

SHOCK INTENSITY AND CONDITIONING
IN CURARIZED DOGS

SIMPLE AND DIFFERENTIAL CONDITIONING
IN CURARIZED DOGS AS A
FUNCTION OF SHOCK INTENSITY

By

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CHAPTER ONE

HISTORY

The first study of the relationship between level of noxious stimulation and learning was conducted by Yerkes and Dodson in 1908 (30). Their experiment involved a discrimination task in which electric shock was given if an incorrect response was made. The procedure consisted of training hungry rats to discriminate between two runway compartments in order to obtain food. If the rat entered the wrong compartment it was given electric shock until it left that compartment, whereupon it was allowed to enter the other. The discrimination was made on the basis of a difference in illumination between the two compartments. Three levels of difference in illumination were used in order to provide three levels of discrimination difficulty. In addition, four levels of shock intensity were used as punishment for incorrect responses.

The results that Yerkes and Dodson obtained were rather surprising. Instead of the highest shock intensity producing the most rapid learning, as might be expected, it actually produced a rate somewhat lower than that produced by the intermediate intensities. Thus, the curve relating shock intensity to rate of learning was in the form of an inverted U. In addition, it was found that the level of shock intensity at which the maximum rate of learning took place decreased as the difficulty of discrimination increased. The interaction between shock intensity, difficulty

of discrimination and learning became known as the Yerkes-Dodson Law.

The problems suggested by the Yerkes-Dodson experiment were of obvious interest and significance. Practically, it has always seemed obvious that a certain amount of stress in the context of a learning task would improve the learner's performance. The Yerkes-Dodson study was the first to point out that, at least under certain conditions, excessive stress might actually impede performance. It suggested that, from the point of view of learning efficiency, there might be such a thing as "over" motivation. The precise specification of the conditions under which a given degree of motivation would facilitate or impede performance was thus suggested as an important experimental problem.

Following Yerkes and Dodson, Cole in 1911 (8) and Dodson in 1915 (9) repeated the experiment using chicks and kittens respectively. Their results indicated the same relationship as those of the previous study. Later Vaughn and Diserens (28), using human subjects in a stylus maze learning problem with shock given for incorrect responses, also reported an inverted U shaped function between shock intensity and learning.

As has been said, these results were surprising because it had been generally believed that increased motivation led to more rapid learning. Consequently, other investigators became interested in the problem. However, the investigations did not retain the same experimental form as that used by Yerkes and Dodson. As has been pointed out by Broadhurst (4), the Yerkes-Dodson experimental procedure was overly complex by today's standards. The use of both hunger and fear, for example, complicates the interpretation of the results. Consequently, in the work

that followed these studies, an attempt was made to study the effects of noxious stimulation in simpler learning situations. For the purpose of this thesis, these later studies will be classified under four headings, which the author feels represents four distinct types of learning situations. These four types are simple (Pavlovian) conditioning, simple operant conditioning, differential (Pavlovian) conditioning and operant discrimination, the order of which may be taken as a rough indication of the complexity of the learning involved.

Simple (Pavlovian) Conditioning

The procedure involved in simple conditioning is, of course, well known (20). It consists of the pairing, in time, of a neutral stimulus (CS) with an unconditioned stimulus (US) which is capable of eliciting some response. After a number of such pairings the CS begins to elicit a response (CR) similar to that elicited by the US. It is the rate at which the CR is acquired, and its magnitude, which are taken as a measure of learning.

The first relevant experiment on the effects of strength of US on conditioning was by Bakin, and is reported by Pavlov in his 1927 book Conditioned Reflexes (20). In this study Bakin used two aversive chemicals (hydrochloric acid and Quassia) as unconditioned stimuli for the conditioning of the salivary reflex in dogs. His results showed that the stronger US, the HCL, produced a greater conditioned response and also a greater resistance to extinction. In 1948 Passey (19), using human subjects, obtained similar results in a study of eye blink conditioning. In this experiment four levels of air puff intensity were used as the US's. His

results indicated that the rate of conditioning of the response increased as a direct function of the US intensity. This result was duplicated in later studies by Spence and Taylor (25), Spence (23), Walker (29), Trapold and Spence (27), and Prokasy et al. (21); all of which used the conditioned eye blink response.

In addition to the studies presented above there is also a type in which it is assumed that simple conditioning takes place, although no actual conditioned response is recorded. The general procedure in such studies is to train a subject in some form of continuous operant responding using intermittent reinforcement. Once this training is completed a CS is presented followed by a noxious US. After a number of such pairings of the CS and US, the presentation of the CS tends to cause a diminution in the rate at which the operant response is being performed. It is this diminution, generally referred to as a 'conditioned emotional response' or conditioned suppression, that is used as the measure of simple conditioning.

Only one experiment of this type is relevant to the present paper. This is a study by Annau and Kamin (1) in which the suppression of a bar pressing response in rats was studied as a function of the shock intensity of the US. Their findings were in line with the other results on simple conditioning, namely that suppression increased as shock intensity increased in a negatively accelerating curve.

The results of the studies using simple conditioning are quite clear cut. In all the experiments there is an increase in conditioning with increasing US intensity. In no case is there a decrease at high stimulation levels.

Simple Operant Conditioning

In the present case the heading 'simple operant conditioning' actually refers to three types of studies; escape learning, avoidance learning and what is generally referred to as the 'Miller type' learning situation. The reason that they are grouped under one heading is that, as far as the experimental design is concerned, no discrimination is required. This does not mean, of course, that no discrimination is taking place.

Escape learning involves in general the learning of some operant response which will allow the subject to escape from a noxious stimulus. It is the latency and vigor of this response which are taken as measures of learning. Avoidance learning is much the same as escape learning, except that a CS precedes the onset of the noxious stimulus. If the subject makes the appropriate response during the CS he is able to avoid the US and, in general, terminate the CS. The Miller (18) type of situation is somewhat more complex. In this case a CS and US are first paired, in time, for a number of trials. At the end of this training the subject is required to learn some operant response in order to terminate or escape from the CS. The US is never presented on these trials. Because these three types of learning are more or less discrete the results of past experimentation of the simple operant type will be presented under three subheadings.

Escape Studies

In a study designed to measure both escape and avoidance learning in rats, Boren et al. (3) reported that the latency of the escape decreased as a negatively accelerated function of shock intensity. Trapold and Fowler (26), again using rats, reported an increasing, negatively accelerated,

relationship between shock intensity and speed of running to escape from shock. However, they also showed that there was an inverted U shaped function between shock intensity and the latency of escape. Keller (14), and later Kaplan (13), using illumination as the noxious stimulus, demonstrated, that when escape performance was intermittently reinforced, the rate of responding first increased and then decreased as the intensity of the aversive illumination increased. In both of these studies rats were used as subjects. Barry and Harrison (2), also using rats, reported the same inverted U function between the rate of escape responding and level of aversive noise. Here again the escape behavior was reinforced using an intermittent schedule. In the same experiment Barry and Harrison reported that, for the group of rats on a continuous schedule of reinforcement, the rate of responding was a positive, negatively accelerated, function of the level of noise used.

