THE EFFECTS OF PUNISHMENT INTENSITY AND STIMULUS CHARACTERISTICS ON DISCRIMINATIVE ESCAPE CONDITIONING

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by

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SCOPE AND CONTENTS:

Punishment intensity and stimulus characteristics were manipulated in a two-choice visual discrimination task using a combined escape-punishment procedure. Under some conditions an inverted U-shaped function was found relating punishment intensity and discrimination performance. There was some indication that optimum punishment intensity was determined by the relative salience of specific features of the discriminative stimuli, rather than simply by task difficulty as suggested by the Yerkes-Dodson Law. In all punishment conditions it was found that discrimination performance was superior when the negative stimulus was relatively more salient or contained the only distinctive feature. The results were interpreted as indicating that discrimination in escape or escape-punishment procedures develops primarily through control by the negative stimulus.

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CHAPTER ONE

Introduction

Many of the patterns of behaviour learned by both man and lower animals are relatively simple, and seem to be learned rapidly. But, even for the most simple response, the animal must learn when and where the behaviour is appropriate, that is, when to produce and when to withold a specific response. The signals which indicate when it is appropriate to make a particular response are usually provided by the external environment. The animal, therefore, must learn to discriminate between various environmental cues, and to associate specific cues with specific responses. This process is called discrimination learning, and is, obviously, an important part of the study of learning.

The purpose of the research described in this thesis is to study visual discrimination learning by rats, as controlled by aversive stimulation. The aversive stimulus most commonly employed in such experiments is a mild electric shock delivered through the grid floor of the apparatus. In a typical visual discrimination experiment, the rat is placed in a small experimental chamber and required to respond to one of two visual stimuli. For example, a black triangle and a black circle, a few inches apart, might be presented against a white background on one wall of the chamber. One of these discriminative stimuli would be designated as the positive stimulus (S+). A response to that stimulus, a correct response, would be reinforced by the termination of the aversive stimulus. The other stimulus would be designated the negative stimulus (S-). A response to it, an incorrect response, would not be reinforced by termination of the aversive stimulus.

The procedure outlined above is termed simultaneous discrimination learning, since the animal is required to respond to one of two simultaneously presented visual stimuli. This may be contrasted with a successive discrimination procedure, where only a single response is possible, and where the response must be produced or witheld depending on which of two stimuli is present at a given moment. The present research, and most of the earlier research to be reviewed in the following section, involved the simultaneous discrimination procedure.

There are a number of ways in which aversive stimulation can affect behaviour in a simultaneous discrimination task. The first, and most obvious, is the motivating effect of the aversive stimulus. In the presence of an aversive stimulus such as electric shock, the animal becomes highly aroused and certain characteristic defensive and aggressive behaviour patterns occur. Second, the frequency of occurrence of specific instrumental responses can be manipulated by making changes in the aversive stimulus contingent upon those responses. There are a variety of possible contingencies that can be arranged between responses and changes in the aversive stimulation. If an aversive stimulus is already on when a response occurs, one can (a) increase the stimulus intensity, (b) decrease its intensity (in the extreme case, turn it off), or (c) continue it unchanged. The first of these is usually called a "punishment" contingency, and the second an "escape" contingency. The third possibility, as we shall see later on, is difficult to classify. If an aversive stimulus is not already on when a response occurs, there is only one choice. One can turn it on following the response, or not. Turning it on obviously is a "punishment" contingency. The experiments on discrimination learning which have employed these "escape" and "punishment" contingencies fall into three procedural categories which can be labelled reward-punishment, escape, and escape-punishment.

In the reward-punishment category, responses to S+ are usually reinforced by some positive reward such as food, and responses to S- are followed by the onset of aversive stimulation. For example, while a response to S+ in a simple two choice maze might lead to a goal box containing food, a response to S- might lead to a goal box with an electrified grid floor. This type of procedure was used in some of the earliest experiments on the effects of aversive stimulation on discrimination learning (Hoge & Stocking, 1912; Warden & Aylesworth, 1927). Another less obvious reward-punishment procedure involves delivering first a brief shock and then food following a response to S+, while neither reinforcement nor punishment follow a response to S- (Fowler & Wischner, 1969; Muenzinger, 1934; Wischner, 1947).

