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Traumatic Avoidance Learning: Acquisition in Normal Dogs[1]

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When a "typical," normal, mongrel dog is put into a small compartment with a steel grid floor, he will usually exhibit persistent exploratory behavior. Thus confined, he will sniff at the grid bars and the corners of the compartment, walk back and forth, intermittently stand up on his hind legs with forepaws against the walls of the compartment, occasionally look over the head-high barrier which separates him from another compartment, but will make no attempt to jump over the barrier into the other compartment. If this dog is suddenly stimulated through the steel grid floor by a high-voltage electric shock, of an intensity just below the tetanizing level, the dog will immediately exhibit an intense fear reaction. If the shock is left on during the time the dog remains in the compartment, this intense fear reaction will typically contain these components: The dog will scramble rapidly and vigorously around the compartment, slamming into walls, perhaps, or leaping up against them; he will simultaneously emit a high-pitched screech, will salivate profusely, will urinate and defecate in a manner which could be called "projectile elimination," and will roll his eyes rapidly and jerkily; in addition, his pupils will dilate, portions of his hair will stand on end, small muscle groups all over his body will tremble, and his breathing will consist of short, irregular gasps. Sooner or later the dog's vigorous scrambling movements result in his getting over the barrier into the other compartment, to safety. If the shock is repeated at a later time, the same fear responses will occur again.

When a dog exhibits the components of a massive fear reaction in the presence of noxious stimulation that is very intense, we should like to define the whole event as a "traumatic experience." Such an event will typically include an intense, unconditioned stimulus which elicits an intense, unconditioned reaction pattern containing the following components: (*a*) visceral responses of high magnitude, with their correlated feedback stimulation; (*b*) skeletal responses of vigorous intensity, with their correlated proprioceptive feedback stimulation; (*c*) hormonal responses from endocrine glands and nonendocrine glands, with their correlated effects upon the body chemistry, muscles, and neural centers; and (*d*) higher brain-center activity.

One often refers to the visceral responses as emotional reactions; they are often considered to be "expressive" rather

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than instrumental in nature. The skeletal responses are partly expressive (elicited directly by the unconditioned stimulus) and partly instrumental; we usually interpret the instrumental portion of the skeletal reactions as "adaptive" escape or aversive movements.[2] (There is also a possibility that certain visceral responses can become instrumental, as in Yogi control of autonomic responses.)

Within the pattern of the reactions of the typical dog, when he is stimulated with an intense electric shock, are contained the essential components of an unconditioned fear reaction pattern. Because the components have all occurred with high response amplitudes, and because we know the intensity of the unconditioned stimulus to be high, we shall define the *stimulus-response pattern* as indicative of a *traumatic* experience; and any learning which has as one of its conditions the occurrence of such a stimulus-response pattern, we shall define as *traumatic learning*. Furthermore, if the traumatic learning is of such a nature that it prevents the unconditioned stimulus from occurring, we shall define it as *traumatic avoidance learning*.

We have taken pains with this definition because there is some reason to believe that traumatic learning may possibly have certain functional properties which differ qualitatively and quantitatively from those of "ordinary motivated learning."

This paper will be restricted to the characteristics of the *acquisition* of traumatic avoidance learning in dogs. Elsewhere we describe the characteristics of extinction and the effects of special procedures (18, 19).

[2] There are alternative classifications in wide use today which can be *partially* substituted for the "visceral" and "skeletal" categories. For example, autonomic nervous system and central nervous system functions, involuntary and voluntary actions are often distinguished. Any of these categorizations should be used with the realization that these functions overlap considerably in the intact organism.

Apparatus

A schematic drawing of the apparatus is presented in Figure 1. It is an adaptation of the Miller-Mowrer shuttle box (11) which has been used for avoidance learning in rats. We have modified the shuttle box extensively for use with dogs.

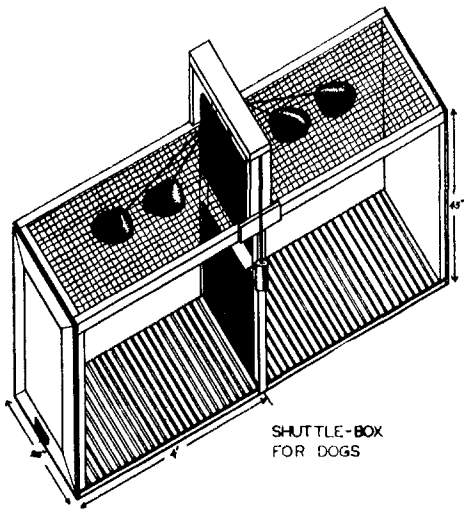


Fig. 1. Schematic drawing of the shuttle-box apparatus.

The shuttle box consisted of two compartments separated by a barrier and guillotine-type gate. The inside dimensions of each compartment were 45 in. long, 24 in. wide, and 40 in. high. The barrier was adjustable in height. The gate could be raised by means of a pulley system above the level of the top of the compartments. When the gate was closed it rested on top of the barrier, thus creating a solid wall completely separating the two compartments.

Owing to the vigorous battering the apparatus received, the construction had to be rugged. The frame was built of 2 × 4-in. pine. The walls were composed of 3/8-in. plywood, sheathed on the inner surface by 1/32-in. aluminum, half-hard plate. These aluminum inner walls were painted flat black. The doors to the two compartments are omitted in Figure 1. They were composed of 5/8-in. plywood sheathed with

aluminum, painted flat black. They were hinged on the end post of each compartment and were locked in the closed position by means of slide bolts.

The ceiling of each compartment was covered with 1-in. hardware cloth (No. 8 gauge). Directly above each compartment were two 40-watt lights, shielded so that each pair cast light only into the compartment directly below. When the gate was up and only one pair of lights was on, one compartment was dark and the other illuminated. Above the gate was a wooden scaffolding on which were mounted two pulleys. A cord was strung from the middle of the top of the gate through the pulleys to a counterweight hanging at the side between the two doors. Draped over the scaffolding and the whole apparatus was a double thickness of cheesecloth serving as a crude, one-way screen.

The floor of the apparatus consisted of polished 1-in. stainless steel (channel) bars ½ in. apart, parallel to the barrier. The bars were suspended on two bars of bakelite (1 in. × ¾ in.) running the length of the apparatus outside of the compartments. The walls were supported by angle irons so that there was a ½-in. space between the bottoms of the walls and doors and the surface of the steel bars. Thus the steel bars were only in contact with bakelite outside the compartments. This type of construction insured that urine would not create an electrical contact between the bars.

The steel grid bars of each compartment were individually wired to two cannon plug receptacles, one mounted at each end of the apparatus. A multiple-strand cable connected each plug to a commutator circuit. This type of circuit for supplying fairly stable electric shocks has been described by Skinner (17). It is so designed that an alternating current is supplied to the grid bars with a rapidly shifting polarity pattern. Such a technique for distributing electric current to the grid bars effectively prevents dogs from escaping shock by shorting out adjacent grid bars with feces. The shock circuit was powered by a 500-v. A.C. transformer energized by 110-v. A.C. A fixed resistance of 3,500 ohms was placed in series with the grid bars so that the experimenters could not accidentally electrocute a dog. In addition, a 1000-ohm variable voltage divider was placed in parallel with the 500-v. power supply in such a way that the voltage at its source could be varied from 0 to 500 v. An electronic voltmeter was placed across the fixed resistance so that the voltage drop could be continuously read. In this way, the current flow in the circuit could always be known.

SUBJECTS

The subjects used in this study were 30 mongrel dogs of medium size. Their range in weight was approximately from 9 to 13 kg. All the subjects were strays and probably free from experimental sophistication. The data in this study were obtained while the dogs were apparently healthy.