The results of these experiments are somewhat ambiguous. In some cases the escape performance increases as the level of noxious stimulation increases, while in others there is first an increase and then a decrease. The form of the relationship seems to be in part dependent upon the schedule of reinforcement of the escape response. With intermittent reinforcement one seems to get an inverted U shaped function, while with continuous reinforcement, a monotonic function is obtained.

Avoidance Studies

In the experiment by Boren et al., cited above, the results of avoidance training (using a Sidman type procedure) showed an increase in the rate of the avoidance response with increasing shock intensity. Kimble (15),

in a 1955 study using rats, reported similar results. In his work the performance curve became asymptotic at 1 ma. of shock intensity. Brush (6), using dogs, also reports a decreasing, negatively accelerated, function between shock intensity and latency of avoidance responding.

These three studies all give similar results, namely, that avoidance performance increases to an asymptotic level with increasing levels of noxious stimulation. There is no indication here that high stimulus intensities retard learning.

Miller Type Studies

Mather (17) has reported a study of this type, using rats, where the intensity of the US (an electric shock) with which the CS was paired was varied systematically. The response measure was the number of trials needed to extinguish a wheel turning response, which had been learned in order to terminate the CS. His results showed a U shaped function between shock intensity and trials to extinction. Goldstein (11), however, reported somewhat conflicting results in a 1960 study. In this work rats learned a hurdle response in order to terminate a CS which had previously been paired with various levels of electric shock. The results indicated that the latency of the hurdle response decreased as shock intensity increased. Unfortunately, these two studies are not directly comparable because two different response measures were used, as well as different units for the measurement of shock intensity.

In summary, the results of these simple operant conditioning studies are somewhat ambiguous. The studies of escape learning (using continuous reinforcement) and the studies of avoidance learning show a positive,

negatively accelerated, relationship between the intensity of the noxious stimulus and learning. However, those escape studies where intermittent reinforcement was used report an inverted U shaped relationship. In the studies using the Miller procedure one study showed a positive, negatively accelerated, relationship, while the other reported a U shaped function.

Differential Conditioning

Differential conditioning (Pavlov, 20) is identical to simple conditioning, with the exception that one or more CS's are presented in addition to the CS, which is paired with the US. These additional CS's are generally referred to as negative CS's (CS-), and are never followed by the US. That a CR occurs to these stimuli prior to differential conditioning is generally attributed to a generalization of the conditioned response elicited by the CS (CS+) which is paired with the US. Due to the nature of the situation the two stimuli, the CS+ and CS- must be presented in succession. It should be kept in mind that this procedure is considerably different than that of operant discrimination where the stimuli to be discriminated are usually presented simultaneously.

There is only one study of this type to be found in the literature. This is a study by Runquist, Spence and Stubbs (22) in which various levels of air puff intensity were used as the US, in the differential conditioning of the eye blink response. These results indicate that discrimination performance, as measured by the difference in response to the CS+ and CS-, increased as the intensity of the air puff increased. The two CS's in this experiment were 5,000 c.p.s. and 500 c.p.s. tones. The results, while

suggesting a tendency for discrimination to improve with higher US intensities, were not statistically reliable.

Operant Discrimination

Operant discrimination involves the learning of a correct response when two or more response alternatives are presented simultaneously. The correct response may be identified in this situation by any number of stimulus dimensions. In general, it is the number of trials to reach some arbitrary criterion of learning that is taken as the behavioral measure.

In regards to this type of study the work of Yerkes and Dodson, Cole, Dodson and Vaughn and Diserens has already been cited. The results of all of these experiments indicate that there is an inverted U shaped function between level of noxious stimulation and discrimination performance. In addition Hammes (12), in a study of discrimination using the escape from shock situation, found that for a difficult discrimination there was an optimal level of shock intensity, above which discrimination performance deteriorated. Broadhurst (5), in another attempt to test the Yerkes-Dodson Law, found that, when rats were forced to discriminate between two alleys of a Y water maze in order to escape from the water, there was an optimal level of air deprivation above which discrimination deteriorated.

The results of these studies of operant discrimination seem quite clear cut. In all the reports there is an inverted U shaped function relating level of noxious stimulation to discrimination performance.

To summarize the past research, it may be said that if one views the four types of studies presented here as forming a continuum from relatively simple to complex learning then the results of the studies at

each end are quite clear. In the case of simple conditioning all studies support the notion that learning performance increases, at least to an asymptote, as the level of noxious stimulation increases. At the other end of the continuum the results of the studies of operant discrimination all showed an inverted U shaped function between the level of noxious stimulation and discrimination learning. It is the two intermediate categories which are ambiguous. In simple operant conditioning both types of functions relating shock intensity and learning were found. In differential conditioning there is one previous study on the effects of the level of aversive stimulation and the results of this study were not conclusive. The experiment which will be described here is an attempt to provide additional information on the effect of shock intensity on differential conditioning. However, before presenting the experiment, two theoretical positions which are relevant to the study will be presented.

CHAPTER TWO

LEARNING THEORY AND THE EXPERIMENT

In the preceding history an attempt has been made to point out the various methods that have been employed in the study of the effects of US intensity on learning. In this section a brief outline of two current theoretical positions which attempt to deal with these problems will be presented. In discussing the relevant theories, it is not the intent of the author to cover all theories of learning, nor to present the entire structure of the theories considered. Only the parts of the theories most directly relevant to the present experimental investigation will be discussed.

The Spence Theory

K.W. Spence (24), working from the framework of Hullian theory, has presented perhaps the most comprehensive theory of the relationship between drive and learning performance. In the Spence theory drive (D) multiplies with the existing habit strength (sHr) to produce behavior (sEr). Simply stated, this means that as drive increases, with habit strength constant, the magnitude or quality of response also increases, (sEr = D x sHr). In a classical conditioning situation the magnitude

of sHr increases with the number of reinforced trials and increases with the number of non-reinforced trials. On the other hand the value of D increases with increasing US intensity or, more generally, with any increase in noxious stimulation or biological deprivation. The result is that as one increases the US in classical conditioning, with the habit strength constant, there should be an increase in the rate of learning and in the magnitude of response.