In the escape learning category, behaviour is aversively motivated; that is, the aversive stimulation is turned on at some arbitrary point in time. A response to the S+ results in termination of the aversive stimulation, while a response to the S- is followed by continuation of the aversive stimulation. There have been only a few visual discrimination experiments of this type (Annau, 1963; Hammes, 1956; Marriott & Russel, 1969).

The third category consists of a combination of escape and punishment procedures. As in the escape category, the aversive stimulus is turned on at some arbitrary point in time. A response to S+ results in termination of aversive stimulation, while a response to the S- would be punished, either by presentation of another aversive stimulus, or by an increase in the intensity of the aversive stimulus already present. The research reported in this thesis was the first to intentionally use such a procedure; however, several earlier experiments should probably be included in this combined category (Broadhurst, 1957; Cole, 1911; Dodson, 1915, 1918; Yerkes & Dodson, 1908).

The distinction between a discrimination procedure based on escape learning alone, and a procedure involving combined escape and punishment is open to question. If an incorrect response is followed by the addition of some new aversive stimulus, or a distinct increase in the intensity of an already present stimulus, then punishment is obviously involved. If there is no change in aversive stimulation following an incorrect response, we might be tempted to conclude that no punishment has occurred. On the other hand, the continued presence of the aversive stimulation following an incorrect response may have punitive effects on the incorrect response. In short, it is not clear whether the operative factor in punishment is the onset of, or increase in, aversive stimulation, or simply the continued presence of an aversive stimulus following a response. Indeed, it has been argued previously (Bolles & McGillis, 1968) that escape learning develops not through reinforcement of the correct response, but through suppression of all alternative responses due to the punishing effects of the continued presence of shock. Therefore, it might be that the escape category should be considered as a member of the escape-punishment category. The distinction will be maintained, however, in the present discussion since it focuses our attention on certain important issues.

It should be kept in mind in reading the following discussion of research on the reward-punishment, escape, and escape-punishment categories of discrimination learning that other categories of research which employ aversive stimulus-control have been omitted. There are many non-discriminative experiments which deal with punishment (see reviews by Azrin & Holz, 1966; Church, 1963; Solomon, 1964) escape (Bolles & McGillis, 1968; Dinsmoor, 1958), and combined escape and punishment (Brown, 1969). These experiments will not be discussed in the detailed historical review to follow, except insofar as they illuminate the discussion of discriminative control. Also excluded on the same basis are those experiments on visual discrimination which employ positive reinforcement alone (Hearst, 1969; Honig, 1969; Jenkins & Sainsbury, 1969), as well as those experiments (Rescorla, 1969) which involve stimulus contingent (classical conditioning) rather than response contingent (operant conditioning) presentation of aversive stimulation. Finally, the escape and escape-punishment categories will be discussed in the greatest detail, since these are the procedures that were employed in the present research.

Reward-Punishment Contingencies in Discrimination Learning

Both common sense and the results of non-discriminative research (Azrin, 1956; Church, 1969) suggest that the primary function of punishment is to suppress responses which it follows, and the findings on the effects of punishment for responses to the S- in simultaneous discrimination are generally consistent with this point of view. Early experiments (Hoge & Stocking, 1912; Warden & Aylesworth, 1927) compared discrimination using the reward-punishment procedure with a procedure with food reward for correct responses and no punishment for errors (a reward-alone condition). They found fewer errors and more rapid discrimination for the reward-punishment condition than for the reward-alone condition.

Recent experiments (Curlin & Donahoe, 1965; Wischner, Fowler & Kushnick, 1963) have varied the intensity of punishment for errors in simultaneous discrimination learning tasks, and found that the speed of discrimination learning was directly related to punishment intensity.