PROCEDURE

The barrier was adjusted to approximately the height of the dog's back. Therefore, the dogs could look over the barrier from one compartment to the other when the gate was raised.

Pretesting. Each dog was pretested in order to reveal the presence of a previously acquired tendency to jump the barrier. Each subject was led into the experimental room on a leash and was coaxed into, or put into, one of the compartments. The door to the compartment was then locked and, since the gate was down (closed), the dog was thus completely confined. The lights above the compartments were on. The commutator motor was running, providing a low background noise. The dog was observed during a 10-min. pretrial "acclimation period."

Then, at the end of this period, the first pretest trial was conducted. The lights above the compartment in which the dog was confined were turned off by means of a foot pedal. Simultaneously, the experimenter raised the gate by pulling the counterweight on the pulley system. Therefore, the subject was in relative darkness but was, at the same time, exposed to the presence of the barrier, and immediately beyond it the other compartment was still illuminated. This situation will be referred to as the conditioned stimulus pattern (CS), or the "signal."

Each dog's reaction to the CS was observed. If, at the end of a 2-min. interval, the dog had not jumped out of the darkened compartment over the barrier into the illuminated compartment, the gate was lowered and the lights turned back on. Such a trial was recorded as "no response" with respect to jumping, but salient features of the dog's activity during his exposure to the CS were recorded in protocols.

One minute after the gate was closed, the second pretest trial was begun. It was identical to the first trial. Thus, the interval between presentations of the CS was 3 min. For most dogs, 10 pretest trials were conducted in order to make certain that each dog was not a "jumper" in this situation. (A few dogs were pretested for only five trials if they evidenced complete indifference to the CS.) After the tenth trial, the dog was left in the illuminated compartment with the gate down for a 10-min., postrial "cooling-off period." Then the dog was taken out of the apparatus and returned to his living cage. The 30 dogs used in this report were

not "jumpers." That is, their "operant level" for jumping over a barrier approximately the height of their backs was close to zero.

Training. On the day after the pretest, each dog was subjected to avoidance training. The dog was brought into the experimental room in the same manner as for the previous pretest. He was, however, placed in the compartment opposite to the one in which he had been pretested. Just as had been done on the previous day, each dog was kept in one of the compartments, with lights on and gate closed, for a pretrial acclimation period of 10 min. duration. Then, at the end of this period the first training trial was begun. The CS was presented, just as has been described for the pretest trials. Ten seconds later, the grid on the floor of the darkened compartment was electrified with a voltage which was the *highest possible* without producing tetany of the dog's leg muscles. This shock voltage was monitored with the aid of the electronic voltmeter, and the current drawn at a *just-subtetanizing* stimulation level was approximately 10.0 to 12.5 ma. for most dogs. The voltage applied to the shock circuit was slightly different from dog to dog, since resistance conditions were not constant from dog to dog, and current flow necessary for tetany differed from dog to dog.

The shock was kept on in the darkened compartment until the dog jumped or scrambled over the barrier into the illuminated compartment. The gate was closed immediately following such an escape from shock, thus preventing any retracing on a given trial. If a dog failed to get out of the electrified compartment within a 2-min. interval following the presentation of the CS, the lights were switched on and the gate was lowered, accompanied simultaneously by termination of the shock. In such a case, the next trial was started after a 1-min. interval following the termination of the CS.

There was a standard CS-US temporal interval of 10 sec. maintained throughout all escape trials (the shock is the unconditioned stimulus). The time interval between trials (between successive presentations of the CS) was kept constant at 3 min. The latency of response was measured for each trial and was defined as the time interval elapsing between the presentation of the CS and the occurrence of jumping over the barrier. The latency was measured by stop watch to the nearest tenth of a second.

If a dog jumped within less than 10 sec. following the presentation of the CS, the gate was lowered to prevent retracing just as was the case in those trials on which the dog had a latency of over 10 sec. and was shocked. If a dog was moving toward the barrier at the end of the 10-sec. interval after the CS, the shock was withheld until the dog stopped moving toward the barrier. (This procedure was actually necessary on only 17 of 800 training trials.)

An *escape* trial or *shock* trial is defined as a trial in which the dog is shocked *before* he jumps the barrier. An *avoidance* trial is defined as a trial in which he jumps the barrier without being shocked. Thus, with the exception of the very few trials in which shock was withheld when the animal was approaching the barrier at the end of 10 sec., all avoidance trials have a response latency of 10 sec. or less, whereas all escape trials have a latency of more than 10 sec.

Ten training trials were conducted in each experimental session. Each session was concluded with a 10-min. posttrial cooling-off period. Then the animal was removed from the apparatus and returned to his home cage.

Certain aspects of the maintenance schedules for the animals were left uncontrolled. While the dogs were fed once a day, and usually had water in their home cages, it was true that sometimes they might be hungry and sometimes not hungry at the time of an experimental session. Usually the dogs were not thirsty. We believe that the variations in the maintenance schedule do not reflect themselves in our data on avoidance learning motivated by intense electric shock.

Results

1. *Definition of Acquisition*

In *avoidance learning* it is very difficult to point out logically where the acquisition phase ends and extinction begins. This is so because the delivery of the unconditioned stimulus (shock) to the subject is contingent upon the subject's aversive movements. Thus, if one considers the *shock* to be the reinforcing agent necessary for acquisition, one might argue that extinction of avoidance begins when the aversive movements are such that shock is avoided. However, in terms of the experimenter's own operations, the acquisition-extinction distinction is not as easy to define as one might think. Suppose a subject suffers a *reversal;* that is, after avoiding successfully for a few trials, he has a long latency and is shocked before he responds with aversive movements. Where, then, would extinction begin? Also, if one takes an anxiety-reduction point of departure, the

point at which acquisition ends and the extinction process begins is even more ambiguous. We cannot ascertain accurately at present whether or not anxiety reduction takes place after a given response on a given trial, so to define presence or absence of reinforcement in those terms is not feasible.

We have taken the stand that an arbitrary criterion is probably the best we can do—one based on how many times the experimenter has *not* shocked the dog. For all animals, if no shocks have been received for 10 consecutive trials, the acquisition phase is over; the animal has met our criterion for avoidance learning. And from then on, *no matter what the dog happens to do in the presence of the signal, he will never receive the shock.* The state of affairs that defines the extinction procedure is thus the *impossibility of receiving a shock* in either compartment, no matter how long the dog may delay jumping after presentation of the CS.

Despite such a definition of the onset of extinction, the *response characteristics* of our dog suggest that, in traumatic avoidance learning, rarely, if ever, do we enter a *true extinction* phase, a sequence of trials where no reinforcement occurs. For this reason, we will present behavioral data for several trials beyond the point at which the 10 avoidances out of 10 trials criterion has been met. In a later paper, we shall discuss extinction characteristics at greater length, but it should be clear here that we do not believe that there is any strongly tenable distinction available at present which would enable us to separate acquisition procedure from extinction procedure in the case of traumatic avoidance learning.