The same relationship between drive and habit strength is also applied to discrimination learning, or more specifically to differential conditioning. In this situation two habit strengths are postulated. First there is the habit strength developed by the pairing of a CS and a US, (the $sHr +$). Second, there is the habit strength generated by the generalization of the $sHr +$. This is the habit strength ($sHr -$), to the CS which is never followed by a US during the differential conditioning, and which consequently decreases in magnitude because of the lack of reinforcement. It is assumed that the drive, which is either produced through US stimulation or which is present due to some other factor, multiplies in equal strength with each of these two habit strengths. Consequently, if both habit strengths are equal for all experiment subjects, the difference between the response to the two CS's associated with the two habit strengths is predicted to increase with drive, $(sEr +) - sEr -) = D [(sHr +) - (sHr -)]$, i.e., differential conditioning will be better for higher drive subjects.

The Yerkes-Dodson Law

The Yerkes-Dodson Law (30) is not a theory at all. Rather, it is an observed phenomenon which was first described in the experiment by Yerkes and Dodson, to which reference has been made before. The "law" itself is relatively simple. It states that, as drive increases, the performance on a discrimination task increases to an optimal point and then starts to deteriorate, and also that this optimal point of drive intensity decreases as the difficulty of the discrimination increases. It should be kept in mind that this law is referring to simultaneous discrimination and not to differential conditioning. If, however, it does apply to differential conditioning, one would expect that as drive increases there would first be an increase in the quality of differential conditioning followed by a decrease; the opposite of Spence's hypothesis.

The Experiment

The experiment to be presented is an attempt to study the effects of US intensity on both the magnitude of a simple conditioned response and the development of differential conditioning. As has been pointed out earlier, there is only one study of this type in the literature, the results of which were not conclusive.

The response selected for study was the autonomic cardiac response. This response was selected instead of a phasic response such as eye blink because it conforms more closely to the type of response traditionally employed in Pavlovian conditioning.

The conditioning procedure was conducted while the subjects (dogs) were under the influence of d-tubocurarine chloride in order to minimize

the artifacts in the cardiac response produced by movement, and also to allow for better control of the presentation of the stimuli. The following section describes in detail the experimental procedure employed.

CHAPTER THREE

METHOD

Subjects

The subjects were 32 naive mongrel dogs which were assigned at random to four groups of eight dogs each. Of these 32, four were eliminated due to apparatus failure, reducing the number of dogs in each group to seven. All dogs were well fed, healthy, and weighed an average of thirty pounds.

Apparatus

The apparatus in which the dogs were restrained during the experiment consisted of an adjustable table, above which a rectangular frame extended. Across this frame was suspended a rubberized cloth hammock, having four holes to accommodate the animal's legs. This enabled the dog to be supported in a standing position. By adjusting the table top it was possible to allow the dog to support itself during the precurarization phase. This apparatus was housed in a sound proof room, completely separate from all control equipment. The apparatus is shown in Figure 1A (See Appendix 3).

The electro-cardiography (ECG) recording was made with a three channel Grass pen-writing oscillograph. One channel was used as the conventional ECG amplifier and the other as a tachograph. While the final data were taken from the ECG record, the tachograph enabled one to monitor the on-going heart rate in order to make any necessary corrections in respiration or level of curarization. The third channel was used to mark

the periods of CS and US presentation.

The presentation of both the conditioned and unconditioned stimuli, as well as the timing of all intervals, was done automatically by the use of electrical programming circuits. The conditioned stimuli were two tones of 70 decibels intensity produced by an Ashman sine-wave tone generator. These were presented to the animal by means of a speaker placed approximately three feet in front of the dog. The UCS, a 60 c.p.s. electric shock, was administered to the dog's rear legs through two standard EEG scalp electrodes. A high resistance, high voltage shock circuit was employed in order to minimize the effects of changes in the dog's resistance during experimentation.

Procedure

1. Curarization

When the dog was secured in the hammock a portion of the rear leg surrounding the recurrent tarsal vein was anaesthetized by a 1 c.c. subcutaneous injection of two per cent procaine hydrochloride (Winthrop). (Since the anaesthetized area was small and the effects of such an injection dissipate rapidly, this procedure did not seem to affect the reaction to shock.) A polyethelene tube was then inserted into the vein and fixed in place. This allowed intermittent injections without necessitating further vein puncture. Next d-tubocurarine chloride (Squibb) was slowly injected through the implanted tube until the dog was completely immobilized. At this time an endotracheal tube was inserted and artificial respiration begun.

2. Conditioning

Approximately ten minutes after curarization was achieved the dog was given a number of "pre-conditioning" trials. Each of these consisted of a fifteen second presentation of either a 4,000 or 400 cycle tone. The tones were presented in a fixed irregular order until they no longer produced a change in heart rate. Because the dogs varied in their initial responses to the tones, it was necessary to give some dogs as many as eighteen trials to achieve complete habituation, while others required only four trials. Habituation was considered complete when three consecutive trials showed a response to the CS of less than five beats per minute.

When habituation was complete a series of ten "simple conditioning" trials was given. These consisted in all cases of a presentation of the 4,000 c.p.s. tone (CS+) followed by shock (US). The (CS-US) interval was ten seconds and the shock duration was five seconds. The CS overlapped with the shock and both terminated at the same time. The inter-trial interval averages two minutes with a deviation of \pm thirty seconds. The shock intensities employed were 1, 2, 4, and 8 ma. Each dog received one intensity throughout the experiment, with a total of seven dogs receiving each intensity.

Simple conditioning was followed by forty trials of "differential conditioning". In these trials the 4,000 c.p.s. tone (CS+) was paired with shock in the same way as in simple conditioning. In addition, the 400 c.p.s. tone (CS-) was presented for fifteen seconds without being followed by shock. These two types of trials totalled sixteen and twenty four respectively and were given in a fixed irregular order with the same

inter-trial interval as in simple conditioning. The ordering of trials for the whole experiment is given in Appendix 1. Because the pre-conditioning trials varied in number, only the last four of each dog's series were used in the data analysis. The pre-conditioning trials referred to in the section on results are the first and fourth trials of these last four pre-conditioning trials and the first trial of conditioning. These three trials are referred to collectively as pre-conditioning trials 1, 4, 1.

Collection of Data

The average heart rate, in beats per minute (BPM), for the ten second period prior to the CS and for the CS period itself was taken from the ECG recording by the following method of measurement. The distance in millimetres from the first to the last R wave occurring within a period was measured. (See Figure 1.)