Although experiments involving punishment for discrimination errors indicate that punishment functions as a response inhibitor, research employing punishment for correct responses has shown that punishment may also have other effects. The first indication of this was provided in an experiment by Muenzinger (1934) in which he compared the speed with which three groups of rats learned a simultaneous brightness discrimination. One group received food reinforcement for correct responses and no punishment for errors, a second group received reinforcement for correct responses and punishment for errors, and a third group received both reinforcement and punishment for correct responses. Surprisingly, he found faster learning for the conditions in which reinforcement and punishment were combined; it did not matter whether the punishment was delivered for the correct or the incorrect response. Analysis of the basis of this finding has been the aim of much of the research on punishment in discrimination learning since that time (Muenzinger & Powloski, 1951; Fowler & Wischner, 1965; Wischner, 1947; Wischner, Fowler & Kushnick, 1962).

In a recent review of research on the problem, Fowler and Wischner (1969) argue that punishment has both "an avoidance-producing and distinctive cue effect;" that is, it not only suppresses behaviour associated with it, but also acts as a cue which increases discriminability of stimulus alternatives. They cite evidence which indicates that both shock intensity (Fowler, Goldman, & Wischner, 1968) and discrimination difficulty (Fowler & Wischner, 1965) affect the relative importance of the different functions of punishment.

With an easy discrimination task, the cue function of punishment is thought to be of little importance, and the avoidance function predominates. Thus with a simple black-white discrimination task, it was found (Wischner, Fowler & Kushnick, 1963) that the number of errors to a criterion of learning was an increasing monotonic function of intensity of punishment for correct responses, but a decreasing monotonic function of intensity of punishment for incorrect responses. With a more difficult discrimination task, the cue function is thought to assume greater relative importance, and at least at low shock intensities it should predominate over the avoidance function. Using a more difficult bright-dim discrimination task, Fowler, Goldman, and Wischner (1968) found that in comparison to a control group receiving reinforcement alone, learning was faster with the addition of low intensity punishment for correct responses, but slower with high intensity punishment for correct responses. Curlin and Donnahoe (1965) found the same results with a similar procedure.

It is clear from this brief review of the reward-punishment literature, that three variables interact to determine the effects of punishment on discrimination performance. The punishment contingency (for example, punishment for correct or incorrect responses) the stimulus properties (discrimination difficulty), and the intensity of the aversive stimulation must be specified.

Research involving the escape and combined escape and punishment procedures for aversive control of discrimination, has manipulated the same three variables, with the major focus on intensity of aversive stimulation. Since virtually all of the experiments in these two categories have been concerned with a common theoretical issue, they will be discussed together.

Escape and Escape-Punishment Contingencies in Discrimination Learning

Although there have been relatively few experiments employing these procedures, they divide into two groups on historical as well as procedural grounds. The earliest experiments (Cole, 1911; Dodson, 1915, 1918; Yerkes & Dodson, 1908) should probably be classified as examples of the combined escape and punishment category, although they nominally involved punishment alone. These experiments all varied the intensity of electric shock delivered as punishment for for incorrect responses, but there was no explicit reinforcement provided for correct responses. Evidently reinforcement for the correct response came through escape from the maze, which had become aversive through association with punishment. Another possible basis for the reinforcement for correct responses derives from the report by Yerkes and Dodson that they pushed their animals to the choice point with a piece of cardboard. One recent author (Annau, 1963, 1968) speculates that this procedure was sufficiently aversive in itself to motivate escape responding.

Following the early experiments there was a gap of nearly 40 years before the publication of further research involving aversively motivated discrimination learning (Annau, 1963; Broadhurst, 1957; Hammes, 1956). Whereas the early experiments involved explicit punishment contingencies the recent experiments involved explicit escape contingencies. Two of the recent experiments (Annau, 1963; Hammes, 1956) varied the intensity of electric shock from which rats could escape. The other recent experiment (Broadhurst, 1957) used anoxia as the aversive stimulation, by requiring rats to swim an underwater maze. The intensity of the aversive stimulation was varied by restraining the animals underwater for different lengths of time before releasing them to swim the maze.

Although on a procedural basis these recent experiments would be classified as falling in the escape category, they also involved the possibility of adventitious punishment for errors, as a result of the continuation of the aversive stimulation following responses to S-. The main difference, then, between these two groups of experiments is not that only the escape contingency occurred in one, and only the punishment contingency occurred in the other; rather, it is that only the punishment contingency was carefully explored in the early experiments, and only the escape contingency was carefully explored in the later experiments. It is possible that both escape and punishment contingencies were involved in most, if not all, of these experiments.