2. *Latencies of Jumping Responses*

a. Beginning of training as anchor point. The mean reciprocal of latency for the 30 dogs is plotted for each trial in Figure 2. Note that a logarithmic ordinate is used; this is merely for convenience. The median reciprocal of latency for the 30 dogs is plotted for each trial in Figure 3. Notice that as the response latencies decrease, the logarithms of the reciprocals of response latency increase in magnitude. The right-hand ordinate

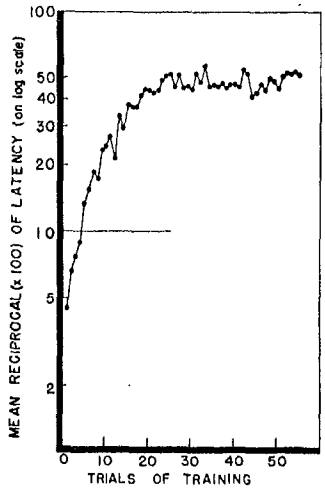


FIG. 2. Mean reciprocals of latency, trial by trial, for the 30 dogs.

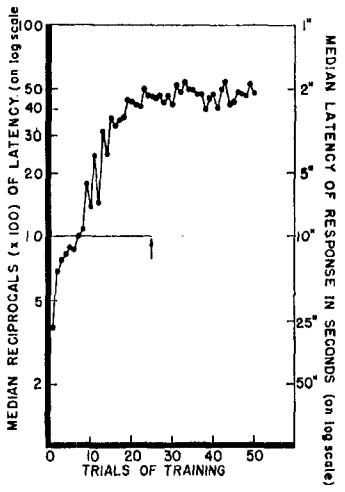


FIG. 3. Median reciprocals of latency, trial by trial, for the 30 dogs.

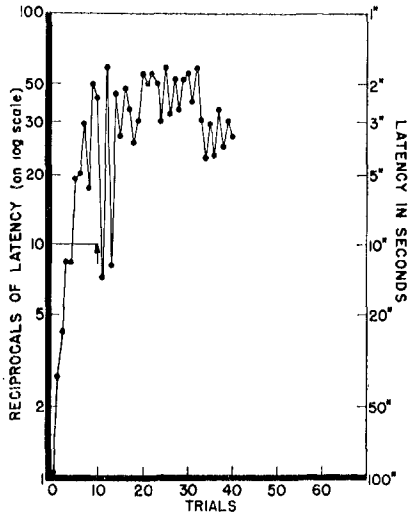


FIG. 4. An individual acquisition curve for a fairly typical subject. Note the two long latencies after the criterion has been met, followed by gradually shortening latencies.

translates the median reciprocals into the original latencies in seconds. For means, however, the right-hand ordinate is an approximation, since the antireciprocal of the mean reciprocals may not be the same as the mean raw latency. It may be convenient for the reader to interpret the graphs as indices of response strength, or response velocity. As response latencies decrease, response strength increases.

We have found that the distribution of latencies on given trials in our experiment may be either bimodal, skewed, or normal, depending upon the phase of training. Therefore, ordinary techniques of data combination led to measures of central tendency which were definitely not representative of most of the individual animals in our experiment. In view of this we have selected a set of representative individual acquisition curves, Figures 4-9.

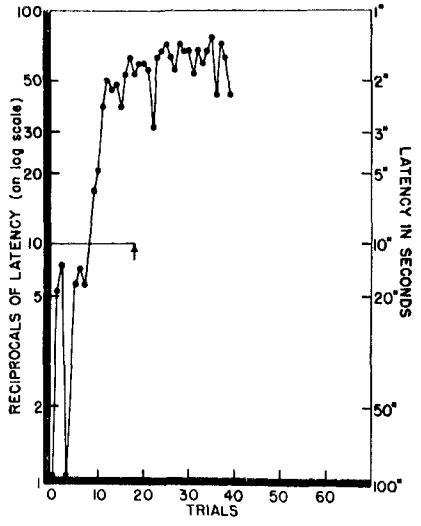


FIG. 5. An individual acquisition curve for a fairly typical subject. Note that the transition from escape responses to avoidance responses is final and complete, with no reversals. Here is an instance of avoidance learning which is not a case of irregular or aperiodic reinforcement.

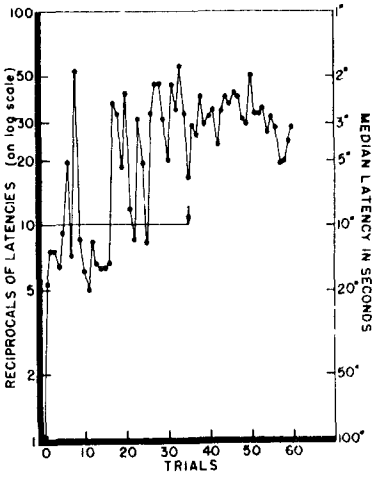


FIG. 6. An individual acquisition curve for a very slow learner. Note the large number of alternations from escape to avoidance responses, from avoidances to escapes.

In all of the graphs (Fig. 2-9), the horizontal line at 10 sec. (or at 10 on the scale of 1/latency $\times$ 100) indicates the boundary between escape and avoidance. Above the horizontal line, the points indicate a latency of response to the *con-*

ditioned stimulus alone, with no shock administered. Below the line, the points represent a latency of response to the US as well as to the CS. The distance that each point below the horizontal line lies from the horizontal line is the number of seconds of shock received while the animal was failing to get out of the "hot" compartment. These points represent escape or shock trials.

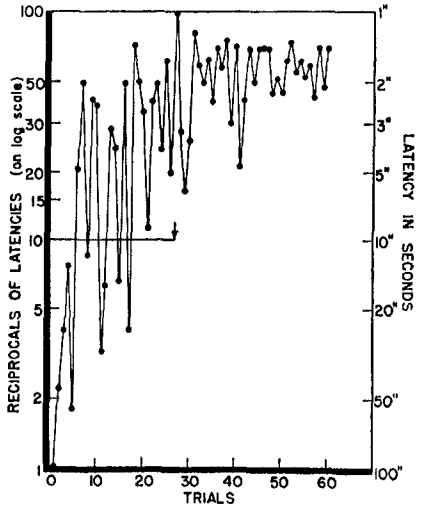


FIG. 7. An individual acquisition curve for a very gradual learner.

The vertical arrows in Figures 2-9 indicate the trials on which the criterion of acquisition was reached (10 avoidances in a row). After the arrow has appeared, the dogs are under extinction rules—they *cannot* receive shock for latencies of response to the CS of 10 sec. or more. They are now "safe," no matter what their responses are like.

An examination of the six individual records (Fig. 4-9) would lead one to suspect that the function in Figure 3 is *more representative of what actually occurred in our experiment* than is the function in Figure 2. That is, combination of data through use of *means* distorts our data more than with medians. This is very interesting on several counts. If we had generalized solely from the graphs of *individual* performance, we would have described a trend more simi-

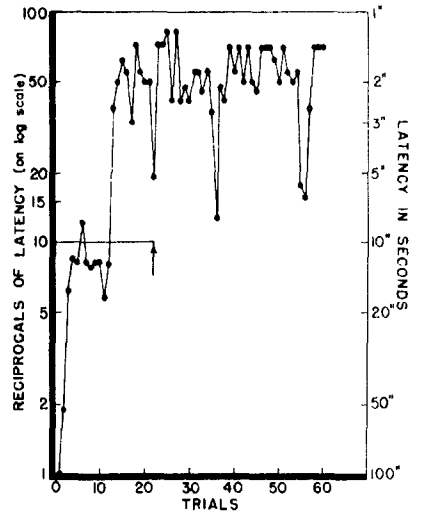


FIG. 8. An individual acquisition curve for a very sudden learner. Note the plateau of escape or shock trials, suddenly followed by avoidance responses of regular, short latencies.