Insert Figure 1

This value was converted to seconds by dividing it by six and the value in seconds was divided by the number of inter-R wave intervals it contained to give the average inter-R wave duration in seconds. Finally this inter-R duration was divided into sixty to give BPM. A sample calculation for the CS period of the trial shown in Figure 1 is as follows. The distance from the first to the last R wave occurring within the period is 59 mm. This value divided by six gives 9.83 seconds. The number of inter-R wave intervals is 17, which when divided into 9.83 gives .578 seconds for the average inter-R wave duration. This value divided into sixty gives 103.81 BPM as the average rate for the CS interval. The distance from first to

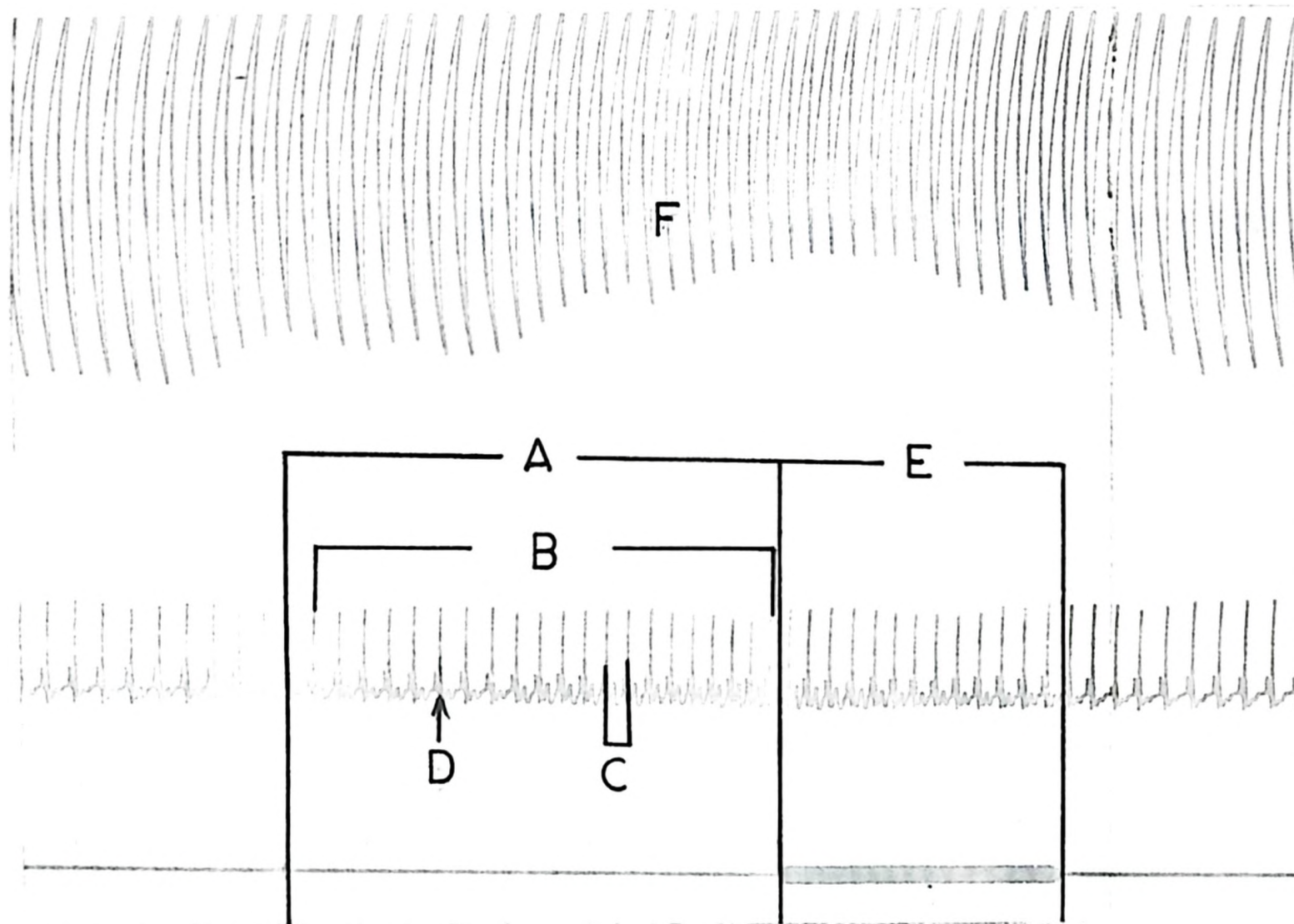


Figure 1. An example of a conditioned cardiac response. (This example is taken from an actual record of one of the dogs used in the experiment.)

A - 10 second CS period

B - Distance from first to last R wave

C - Inter-R wave interval

D - An R wave

E - 5 second US period

F - Tachograph record

last R wave was measured with the aid of a modified micrometer, accurate to $\pm .1$ mm. The standard error of measurement, determined by twenty calculations of the same interval, was ± 3 BPM at 120 BPM.

As can be seen, our collection method ignores any partial inter-R wave intervals which might occur at the beginning or end of a period. (See Figure 1.) Our disregard of these partial waves was based on two considerations. The first, and most obvious, is that such intervals must be either approximated by sight, an extremely inaccurate procedure, or by the laborious and impractical method of measurement and calculation. The second reason is that the use of such intervals might tend to confound the data and should, therefore, be excluded. This confounding arises from the problem of whether or not the effects present at the start of the last R to R wave of one period carry over into the next when the wave is split between the two. That is, can the R to R wave be affected at any point in its cycle, or does it, once it begins, remain of fixed length until the start of the next cycle? At the present time this question is not answered. However, we may consider what effects these two possibilities would have on the data.

We are interested in the difference in heart rate between a control or base-line period (the pre-CS period) and a treatment period (the CS period), and it is, therefore, desirable that this difference be derived from independent values. If we first assume that the R to R wave may be affected at any point in its cycle, then a wave which starts in the pre-CS period and ends in the CS period is under the influence of both conditions. This makes it impossible to fractionate the wave so that each part depends

upon only one of the conditions, i.e., we cannot estimate partial waves without having inherent confounding. Under this same assumption this argument also applies to the end of the CS period because it is followed in all positive trials by the US condition. Therefore, if one does not eliminate these partial waves from the data he runs the chance of confounding. If such waves are eliminated this possibility is removed. However, some information is lost at the beginning of the pre-CS period and at the end of the CS period of negative trials due to the fact that no change in conditions occur at these points.

If we make the second assumption, i.e., that the R to R wave duration remains constant until the start of the next cycle, then it becomes obvious that when a wave is split between two conditions the part appearing in the second condition should not be considered in calculating BPM during the second condition. In our case this applies to the first partial wave of the CS period. Under this assumption, if we eliminate all partial waves we sacrifice information at the end of the CS period, but escape the confounding present at the start of the CS period.

As can be seen from the above, it is safe to eliminate all partial waves, because in so doing one avoids the risk of confounding at the possible expense of losing some information. The actual amount of information lost is quite small. The maximum amount sacrificed at a constant rate of 120 BPM would be approximately eight per cent of the total available.

CHAPTER FOUR

RESULTS

The experimental results will be presented in three sections. The first will be concerned with habituation of groups prior to conditioning. The second and third will cover simple and differential conditioning. However, before the results are presented a problem of analysis must be considered.

