for the "conservation of anxiety" suggested by Solomon and Wynne (1954).

However, before concluding that Pavlovian inhibition was the source of the depressed response rates, it is necessary to demonstrate similar effects from other Pavlovian conditioning paradigms known to yield inhibitors. The next experiment does this.

Experiment 2: Discriminative and Conditioned Inhibition

Pavlov (1927) reported the development of both discriminative and conditioned inhibitors of the salivary reflex. The present experiment explores these conditioning paradigms for the conditioning of fear. One group of *S*s received discriminative Pavlovian conditioning in which one stimulus was always followed by shock and another never followed by shock. A second group received conditioning designed to establish a Pavlovian conditioned inhibitor; unlike the inhibitor in Experiment 1, this stimulus preceded CS_1 and bore a constant time relation to it.

Method.

Subjects and Apparatus. The apparatus was identical to that used in Experiment 1. The *S*s were 10 mongrel dogs.

Procedure. The *S*s first received 3 days of Sidman avoidance training. On Day 1, the barrier height was 9 in.; on all subsequent days the height was 15 in. Beginning with Day 4, each *S* received Pavlovian conditioning while confined to one-half of the shuttle box. The *S*s received this treatment on alternate days, with avoidance days intervening, for five Pavlovian conditioning and seven avoidance training days. Each *S* was then tested in the manner described in Experiment 1.

For five *S*s the Pavlovian conditioning was discriminative, involving two kinds of trials: *(a)* CS_1 came on for 5 sec., and coincident with its termination a 3-ma. shock was presented for 5 sec. *(b)* CS_2 was presented for 5 sec., and no shock was delivered. Another group of five *S*s received a conditioned inhibition procedure involving two kinds of trials: *(a)* CS_1 came on for 5 sec., and a 5-sec. shock was presented coincident with its termination. *(b)* CS_2 was presented for 5 sec., and coincident with the termination of CS_2, CS_1 came on for 5 sec.; on these trials no shock was delivered.

Thus, the Pavlovian conditioning procedures for the two groups were identical with but one exception: On trials when the Discrimination group received CS_2 alone, the Conditioned Inhibition group received CS_2 alone, the Conditioned Inhibition group received CS_2 followed by CS_1. Half the *S*s had the 400-cps tone and half the 1,200-cps tone as CS_2. Eighteen trials of each type were given per day in random order. The intertrial intervals were 1, 1.5, and 2 min. ($M = 1.5$ min.).

In addition to these two groups, a control group of seven *S*s was run in order to check on the unconditioned properties of the 1,200- and 400 -cps tones. The treatment of these dogs was identical to that of the experimental *S*s except that the Pavlovian conditioning days were omitted.

Results

Avoidance learning proceeded as in the previous experiment. Two *S*s, however, had to be discarded because of ill health—one from each of the two experimental groups. On the last avoidance training day, the mean jumping rate for the Discrimination group was 8.0 responses per minute; for the Conditioned Inhibition group 9.3. The difference is not significant ($U = 7$, $p > .40$).

A three-way analysis of variance performed on the test-session scores of the two experimental groups revealed no significant effect involving groups. Therefore, for all subsequent analyses the results of these two groups have been combined. Fig. 2 shows the mean jumping rates for various 5-sec. periods of the test session as a function of blocks of 10 stimulus presentations. Because the analysis of variance indicated no reliable

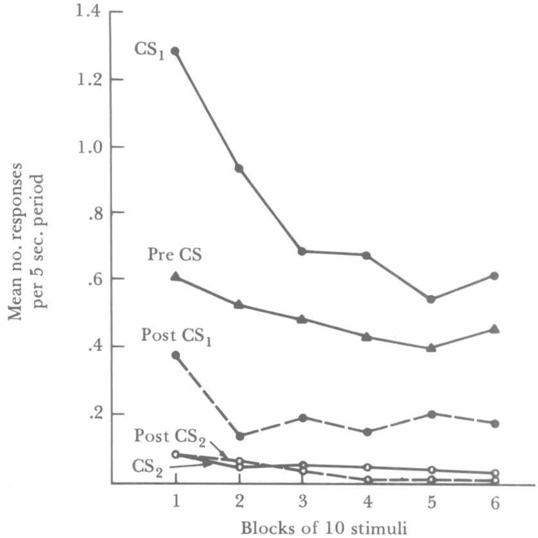


FIG. 2. *Mean number of responses during 5-sec. periods before, during, and following stimulus presentations in the test session (Experiment 2).*

difference between the response rates in the pre-CS_1 and pre-CS_2 periods, these rates were averaged to give a single base rate.