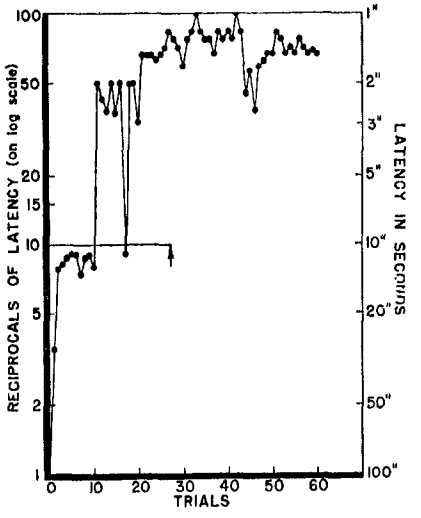


FIG. 9. An individual acquisition curve for a very sudden learner. Note the sudden transition to short-latency avoidance responses.

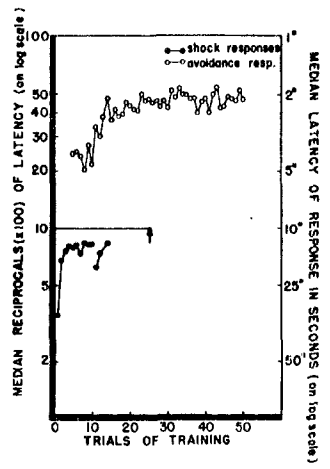


FIG. 10. Median reciprocals of latency for shock (escape) responses and avoidance responses considered separately. Note that the latency plateau for shock responses is reached after the first few trials, while the latency plateau for the avoidance responses is reached more gradually. Note also the absence of response latencies in the range between 5 and 10 seconds.

lar to that indicated by the *medians* of Figure 3. (This is what many physiologists typically do, without resort to statistical operations for combining data.)

An inspection of the individual acquisition curves reveals to some extent why the combined data, especially the means, are unrepresentative. First, the animals learn at different rates. In addition, there is a suggestion that we have a bimodal distribution of latencies because of a scarcity of latencies between 5 and 10 sec. Finally, we felt that there was an over-all tendency for the animals to learn abruptly, and if this were true, together with the differential learning rates, then such a tendency would be obscured by combining data in conventional ways. Many of the methods of analysis which we shall present have been designed to clarify the extent to which this tendency to learn abruptly exists. If there is a strong tendency for our animals to learn abruptly, then the following should be true: (*a*) There should be a sudden change from 100% escape responses to 100% avoidance responses; and (*b*) the latency of *response to the shock* on escape trials should be approximately equal to the latency of *response to the signal* on the first avoidance trials—that is, there should be no gradual shortening of latencies in making the transition from escape reactions to avoidance reactions.

Since the combination of latencies for escape and avoidance responses by different animals on any given trial will give intermediate values for the means, it seemed reasonable to separate escape and avoidance responses. Such a procedure is indicated for medians in Figure 10. Both of these graphs show that *escape* latencies change very little after the first few trials. On the other hand, the *avoidance* latencies do not begin in the vicinity of 10 sec. and gradually diminish; rather, avoidance responses begin in the vicinity of 5 sec. and decrease gradually to an asymptote.

In the first four trials, very few animals avoided. From Trial 5 to 7 there was a considerable increase in the proportion of the animals avoiding (43% on Trial 5, 37% on Trial 6, and 57% on Trial 7).

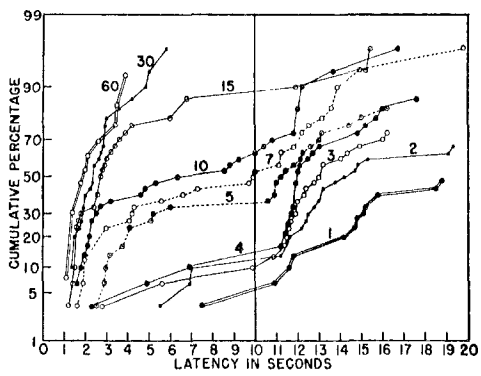


FIG. 11. Cumulative frequency of occurrence curves plotted on probability paper, showing the frequencies of occurrence of different response latencies at differing numbers of trials.

Hence, at this point in learning, if most of the animals are making an abrupt change from relatively long latencies to relatively short ones without a gradual diminution of latency, then the distribution of latencies on those trials should be bimodal.

A convenient way of demonstrating the characteristics of several different frequency distributions on one graph is the use of cumulative frequency distributions. If these are plotted on probability paper, they clearly demonstrate the degree of departure from a normal curve. (In such a graph a normal distribution will yield a linear function.) Figure 11 presents these curves for a selected sample of trials. For the first four trials, the frequency distributions of latencies are skewed, tending to pile up progressively at a latency of about 12 sec. On Trial 5, along with a marked increase in the number of animals avoiding the shock, a striking change in the shape of the frequency distribution takes place. There is a sudden increase in the percentage of latencies in the 2 to 5-sec. range. At the same time, there is *no increase* in the percentage of latencies in the 5 to 10-sec. range. Those latencies greater than 10 sec. continue in their tendency to pile up at about 12 sec. This bimodality gradually disappears as the number of training trials increases, so that by Trial 15 we again find a skewed distribution, piling up now in the 2 to 3-sec. range. This degree of skewness progressively diminishes, as illustrated in the plots of Trials 30 and 60.

A general, though not complete, description of acquisition of avoidance in this experiment can be derived from combining the implications of Figures 10 and 11. It would go something as follows: On the first four trials, most animals are getting considerable shock but their response latencies are decreasing. On Trial 5, a number of the animals shift over to respond quickly to the signal alone, while the rest continue to receive the shock. Finally, all of the animals avoid with very short latencies.

b. First avoidance trial as anchor point. Since the trial on which the first avoidance response occurs varies from animal to animal, combining the data on the basis of the number of trials of training obscures the characteristics of the first avoidance, as well as the responses preceding and following it. Therefore, we constructed a new baseline which is defined as *trials after the first avoidance,* and we combined the data of all animals for each of these trials.

When the escape latencies and avoidance latencies for *trials after the first avoidance* are unsegregated, as in Figure 12, an acquisition curve is obtained which would lead one to believe that there is a gradual transition from long to short latencies and that there is a high frequency of response latencies in the 5 to

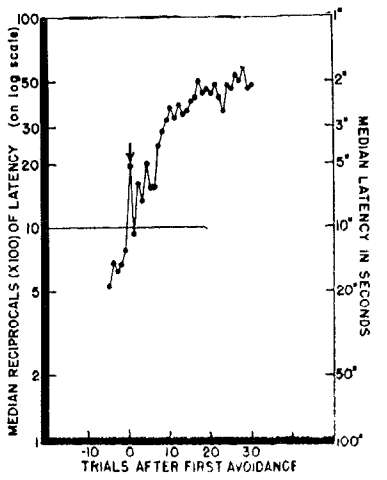


FIG. 12. Acquisition of avoidance as represented by the median reciprocals of response latency for trials after the first avoidance response. Escapes (shock trials) and avoidances are combined in determining the medians.

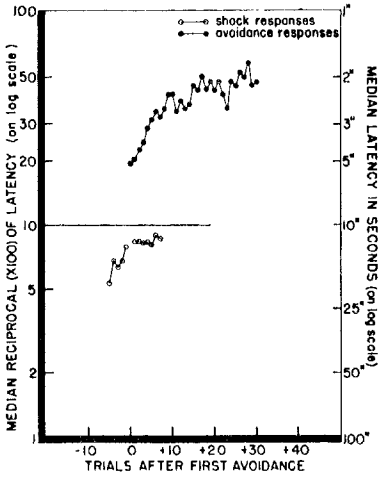


FIG. 13. Acquisition of avoidance as represented by median reciprocals of response latency for trials after the first avoidance response. Note that the shock trials and avoidance trials are treated separately.