The occurrence of a CR is shown by comparing the behavior present during the CS with the behavior preceding the CS. In the present case this is a comparison of the heart rate during the ten second CS period with the rate during the ten second period prior to it. To provide a measure of the CR the rate for the pre-CS interval was subtracted from that for the CS.¹ These difference scores provide a method for comparing the differences in magnitude of the CR as a function of shock intensity and number of conditioning trials. However, the use of these scores in analysis of variance was found to produce heterogeneity of variance. Even though this failure to fulfill one of the assumptions necessary for the analysis of variance, (i.e., that the variances be homogeneous) is said to have little effect on the results of the analysis (Edwards 10), the experimenter felt that the safest procedure under the circumstances was

¹ The "autonomic liability" scores suggested by Lacey (16) can not be used in the present experiment because the baseline rate tends to increase throughout the experiment. (See Appendix 2.)

to support all analyses using difference scores with others in which variances were homogeneous. These supporting analyses used the rates for the pre-CS and CS periods as scores. The use of these analyses permit the same conclusions to be made as those using difference scores, but complicates the graphical and verbal presentation of the results due to the addition of the extra factor of the pre-CS, CS comparison. Thus many of the effects in which we are interested would appear as significant interactions. Because of this limitation the results will be presented by the use of both types of analyses. Where the results can be clearly and simply presented using rate analyses, such will be used; in other cases the analysis of difference scores will be employed. It should be kept in mind that wherever an analysis of differences is presented there was an analysis using rates which permitted the same conclusions.

The results that will be shown here are these. Prior to conditioning there was no significant response to the (CS+) but at the end of simple conditioning the four and eight ma. groups showed significant responses to the (CS+). There was, however, no significant difference in the magnitude of conditioned response between these two groups. It will also be shown that at the start of differential conditioning the responses to the (CS+) and (CS-) were not significantly different. Finally, it will be shown that at the end of discrimination learning the four and eight ma. groups had discriminated.

1. Habituation Prior to Conditioning

That there was no significant response to the (CS+) prior to simple conditioning is shown by Analysis A.

 Insert Analysis A

This is a 2 x 4 factorial design which compares the average pre-CS and CS rates on pre-conditioning trials 1, 4, 1. The lack of a significant F for any of the factors indicates that there was no significant difference in rate, either between CS conditions or between groups.

 2. Simple Conditioning

At the end of simple conditioning there was evidence that conditioning had occurred and that there were differences in the magnitude of the CR as a function of shock intensity. This is shown by Analysis A₁.

 Insert Analysis A₁

This is a 2 x 4 factorial design which compares the average responses to the (CS+) on pre-conditioning trials 1, 4, 1, with that on simple conditioning trials 8, 9, 10. The factor of interest here is the trials x group interaction. The significant F for the factor indicates that there are differences between the pre-conditioning and conditioning trials and that this difference varies with shock groups. These results are shown in Graph A.

 Insert Graph A

As can be seen the four and eight ma. groups tend to show the greatest response difference. The four groups fall into two clusters, with the one and two ma. groups in the low response cluster and the four and eight ma. groups in the high response cluster. Graph A shows that there is a significant

ANALYSIS A

ANALYSIS OF VARIANCE OF PRE-CS, CS RATES

PRE-CONDITIONING TRIALS 1, 4, 1.

Source	SS	df	MS	F	P
Between Subjects	49,787.11	27			
Groups	3,975.73	3	1,325.24	< 1	-
Error	45,811.38	24	1,908.80		
Within Subjects	4,363.96	28			
CS	3.31	1	3.31	< 1	-
CS x Group	52.15	3	17.38	< 1	-
Error	4,308.50	24	179.52		

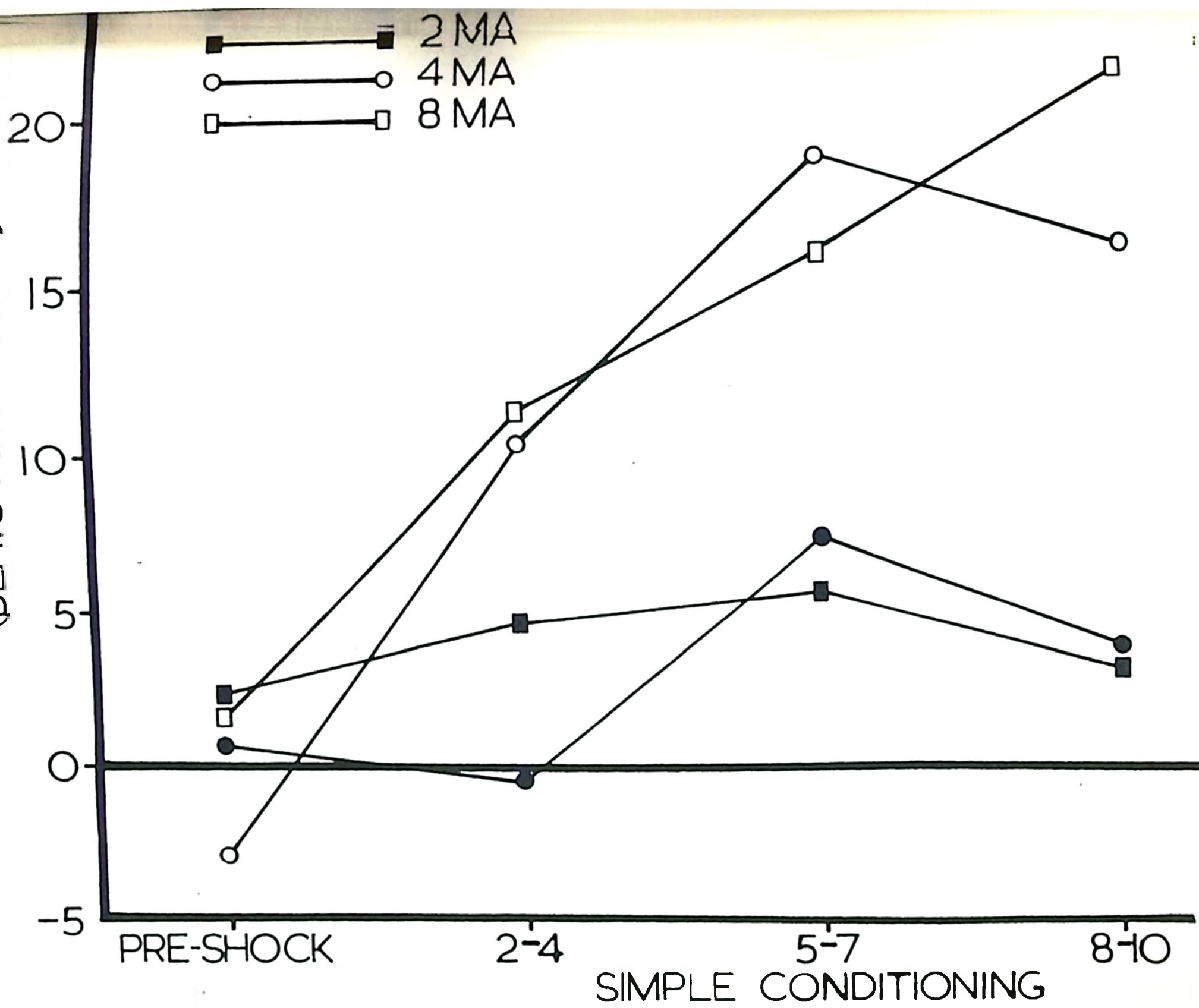
ANALYSIS A₁

ANALYSIS OF VARIANCE OF CONDITIONED RESPONSE PRE-CONDITIONING

TRIALS 1, 4, 1, AND CONDITIONING TRIALS 8, 9, 10.