For the session as a whole, the rate during CS_1 was significantly greater than the base rate ($T = 4$, $p < .05$). However, it is clear from Fig. 2 that the main effect of CS_1 occurred during the first 10 stimulus presentations. The rate of jumping during the 5-sec. period following the termination of CS_1 also differed from the base rate ($p < .01$). However, unlike the post-CS_1 rate of Experiment 1, the rate following the fear-eliciting stimulus was considerably lower than the base rate. This depression appeared early, lasted throughout the test session, and extended into the period 5–10 sec. following CS_1 termination (not shown).

In both experimental groups jumping rate during CS_2 was depressed considerably below the prestimulus rate ($p < .01$). Depression of rate also appeared during the 5–10 sec. following CS_2 ($p < .01$). These depressed rates continued throughout the session, and were lower than the rate during the 5 sec. following CS_1 ($p < .05$).

The test session results for the seven control *S*s showed no differences between the rates during the two tones. For the session as a whole the mean number of responses in the 5-sec. periods before, during, and after stimulus presentations were 0.51, 0.62, and 0.42, respectively. Both the higher rate during the tones and the lower rate following stimulus termination were significantly different from the prestimulus rate ($p < .05$). The effects of the tones occurred primarily early in the test session.

However, unconditioned effects of the tones were minor compared with the effects of CS_1 and CS_2 in the two experimental groups. Comparison was made between the control group and the combined experimental groups by means of suppression ratios (Annau & Kamin, 1961). This ratio of response rate during the CS to the sum of the rates during and pre-CS allows comparison among animals independently of their base rate. Using this ratio, the increase in rate during CS_1 was found to be greater in the experimental groups ($p < .05$). Similarly the ratios for the periods during CS_2, and following CS_1 and CS_2, in the experimental groups differed from the corresponding ratios for the control group ($p < .01$).

Discussion

The results confirm the hypothesis that Pavlovian conditioned inhibitors and discriminative inhibitors can depress the rate of avoidance responding. Though the effects of CS_2 in this experiment were consistent with the results obtained in Experiment 1, several findings about the properties of CS_1 were unexpected and somewhat puzzling. First, the fear reaction to CS_1 in the present experiment seemed to extinguish more rapidly than in Experiment 1. Perhaps the variable temporal gap between CS_1 and US in Experiment 1 retarded extinction in that experiment; such phenomena are well known in instrumental learning (e.g., McClelland & McGown, 1953).

Equally unexpected was the depression of response rate immediately following the unreinforced presentation of CS_1. This depression seems independent of the fear-eliciting properties of CS_1 since it remains relatively constant through the session in spite of the decreasing capacity of CS_1 to elicit fear. A possible explanation is that during Pavlovian conditioning CS_1 termination preceded the intertrial interval. The end of a conditioning trial was an event which reliably signaled a period free of shock. To the extent that the termination of CS_1 occurred near the end of a trial, that termination might become an inhibitory stimulus. The failure of the termination of CS_1 in Experiment 1 to produce the depression may be related to its favorable position for fear conditioning during the Pavlovian conditioning sessions. The next experiment explores the possibility that an event which precedes a long period without shock becomes inhibitory.

Experiment 3: Contrast

Experiments 1 and 2 have varied the relationship of CS_2 to CS_1, and the relationship of CS_1 to shock, without affecting the reliable depression in avoidance responding produced by CS_2. These experiments have held constant only the relationship of CS_2 to shock—CS_2 was always followed by a period free from shocks. It may be that for CS_2 to depress the rate of avoidance responding, it need only have preceded a period which is shock-free; differentiation or contrast between CSs may be unnecessary.

Method

Subjects and Apparatus. The apparatus was identical to that of the previous experiments. The *S*s were 10 mongrel dogs.

Procedure. Two groups of five *S*s each received treatment identical to that of *S*s in Experiment 2 in all respects except that the procedure on Pavlovian conditioning days differed. For one group (Contrast) two kinds of conditioning trials occurred: *(a)* a 5-sec. 3-ma. shock occurred without any warning signal and *(b)* a 5-sec. presentation of a tone (CS_2) occurred without a shock. Thus, this group received exactly the same Pavlovian conditioning procedure as the Discrimination group of Experiment 2,