10-sec. range. This impression, however, would be erroneous. When the escape or shock responses are treated separately from the avoidance or nonshock responses (Fig. 13), the median latency of the first avoidance response is approximately 5 sec. Thereafter, on successive trials following the first avoidance response, the latency of escape responses remains fairly stable at about 12 sec., but the latency of avoidance responses progressively diminishes. It is interesting to note that after an animal has made his first avoidance, he responds very quickly to shock. Immediately prior to the first avoidance the latency of the escape responses was still decreasing.

The cumulative frequency distributions for a selected sample of trials after the first avoidance are shown in Figure 14. The first avoidance trial (0) seems to be a transitional trial. On the trials before the first avoidance, the distributions are highly skewed, tending to pile up at a latency of about 12 sec. The trial after the first avoidance (+1), in contrast, shows a distinctly bimodal distribution of latencies. The distribution of latencies on the first avoidance trial is intermediate between the highly skewed type immediately before the first avoidance and the definitely bimodal type immediately after the first avoidance trial. Thus, with the exception of the first avoidance trial, the trials immediately following those on which 100% of the animals were failing to avoid exhibited bimodal distributions. On these trials after the first avoidance, if an animal failed to avoid, he jumped very quickly when shocked, and if he made an avoidance response, he jumped very quickly to the signal alone. There are very few responses in the 5 to 10-sec. range. Figure 14 shows this quite clearly.

c. Last shock trial as anchor point. Since the number of trials needed to meet the criterion for acquisition of avoidance learning (10 consecutive avoidance responses) differed from ani-

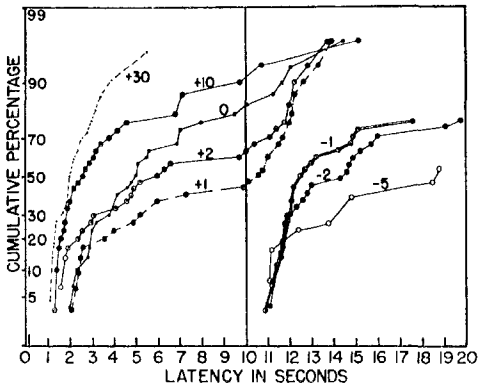


FIG. 14. Cumulative frequency distributions of latencies for various numbers of trials after the first avoidance response. The ordinate is on a probability scale.

mal to animal, combining the data on the basis of the number of training trials obscures the characteristics of the trial on which the last shock was given, and those "criterion" trials directly following it. Therefore, we constructed another base-

line which is defined as *trials after the last shock,* and we combined the data for all animals for each of these trials.

When the latencies for all 30 animals for *trials after the last shock* are combined, leaving escape and avoidance responses unsegregated, the acquisition curve for median response latencies for trials after the last shock is quite striking. (See Fig. 15.) When the latencies for the shock and avoidance responses are separated, we obtain the curves plotted in Figure 16. The separated curves show

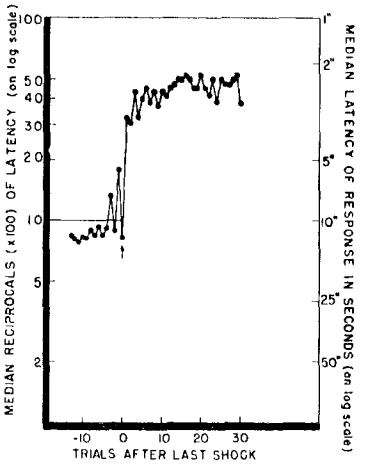


FIG. 15. Acquisition of avoidance as represented by median latencies for trials after the last shock (escape) trial. The shock and avoidance responses have been combined in determining the medians.

clearly that the latencies of the avoidance trials were gradually decreasing *before* the trial on which the last shock was given. This indicates that, despite the relatively abrupt appearance of quite short avoidance latencies, these latencies diminish progressively with increased number of training trials. Interestingly enough, *the latencies of avoidance responses after the last shock has been received by all animals continue to decrease in an orderly manner,* approaching a median asymptote at approximately 1.8

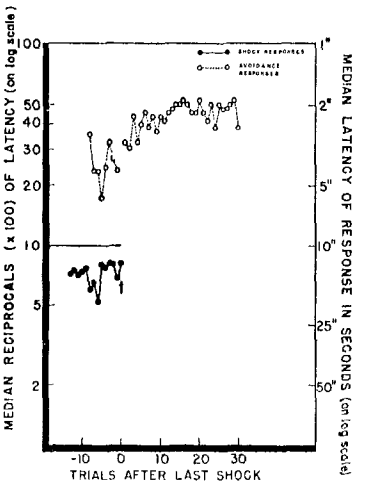


FIG. 16. Median reciprocals of latency for trials after the last shock when the shock and avoidance responses are separated.

sec. As was the case for the other baselines, the *shock response* latencies change little during those trials directly preceding the last shock trial.

The cumulative frequency curves for a selected sample of trials after the last shock are shown in Figure 17. The trials immediately preceding the trial before the last shock show the familiar bimodal distributions. The frequency distribution for the trial before the last shock (−1), however, seems to be transitional in

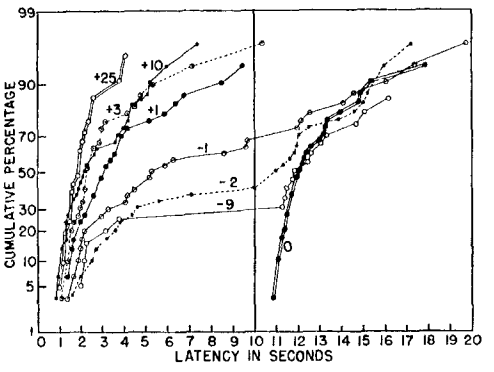


FIG. 17. Cumulative frequency distributions of latencies for different numbers of trials after the last shock trial.

shape, in that it is neither highly skewed nor bimodal in character. In contrast, the last shock trial (0) is definitely skewed with a piling up of response latencies at 12 sec. The trial after the last shock (+1) appears to have the same type of frequency distribution as the last shock trial (0), *but the median latency of the trial after the last shock is 9.1 sec. shorter than the median latency of the last shock trial.* The fact that the magnitude of the difference between these two medians approximates the magnitude of the CS-US interval used in training is probably not accidental, and the significance of this finding will be discussed later.

3. *Sequential Patterns of Escapes and Avoidances*

In the section above we have discussed response latencies. It should be pointed out that this has not been the accepted way of reporting the data of avoidance learning experiments (see, for example, Brogden, 2, 3). Usually the ordinate of the learning curve has been in terms of the percentage of avoidances in blocks of trials of arbitrary length, though there have been exceptions (see, for example, Miller, 6, 7). In our experiment, learning took place so rapidly that this method of analyzing the data was not feasible. Neither was the Vincent curve technique feasible. Instead, it seemed more reasonable to supplement the latency data with an analysis of sequential patterns of escape responses and avoidance responses, *without regard to latency magnitudes within each class of responses.*

Before examining the specific sequential patterns, an over-all summary of occurrences of escapes and avoidances for