Source	SS	df	MS	F	P
Between Subjects	3,255.52	27			
Groups	1,223.97	3	407.99	4.82	<.01
Error	2,031.55	24	84.65		
Within Subjects	4,201.94	28			
Trials	1,990.04	1	1,990.04	30.68	<.01
Trials x Groups	655.28	3	218.43	3.37	<.05
Error	1,556.62	24	64.86		

HEART RATE RESPONSE (BEATS PER MINUTE)



Graph A

Average magnitude of the conditioned response to the CS+ for the four shock groups on simple conditioning trials 1-10

Insert Analysis A₂

This is a Duncan's multiple range test for the mean difference in response between the pre-conditioning trials and conditioning trials referred to in Analysis A₁. As can be seen the four and eight ma. groups are both significantly different from the one and two ma. groups, and neither the four and eight ma. groups nor the one and two ma. groups are significantly different from each other. This significant difference between clusters may be explained by the lack of significant conditioning in the one and two ma. groups. Analysis A₃, which is a series of four t-tests of the differences between the average response during the pre-conditioning and conditioning trials cited above, shows that for the one and two ma. groups no significant increase in response was produced by the conditioning trials.¹

Insert Analysis A₃

Thus the main difference in the magnitude of the CR is between the two groups which show significant conditioning and those which do not.

3. Differential Conditioning

In the analysis of differential conditioning (discrimination training) the comparisons to be made are between the response to the (CS+) tone (4,000 c.p.s.), which is always paired with shock, and the (CS-) tone (400 c.p.s.), which is never paired with shock. If discrimination takes place it is expected that the response to the (CS+) will be greater

¹ The use of t-tests is permissible here since the interaction of Analysis A₁ was significant.

ANALYSIS A₂

ANALYSIS OF VARIANCE OF RESPONSE DIFFERENCE PRE-CONDITIONING

TRIALS 1, 4, 1, SIMPLE CONDITIONING TRIALS 8, 9, 10, AND

DUNCAN'S MULTIPLE RANGE TEST

Source	SS	df	MS	F	P
Between Subjects	5,260.58	27			
Shock	2,148.44	3	716.15	5.51	< .01
Error	3,112.14	24	130.09		

Shock Group	2 ma.	1 ma.	4 ma.	8 ma.	Shortest Significant Ranges
Mean	<u>.62</u>	<u>3.15</u>	<u>18.77</u>	<u>19.83</u>	
2 ma.	0	2.53	18.15*	19.21*	R2 = 12.55 R3 = 13.18 R4 = 13.59
1 ma.		0	15.62*	16.68*	
4 ma.			0	1.06	
8 ma.					
		1 ma.	2 ma.	4 ma.	8 ma.

*Significant at less than .05

This and all subsequent Duncan's multiple range tests are presented in the form suggested by Edwards (10 p. 137). Any two treatment means not underscored by the same line are significantly different. Any two treatment means underscored by the same line are not significantly different.

ANALYSIS A₃

FOUR t-TESTS OF THE DIFFERENCE IN RESPONSE BETWEEN PRE-CONDITIONING TRIALS 1, 4, 1, AND CONDITIONING TRIALS 8, 9, 10.

Shock Group	1 ma.	2 ma.	4 ma.	8 ma.
Means	3.15	2.39	18.76	19.88
t	1.67	1.14	3.91*	3.38*

* Significant at less than .01 level (one tail test)

than that to the (CS-). The order in which the two stimuli were presented during differential conditioning was referred to in the section on Method and may be found in Appendix A.

Analysis D shows that, at the start of differential conditioning there is no significant difference in the response to the (CS+) and (CS-). This is a 2 x 4 factorial design which compares the average

Insert Analysis D

responses to the (CS+) and (CS-) on the first ten trials of differential conditioning. The lack of significant F's for either the Sign or Sign x Group factors indicates that there is no significant difference in response to the (CS+) and (CS-) and that there are no significant differences between shock groups in this respect. The significant F for the group factor indicates that there are differences between groups in the combined magnitude of the (CS+) and (CS-) responses, which would be expected from the results of Analysis A₁.

At the end of discrimination training (trials 31-40) there is evidence that discrimination has occurred and that the differences in response between the (CS+) and (CS-) vary between shock groups. This is shown by Analysis D₁.

Insert Analysis D₁

This is a 2 x 4 factorial design comparing the response to the (CS+) and (CS-) on the last ten trials of discrimination training. The significant F for the sign factor means that, considered over all groups, there is a significant difference in the magnitude of response to the two stimuli.

ANALYSIS D

ANALYSIS OF VARIANCE OF RESPONSE TO CS + AND CS-

DIFFERENTIAL CONDITIONING TRIALS 1-10

Source	SS	df	MS	F	P
Between Subjects	3,731.71	27			
Group	1,381.05	3	460.35	4.70	< .05
Error	2,350.66	24	97.94		
Within Subjects	1,440.32	28			
Sign	0.00	1	0.00	-	
Sign x Group	232.43	3	77.48	1.54	> .05
Error	1,207.89	24	50.32		

ANALYSIS D₁

ANALYSIS OF VARIANCE OF RESPONSE TO CS+ AND CS-

DIFFERENTIAL CONDITIONING TRIALS 31-40

Source	SS	df	MS	F	P
Between Subjects	4,131.09	27			
Group	1,066.92	3	355.64	2.79	> .05
Error	3,064.17	24	127.67		
Within Subjects	2,819.37	28			
Sign	752.20	1	752.20	15.44	< .01
Sign x Group	897.77	3	299.26	6.14	< .01
Error	1,169.40	24	48.73		