TABLE 1

PER CENT OF ANIMALS AVOIDING ON EACH TRIAL, FOR ALL THREE BASELINES

Trials of Training			Trials after the First Avoidance			Trials after the Last Shock		
Trial No.	*N*	%	Trial No.	*N*	%	Trial No.	*N*	%
1	29	0.0	−1	30	0.0	−13	13	23.1
2	30	10.0	0	30	100.0	−12	14	28.6
3	30	10.0	+1	30	50.0	−11	17	18.8
4	30	13.3	+2	30	66.7	−10	19	21.0
5	30	43.3	+3	30	56.7	−9	20	25.0
6	30	36.7	+4	30	73.3	−8	23	47.8
7	30	56.7	+5	30	63.3	−7	26	34.6
8	30	60.0	+6	30	66.7	−6	28	50.0
9	30	66.7	+7	30	73.3	−5	30	43.3
10	30	76.7	+8	30	80.0	−4	30	56.7
11	30	73.3	+9	30	83.3	−3	30	56.7
12	30	63.0	+10	30	90.0	−2	30	40.0
13	30	90.0	+11	30	93.3	−1	30	66.7
14	30	70.0	+12	30	93.3	0	30	100.0
15	30	86.7	+13	30	96.7	+1	30	100.0
16	30	90.0	+14	30	96.7	+30	14	100.0
17	30	90.0	+15	30	96.7			
18	30	93.3	+16	30	96.7			
19	30	96.7	+17	30	100.0			
20	30	100.0	+18	30	100.0			
25	30	96.7	+19	30	96.7			
30	30	100.0	+20	30	100.0			
35	21	100.0	+30	22	100.0			
40	21	100.0						
45	14	100.0						
50	14	100.0						

TABLE 2

RELATIONSHIPS AMONG ESCAPE AND AVOIDANCE RESPONSES

Relationship	Mean	Median	Range
Number of escapes before first avoidance	4.5	4.0	1– 8
Number of escapes before second avoidance	6.5	6.0	2–14
Number of trials of training to and including the last shock	12.4	12.0	6–25
Total number of shocks received	7.8	7.0	4–13
Number of trials after first avoidance up to and including the last shock	6.8	6.5	0–19
Number of shocks received after first avoidance response	3.3	3.0	0– 9
Number of alternations of escapes and avoidances before meeting criterion of acquisition	5.5	5.0	1–13

the three types of baseline will serve as orientation to the data. An examination of Table 1 will reveal the general characteristics of the acquisition of avoidance without regard to response latency.

The sequential patterns of escape and avoidance responses stand out more clearly if we measure the central tendencies for escapes and avoidances to occur in certain sequential positions, regardless of response latency characteristics. These central tendencies are shown in Table 2.

If we take the median sequential relationship as representative of the "typical" animal in our experiment, we arrive at the following sequential pattern: four successive escapes (shocks) on the first four trials of training; the first avoidance response on Trial 5; two escape and four avoidance responses distributed over Trials 6 through 11, with two alternations of escapes and avoidance within this sequence; the last shock appears on Trial 12, followed by 100% avoidance responses. This sequence pattern makes no reference to magnitudes of response latency within the two classes of response.

4. *Amount of Shock Received*

Since the amount of shock received by a given animal (in seconds of shock) varied from animal to animal, depending upon many factors, it seems important to assess its relevance to the behavioral aspects of individual animals. The total number of seconds of shock varied from 10.1 sec. to 454.9 sec., with a mean of 93.5 sec. and a median of 56.8 sec. The first quartile of this distribution was 24.0 sec., and the third quartile was 146.3 sec. That the total seconds of shock received were related to sequential aspects of the course of acquisition is suggested by the fact that the total seconds of shock were negatively correlated with the number of alternations of escapes and avoidances. The *more* shock an animal receives, the *less* tendency there is for him to be sequentially erratic. The correlations coefficient (rho) is −0.44.

Most of the relationship between amount of shock received and number of alternations is due to shock received *on those trials preceding the first avoidance* response. The correlation of seconds of shock before the first avoidance with number of alternations is −0.38. The correlation between the number of shocks before the first avoidance and number of alternations is −0.42. While these correlations are low, they suggest that *relatively large amounts of shock before the first avoidance tend to decrease sequential variation during the trials following the first avoidance.* Other correlations relating seconds of shock and number of shocks before the first avoidance to other aspects of acquisition were low, but they were consistent with the implications of the correlations cited above.

5. *Behavioral Observations*

In the protocols, we tried to record the following kinds of observations: (*a*) gross skeletal movements and vocaliza-

tion; (*b*) position within the apparatus at selected points in time; (*c*) signs of autonomic reactions, such as: salivation, defecation, urination, shivering, panting, pupillary changes, and respiratory rate; (*d*) anticipatory reactions, such as position shifts directly following presentation of the CS, and autonomic signs, vocalization, and skeletal movements directly following the CS. Clearly, such observations give us little information about the events taking place in the nervous system or details about the animal's motivational state. However, it is possible that such observations may be related to the occurrence or nonoccurrence of avoidance responses. In the present study, we are especially interested in the possible relationship between these behavioral observations and the occurrence of the first avoidance response and the last shock response.

The animals' responses to the unconditioned stimulus (subtetanizing shock) were quite uniform. (A description of these responses was given in the introduction.) However, it was still possible for the experimenters to rank the animals in order of intensity of reaction to the shock. This ranking procedure was carried out in an arbitrary fashion by assigning weights to the occurrence of specific emotional signs. The signs which were recorded in the protocols, and the weights which were assigned to each, are listed in Table 3. Using this scale, an emotionality score could be computed for each dog, and this score could be then correlated with other observations and measures derived from the data.

TABLE 3

CLASSIFICATION OF EMOTIONAL SYMPTOMS AND WEIGHTS USED IN COMPUTING THE EMOTIONAL INDEX

Emotional Behavior	Weight
Urination	3
Defecation, breaking wind	3
Salivation, drooling	2
Yelping, shrieking	2
Attacking apparatus, clawing at it	3
Shivering, shaking, trembling	3
Pupillary dilatation	3
Whining	2
Posturing	2
Restlessness, agitation	1
Barking	1
Panting	1
Scrambling on grid bars	1

The results of the analysis of emotional reactions were highly instructive. The mean trial on which the first anticipatory emotional signs occurred was 3.6. It will be remembered that the trial on which the first avoidance response occurred, as listed in Table 2, was 5.5 (a mean value of 4.5 shock trials before the occurrence of the first avoidance response). Thus, on the average, the dogs tended to exhibit some type of overt emotional reaction to the CS on a trial approximately two trials before the trial on which the first instrumental avoidance response to the CS occurred. It should be emphasized that the analysis showed that the anticipatory emotional signs were predominantly skeletal rather than visceral in nature: symptoms such as restlessness and agitation, whining and barking, and, in several dogs, shying away from the gate and retreating to the rear of the compartment. There is great likelihood that many anticipatory visceral reactions were unobservable without instrumentation. Since the raising of the gate signalled the oncoming shock, it is not surprising that some animals retreated from it; in a few cases, primitive "perceptual defense" was observed when a dog would shy away from the gate and hide his head in a corner of the compartment so that the visual stimuli from the open gate were effectively shut out.

Anticipatory signs in the presence of the CS tended to be more obvious in the fast learners who received relatively few shocks. The correlation coefficient for the

relationship between the number of shocks before the first avoidance response and the emotionality score was −0.39. This might indicate that the more upset a dog appears to be (in the judgment of the experimenters) during the first few trials of training, the quicker will the first avoidance response appear. This could be interpreted to mean that there is a tendency for the more frightened dogs to learn more quickly. However, the correlation between the emotionality score and seconds of shock received before the first avoidance was only −0.16. While the difference between the rho of −0.39 and −0.16 was not significant, it is possible that the *frequency* of shocks is not the same as *seconds* of shock received with regard to psychological significance.

In general, analysis of the emotionality scores both before and after the dogs reached the criterion for learning (ten avoidance responses in 10 trials) reveals that the dogs were more upset before the criterion was met than they were afterward. But it should be emphasized that several of the dogs remained in an extremely agitated state after they were regularly avoiding the shock.

The protocols contained a brief description of the behavior of the animals during the 3-min. interval between trials. There was a strong tendency for stereotyping to develop. For example, immediately after jumping a dog might position himself in a specific part of the apparatus, facing his body and head in a fixed direction, and he might maintain this position until the next presentation of the CS. In opposite compartments of the apparatus, such stereotyped behavior would often be symmetrical or a mirror-image. When such a degree of stereotyping was observed, it was usual to find that many previously exhibited emotional signs were no longer evident.

Discussion

We believe that the data of this experiment are most efficiently discussed within the framework of a two-process learning theory. The theoretical writings of Skinner (15, 16), Schlosberg (13), and Mowrer (8, 9) are prominent in the development of our own point of view. We assume that in the establishment of avoidance learning two processes are operative: (*a*) the process of classical conditioning governed by the principle of stimulus contiguity, and (*b*) the process of trial-and-error learning governed by the S-R reinforcement principles.

The classical conditioning component is responsible for the appearance of *emotional* responses elicited by the conditioned stimulus. Some of the attributes of the original unconditioned response to the noxious stimulus come under the control of the once-neutral CS. The animal then appears to be emotionally upset or anxious, exhibiting a wide variety of reactions that include both skeletal and visceral components. We do not follow Mowrer's relegation of autonomic reactions to classical conditioning and skeletal responses to trial-and-error learning. Rather, we adhere more closely to Schlosberg's conception that diffuse conditioned emotional responses may develop under conditions of stimulus contiguity. These classically conditioned responses give rise to a stimulus pattern having drive properties. It is this stimulus pattern to which Mowrer (8) and Miller (6) refer in describing anxiety as an acquired drive.

The reinforcement of learned instrumental avoidance responses comes about through drive reduction. Early in the learning process when the animal is escaping from shock, the instrumental act removes the US, as well as the CS. Drive reduction then consists of reduction in the intensity of both pain and emotional upset. Later, when the animal is avoiding the shock, drive reduction consists of reducing the intensity of the emotional upset by removing the CS.

Our formulation of a two-process theory enables one to explain without further assumptions: (*a*) the development of conditional emotional responses during the course of avoidance training, and (*b*) the maintenance of avoidance responses once they have occurred. However, the mechanism whereby the animal makes the *transition* from escape to avoidance behavior is usually neglected in theoretical accounts of avoidance learning.

With repetition of the CS-US sequence (during the escape phase), the emotional reaction to the

CS increases in amplitude or intensity. Thus, the response pattern to the CS will gradually approximate more closely the emotional response to the US, and the response-produced drive stimulus pattern which follows the CS will gradually approximate more closely the response-produced drive stimulus pattern which follows the US. During the escape phase the instrumental act has consistently taken place in the presence of a stimulus pattern composed of the CS, US, and emotional upset. When the CS will elicit the same sort of emotional upset, the instrumental act will tend to take place even though the US has not occurred. Presumably the stimulus generalization principle will account for this phenomenon.

The animal which previously responded instrumentally to CS, US, and upset now responds instrumentally to CS and upset. Thus a two-process theory will explain the occurrence of a transition from escape to avoidance responses.

However, whether the transition will be abrupt or gradual is not derivable from such a theory. Nor, indeed, are such predictions possible on the basis of cognitive theory, S-R reinforcement theory, or S-R contiguity theory. The degree of abruptness of avoidance learning can be defined in several ways, but all such definitions seem to fall into two classes: (*a*) those that characterize the rate of change of latency of the instrumental responses, and (*b*) those that characterize the rate of change from 100% escape responses to 100% avoidance (sequential pattern).

It is interesting that a two-process theory allows a prediction about the magnitude of latency of the first avoidance response while not making a direct prediction about abruptness of latency change. Other theories do not seem to lend themselves to making even so limited a prediction. If, as we argued above, the first avoidance response appears as a reaction to the stimulus pattern which accompanies the emotional upset, then the latency of the instrumental response will be the summation of two quantities. The first quantity will be the time between the presentation of the CS and the appearance of the conditioned emotional response. This latency quantity will presumably be inversely correlated with the level of intensity of the conditioned emotional response (1, 12, 20). With a fairly high level of emotional intensity we can reasonably expect a latency of about 1.5-2.5 sec. The second latency quantity is the characteristic time required for performing the instrumental act. This can be estimated from the latency of escape responses. In our data the median latency for the trial before the first avoidance was 12.6 sec., indicating that the instrumental response required 2.6 sec. following the onset of the shock. Adding the two quantities together gives an expected range from 4.1 to 5.1 sec. for the total latency of the first avoidance response. The actual median latency of the first avoidance response was 5.1 sec.

It is interesting to note that whether or not this transition from the escape latency to the avoidance latency is judged to be abrupt depends on the magnitude of the CS-US interval. If the magnitude of the latency of the first avoidance is predetermined by the two processes described above, then with a long CS-US interval the rate of change of latency will seem great on the first avoidance trial. If, however, the CS-US interval is relatively short (for example, if it had been 5 sec. in our experiment), the transition from escape to avoidance will seem to be characterized by a small change in latency. These theoretical considerations point up the importance of carrying out experiments systematically varying the CS-US interval in avoidance learning.

It is to be expected that fluctuations in the physiological state of the animal will affect the intensity of the conditioned emotional response and stimulus pattern. Such changes in intensity will be reflected in fluctuations in the latency of the instrumental response. Then, too, owing to changes in orientation of the animal in the apparatus, the degree of effective exposure to the CS will vary somewhat from trial to trial. The time mechanically necessary for the animal to get over the barrier will also vary with orientation in the apparatus. These fluctuations associated with orientation will be greater in the early stages of training before relatively stereotyped behavior in the interval between trials has developed.

If there is fluctuation in latency, this may produce reversals from avoidance to escape. Such reversals will lead to additional reinforcement of the instrumental act due to reduction of anxiety and pain. Therefore, when the next avoidance response does occur, its latency should be shorter than that of the first avoidance response. Also, the animal may show a lowering of latency associated with adjustments in orientation in the apparatus and increased proficiency in making the instrumental response. In our experiment, the median latency for the second avoidance trial was 4.1 sec., a full second shorter than that for the first avoidance trial.

With repeated reinforcement due to anxiety reduction on avoidance trials, we would expect that the latency of the instrumental act should decrease gradually even after no more shocks are being administered. Our data on trials after the last shock bear out this expectation. The median latency for the first five trials after the last shock was 3.1 sec. The median latency for Trials 26-30 after the last shock was 2.1 sec. It is interesting to note that on the first five trials after the first avoidance response, the

median latency for escape responses, when they did occur, was 12.1 sec. Thus, the instrumental response component, at a comparable level of training, is exactly the same (2.1 sec.) no matter whether the response is elicited by the CS or by the US. When the instrumental response is elicited *at this time* by the CS, it can no longer be argued that a conditioned emotional reaction is operative in eliciting the instrumental response. This can be deduced because the instrumental act occurs before, or simultaneously with, any emotional reactions elicited by the CS. When this occurs, it appears that the animal is acting cognitively.