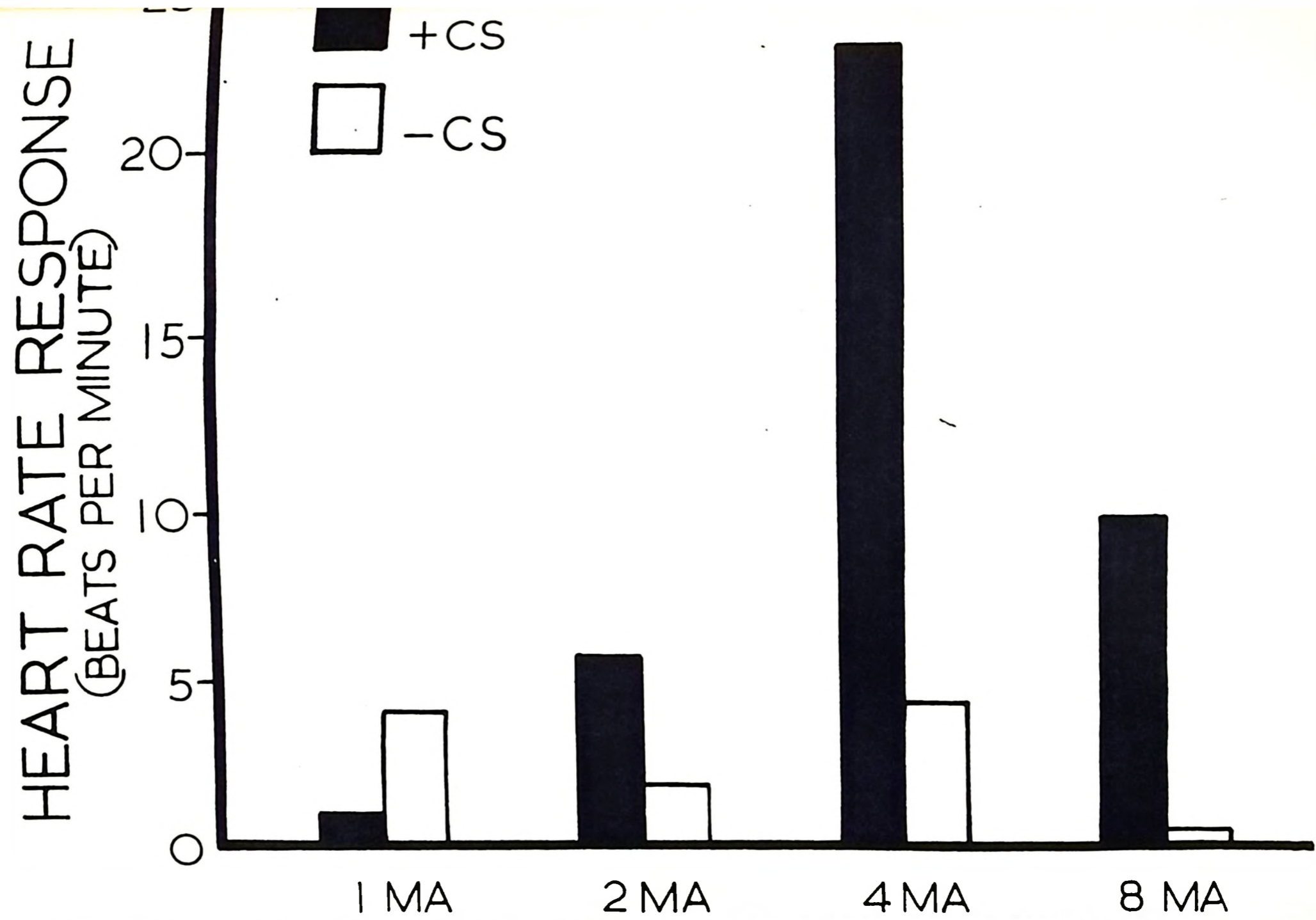
The significant F for the Sign x Group interaction indicates that the differences between the response to the (CS+) and (CS-) are not equal for all shock groups. The results are shown in Graph D.

Insert Graph D

As can be seen, the four and eight ma. groups show the greatest difference in response to the (CS+) and (CS-). In the one and two ma. groups neither the response to the (CS+) nor to the (CS-) is much above zero. This suggests again that the groups can be divided into two clusters; the four and eight ma. groups which show differential conditioning and the one and two ma. groups which show no conditioning at all, neither simple nor differential. Analysis D_2 supports this conclusion. This is a series of

Insert Analysis D_2

four Duncan's multiple range tests, (Edwards, 10), which compare the mean response to the (CS+) on pre-conditioning trials 1, 4, 1, and the (CS+) and (CS-) of the last ten trials of differential conditioning. In the four and eight ma. groups the mean response to the (CS+) at the end of discrimination is significantly greater than both the mean for the (CS-) and the mean of the pre-conditioning trials, indicating that both groups have discriminated and that they have conditioned to the (CS+). The lack of any significant differences for the one and two ma. groups means that no significant discrimination or conditioning has taken place in these groups. That the response to the (CS-) for each group is not significantly greater than the pre-conditioning response for that group indicates that the



Graph D

Average magnitude of the conditioned response to the CS+ and CS- for the four shock groups on differential conditioning trials 31-40

ANALYSIS D₂

DUNCAN'S MULTIPLE RANGE TESTS OF MEANS PER-CONDITIONING TRIALS

1, 4, 1, DIFFERENTIAL CONDITIONING (CS+) AND (CS-) TRIALS 31-40

1 ma. Group

Trials Means	Pre .62	CS+ .99	CS- 4.04	Shortest Significant Ranges
Pre	0	.37	3.42	R2 = 5.82 R3 = 6.10
CS+		0	3.05	
CS-			0	
	Pre	CS+	CS-	

2 ma. Group

Trials Means	CS- 1.97	Pre 2.37	CS+ 6.01	Shortest Significant Ranges
CS-	0	.40	4.04	R2 = 6.26 R3 = 6.55
Pre		0	3.64	
CS+			0	
	Pre	CS+	CS-	

ANALYSIS D₂ CONTINUED

4 ma. Group

Trial Means	Pre 2.68	CS- 4.30	CS+ 23.18	Shortest Significant Ranges
Pre	0	6.98	25.86*	R2 = 16.11 R3 = 16.87
CS-		0	18.88*	
CS+			0	
	Pre	CS-	CS+	

8 ma. Group

Trial Means	CS- .48	Pre 1.71	CS+ 9.94	Shortest Significant Ranges
CS-	0	1.23	9.46*	R2 = 5.46 R3 = 5.71
Pre		0	8.23*	
CS+			0	
	Pre	CS-	CS+	

response to the (CS-) is not greater than that present prior to conditioning.