The reversals from avoidance to escape, or from escape to avoidance appear to be an all-or-none phenomenon, as though the control of the instrumental component were *switching* back and forth from the CS to the US. The median shift of latency from the last shock trial to the first trial after the last shock (first criterion trial, +1) was 9.1 sec., and an all-or-none conception would require this difference to be the magnitude of the CS-US interval, or 10.0 sec. The difference between 10 sec. and 9.1 sec. in this case is, however, not statistically significant. Here again, the carrying out of an experiment which systematically varies the CS-US interval from group to group appears to have strategic importance. For example, using the experimental procedures which produced our data, if the CS-US interval were 20 sec. instead of 10 sec., then the shift in latency from the last shock trial to the subsequent trial should be 20 sec. The first avoidance trial should exhibit a latency of about 5 sec., decreasing gradually to a latency of about 2 sec. at 30 trials following the last shock trial.

The theoretical significance of the "switching phenomenon" is hard to assess. Most cases of classical conditioning (see 1, 4, 5, 20) which seem to fit a stimulus-substitution paradigm are characterized by *gradual* growth in the magnitude of the CR. If the switching phenomenon is a special case of a stimulus substitution process, then under what conditions does it occur? Cognitive theorists might interpret the switching phenomenon as an example of insight. But, then, why do we see reversion to escape reactions after the animal has demonstrated his capacity to avoid the shock? An S-R reinforcement or S-R contiguity interpretation might emphasize the role of competing responses in accounting for the data; such theories might argue that the experimental situation, and especially the US, tends to elicit responses which may be incompatible with the instrumental avoidance response. Such an interpretation would indeed account for plateaus in the learning process, but would not lead to a deduction of the switching phenomenon. As a matter of fact, response incompatibility might suggest the occurrence of a plateau at intermediate latencies in our experiment. Such was not the case in our data. In short, we do not feel that a fully adequate theoretical explanation of such findings is available at present.

An examination of the sequential pattern of escape and avoidance responses reveals that three animals switched from 100% escape responses to 100% avoidance responses without a reversal. Seven animals had only one reversal and eight animals had only two reversals. Sheffield and Temmer (14) have argued that random or aperiodic reinforcement schedules are characteristic of avoidance training. They have explained the relatively slow course of extinction of avoidance responses in terms of the random pattern. However, our data indicate that such a pattern is *not* necessary in the normal course of avoidance learning; and, indeed, a fairly exact analysis of the actual sequential patterns is necessary in interpreting avoidance data. The fact that some animals *can* learn to *avoid* with the same schedule of reinforcement with the US as that used in *escape* training needs to be emphasized in theories which try to account for the difference between escape and avoidance learning.

The descriptive protocols produced some interesting relationships. Despite the incompleteness of the emotionality data, certain strong tendencies stood out, and they pose some special problems for theories of avoidance learning. It will be remembered that, on the average, the first overt emotional reaction to the CS occurred approximately two trials before the appearance of the first avoidance response. Mowrer (8, 10) has reported a similar finding, and both his observations and ours are compatible with a two-process theory. This relationship between the occurrence of conditioned emotional responses and the appearance of instrumental behavior is worthy of more study. While a two-process theory accounts for the development of classically conditioned emotional responses, and for the development of instrumental acts reinforced by drive reduction, the interrelationships between the two processes are not worked out. It is perfectly conceivable that there is a great deal of independence between the two processes under some conditions. An animal might become upset at a signal which had been associated with shock, but because the instrumental response which might eliminate the signal may be low in the response hierarchy, the animal may shift from ritual act to ritual act without developing any strong instrumental behavior. Furthermore, the response hierarchy can vary with differing external environmental conditions as well as differing internal emotional or drive conditions. Internal emotional conditions which are not directly arousable by the CS itself, but

which are long-lasting and a function of the total situation, can determine the response hierarchy so that the act which might eliminate the signal may have either a *low or high* probability of being emitted. In avoidance conditioning, we have argued, there is a close interrelationship between the two processes, a relationship mediated by the assumption that conditioned emotional reactions have drive properties. But the determinants of the extent of this relationship have not been studied systematically. Our data reveal that the observer's prediction of the occurrence of the first avoidance is aided by the data on anticipatory emotional responses recorded in the protocols. The observer is also aided in his predictions by knowledge about the instrumental response as measured by the latency of escape; the shorter the escape response latencies, the greater is the likelihood of a shift to avoidance.

Another indication that the occurrence of emotional reactions is related to the learning of avoidance is the relationship between the emotionality scores and the sequential pattern. The correlation of —0.39 between the emotionality index and the number of shocks before the first avoidance suggests that, other things being equal, with greater emotional upset the animals make the instrumental response of avoidance sooner. However, there is no relationship (rho = —0.06) between emotionality and the total number of trials to meet the learning criterion of ten successive avoidances. Explaining such a finding is extremely difficult because several partial relationships seem to be operating in opposite directions. For example, while the most upset animals require the fewest shocks before the first avoidance, those animals receiving the fewest shocks in early trials tend to alternate between escape and avoidance. Thus, the most upset animals, receiving the least shock in early trials, should alternate more after the first avoidance. That the trend is in this direction is indicated by a rho of +0.27 between the emotionality index and the number of alternations between escape and avoidance.

Although a number of very general theoretical problems have been introduced to this discussion, we wish to emphasize that the particular conditions under which our experiment was carried out dictated, of necessity, the direction that the discussion took. It should be remembered that our animals were exposed to the following important conditions: (*a*) a highly traumatic unconditioned stimulus, (*b*) a CS-US interval of 10 sec., (*c*) a relatively difficult instrumental act in jumping over a high barrier, (*d*) a shuttle sequence which required the animals to return to the same compartment on alternate trials, (*e*) a CS which remained present until the instrumental act took place, and (*f*) the subjects were mongrel dogs. The results were a function of the experimental procedures, and the theory which seemed to fit our results best may prove to be inadequate under other conditions. Many variations of the conditions above will be involved in subsequent tests of the generality of both our findings and the theory we used to account for them. The procedures we did use produced behavioral data which posed challenging problems for theories of learning, and many new experiments were suggested in the course of considering these problems.

SUMMARY

An experiment in traumatic avoidance learning is reported in which dogs were trained to avoid a just-subtetanizing shock by responding to a signal which preceded the shock by a period of 10 seconds. A shuttle-box jumping response was reinforced as the instrumental avoidance reaction. The dogs received ten trials per day with a 3-min. interval between trials.

The results can be stated briefly: (1) During the *escape* phase of learning, when the animals were receiving shocks because they were not "anticipating," the latency of the jumping response decreased rapidly and did not change significantly after the third trial. (2) The first *avoidance* response, a response to the signal having a latency of less than 10 seconds, appeared (on the average) on the fifth trial; it was preceded at about the third trial by the appearance of conditioned emotional reaction to the signal. (3) The latency of the first avoidance response represented an abrupt decrease from the escape reaction latencies preceding it. (4) After the first avoidance trial the latency of avoidance responses continued to decrease in an orderly manner, while the latencies of the escape reactions did not change. (5) The latency of avoidance reactions continued to decrease after the trial on which the last shock was received. (6) The difference in latency between the last shock trial and

the avoidance trial following it was 9.1 seconds, approximately the magnitude of the CS-US interval. (7) The sequential patterns of escape and avoidance reactions showed that some dogs make a complete change from 100% escapes to 100% avoidances without reversal. (8) Relatively large amounts of shock received during the first few trials tended to decrease the number of reversals from avoidance to escape on the trials following the first avoidance response. (9) Stereotyping of behavior was noted in conjunction with decrease in emotional reactions.

The data of this experiment were analyzed, with the aid of several new techniques for representing the course of change of latencies and the characteristic sequential patterns of escape and avoidance responses. These techniques helped to some extent in presenting data on abrupt changes in behavior.

The results were discussed within the framework of a two-process theory of learning. Several inadequacies in current learning theories were revealed in trying to explain our findings.

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