CHAPTER FIVE

DISCUSSION

The results, so far as simple conditioning are concerned, are clear cut. The two highest shock intensities employed (4 and 8 ma.) produced reliable conditioning of the cardiac response, but the two lowest intensities (1 and 2 ma.) did not. There was no significant difference in the magnitude of response between the 4 and 8 ma. groups, which suggests that the response to 4 ma. may already be asymptotic. This conclusion does not seem unlikely, in the light of other studies of the effects of shock intensity.

The failure to obtain reliable conditioning with 1 and 2 ma. may seem surprising, because in rats a conditioned emotional response can be elicited with intensities at least as low as .50 ma. (1). There are several possible reasons for this lack of conditioning. It may be that shock intensities below 2 ma. are not very traumatic in the case of dogs. Brush (6) has found difficulty in conditioning avoidance behavior in dogs with shock intensities below 2.1 ma. It may also be that the level of noxious background stimulation produced by the tracheal tube and curarization is more intense than the stimulation produced by the 1 and 2 ma. shock. Budylin and Levshunova (7) have shown that conditioning is unstable when the background level of aversive stimulation is high.

In general, however, these results are quite in accord with the data presented in our earlier review of the literature. There is still

CHAPTER FIVE

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In general, however, these results are quite in accord with the data presented in our earlier review of the literature. There is still

no evidence to suggest that, in simple Pavlovian conditioning, the function relating US intensity and level of learning might be of the inverted U shape. The failure, in the present experiment, to obtain evidence for a U shape can scarcely be attributed to a failure to study sufficiently high shock intensities. Preliminary observations indicated that 8 ma., our highest intensity, was close to the lethal level.

The results of our study of differential conditioning are somewhat more difficult to interpret. The theoretical conclusions to which one is led will be influenced by how one chooses to define "degree of discrimination". We have followed Spence in choosing to focus on the difference in the subject's responses to CS+ and to CS-. If one does this mechanically, it is true that the 4 and 8 ma. groups show a greater difference between their CS+ and CS- responses than do the 1 and 2 ma. groups. This might seem to support Spence's notion that, at least up to some asymptotic value, degree of differential conditioning should improve with US intensity. The difficulty, of course, is that the small difference between CS+ and CS- responses of the low US intensity groups is attributable to the fact that they are simply not responding to either CS! It seems unreasonable to talk about a low degree of discrimination, when simple conditioning itself has not taken place. Thus, so far as Spence's theorizing is concerned, the most reasonable conclusion seems to be that, contrary to Spence's formal equation, of the two groups which did condition, there is no difference in degree of discrimination. Of course, if Spence's equation were modified to incorporate an asymptotic level of US intensity, it could well be that 4 ma. is already asymptotic.

In any event an exhaustive analysis of the data shows that no matter what index of degree of discrimination is employed, it is clear that the 4 and 8 ma. groups do not differ in this respect. Thus, there is no evidence in our data to justify extending the Yerkes-Dodson Law to Pavlovian differential conditioning. In this respect, our study agrees with the earlier study on differential eyelid conditioning in humans (22).

However, it should be remembered that the Yerkes-Dodson Law asserts that degree of discrimination will vary both with US intensity and with ease of discriminability of the CS's involved. Indeed, the point along the US intensity dimension at which the inflection of the inverted U will occur is said to vary with degree of difficulty of the discrimination. It is interesting to note that both our study and that of Runquist, Spence and Stubbs (22) (the only two relevant studies), employed pairs of CS's which were very easily discriminable. We utilized, with dogs, tones of 400 and 4,000 c.p.s.; Runquist, Spence and Stubbs used, with humans, tones of 500 and 5,000 c.p.s. Thus, it remains conceivable that, had we employed two more similar CS's, we might have obtained evidence for the Yerkes-Dodson effect. A convincing demonstration that the Yerkes-Dodson Law is not applicable would require a series of studies employing pairs of CS's of varying degrees of similarity.

We cannot, of course, prove the null hypothesis. However, if it should be the case that the Yerkes-Dodson Law does not apply to differential Pavlovian conditioning, there is at least one obvious theoretical rationale. When a very intense noxious US is employed, gross motor responses are inevitably elicited from the subject. These may well interfere with the

execution of precise, adaptive responses. This would suggest, then, that the failure of discrimination sometimes obtained when an intense US is employed is not "central" or "perceptual", but a kind of gross motor disorganization. This, of course, would also mean that the Yerkes-Dodson effect could be obtained only when the response being studied is an operant. This last suggestion is not inconsistent with any known empirical data.

We have in any event to conclude that there is still no evidence to suggest that the Yerkes-Dodson Law is applicable to Pavlovian differential conditioning. The data on the problem remain consistent in this respect: the Yerkes-Dodson effect has never been demonstrated in a Pavlovian conditioning situation, simple or differential. Studies of operant discrimination seem invariably to produce the effect, while studies of simple operant responses only do so occasionally.

SUMMARY

This thesis was concerned with the effects of US intensity (electric shock) upon the development of the conditioned cardiac response, and upon the differential conditioning of this response. Four groups of seven dogs each were trained under four intensities of shock while paralyzed by d-tubocurarine chloride. The results of simple conditioning indicated no significant conditioning in the groups receiving one and two ma. shock. The groups receiving four and eight ma. shock showed significant conditioning, but there was no difference between them. The results of differential conditioning were difficult to interpret. There was no significant difference in degree of discrimination between the two groups which did condition; in view of the failure to obtain conditioning in the one and two ma. groups it was unreasonable to compare them with the other two groups for "degree of discrimination".

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APPENDIX 1

Simple Conditioning

Trial	Sign
1	+
2	+
3	+
4	+
5	+
6	+
7	+
8	+
9	+
10	+

Differential Conditioning

Trial	Sign	Trial	Sign
1	-	21	+
2	-	22	+
3	-	23	-
4	-	24	-
5	+	25	+
6	+	26	-
7	-	27	-
8	+	28	-
9	-	29	+
10	+	30	-
11	-	31	-
12	+	32	+
13	+	33	+
14	+	34	+
15	-	35	-
16	-	36	-
17	-	37	-
18	+	38	+
19	-	39	-
20	-	40	-

APPENDIX 2

ANALYSIS OF VARIANCE OF PRE-CS RATES PRE-CONDITIONING TRIALS

1, 4, 1, CONDITIONING TRIALS 8, 9, 10, DIFFERENTIAL CONDITIONING

TRIALS 8, 9, 10, AND 38, 39, 40

Source	SS	df	MS	F	P
Between Subjects	105,070.52	27			
Groups	21,604.95	3	7,201.65	2.07	> .05
Error	83,465.57	24	3,477.73		
Within Subjects	41,968.45	84			
Trials	10,763.27	3	3,587.76	9.34	< .01
Trials x Group	3,557.78	9	395.31	1.03	> .05
Error	27,647.40	72	383.99		



Appendix 3

Figure 1A. Photograph of apparatus used to contain dog during conditioning