A common factor relating these two groups of experiments is that they have all been concerned with a hypothetical relationship between the intensity of aversive stimulation, task difficulty, and speed of learning, that has commonly been referred to as the Yerkes-Dodson Law. One recent writer (Broadhurst, 1959) describes the principle of the law as a "decrease in the optimum motivation with increasing difficulty of the learning task." The concept of an optimum motivation intensity is fairly common in psychology. Probably the best known recent example is the neurophysiological model advanced by Hebb (1955) and Malmo (1959), which postulates an inverted U-shaped function relating level of motivation and performance. Increasing motivation from low levels should produce improved performance, until the optimum level is achieved. Past this point, further increases in motivation should lead to a deterioration in performance.

The Yerkes-Dodson Law, however, goes beyond simply postulating an optimum motivation level for discrimination learning, and states as well that the more difficult the discrimination, the lower the optimum point will be. The results of the original Yerkes and Dodson (1908) experiment on which the two postulates are based are reproduced in

Figure 1. Inspection of the figure seems to support the contention that optimum stimulation intensity is inversely related to task difficulty. (In all of the experiments discussed here task difficulty is defined by the brightness differential between S+ and S-). The difficult discrimination appears to have lowest optimum point, while the optimum point for the easy discrimination appears to be the highest shock intensity used. In addition several other authors (Broadhurst, 1957; Dodson, 1915, 1918; Cole, 1911) claim to have data supporting the original Yerkes and Dodson conclusions.

In spite of this apparent support, and the wide acceptance of the Yerkes-Dodson Law in the literature (Cofer & Appley, 1964; Fantino, Kasden & Stringer,1970), two recent authors (Annau, 1963, 1968; Brown, 1965) who review the literature on the topic conclude that the essential features of the law have yet to be confirmed. In order to clarify these conflicting points of view, it is best to consider the two aspects of the Yerkes-Dodson Law separately. The law postulates first, that for any given level of task difficulty there is an optimum intensity of aversive stimulation for most rapid learning; and second, that the optimum intensity decreases with increasing task difficulty. It is the second of these aspects that has the least experimental support. None of the experiments which varied task difficulty (Annau, 1963; Broadhurst, 1957; Cole, 1911; Dodson, 1915; Yerkes & Dodson, 1908) showed clear differences

Figure 1. Mean number of trials to a criterion of 30 consecutive correct responses as a function of punishment intensity in arbitrary units.

in optimum point with differences in task difficulty. In the two early experiments where the authors claimed differing optimum shock punishment intensities (Dodson, 1915; Yerkes & Dodson, 1908) examination with modern statistical techniques (Annau, 1963; Brown, 1965) indicated the differences were not reliable. The only recent author to claim evidence for differing optimum points (Broadhurst, 1957) based his argument on a significant interaction found between task difficulty and duration of anoxia (produced by restraining rats underwater for different periods of time before the beginning of a trial). However, Annau (1963) and Brown (1965) both point out that the interaction resulted from a significant intensity effect in one group and insignificant effects in two other groups, and provides no evidence for differing optimum points.

Findings have been mixed also with respect to the first aspect of the Yerkes-Dodson Law, which postulates an optimum aversive stimulus intensity for any given level of task difficulty. There is no question that for some tasks a clear optimum aversive stimulation intensity has been shown, but an optimum stimulation intensity has not been demonstrated for all tasks. In both the original Yerkes and Dodson (1908) experiment and in Broadhurst's (1957) experiment, one group of animals demonstrated an inverted U-shaped function relating aversive stimulus intensity and performance on a discrimination learning task, as would be expected from a function with an optimum point in the middle of the range of intensity values tested. Two additional groups in each of these experiments, however, showed no significant effects of aversive stimulus intensity on speed of learning. Nonsignificant intensity effects were also found in other experiments (Dodson, 1915, 1918). An increasing monotonic function relating performance and shock intensity was obtained by Cole (1911), while decreasing monotonic functions were obtained by Annau (1963) and Hammes (1956). Taken together, the various experiments provide evidence that differing optimum aversive stimulation intensities do occur in some discrimination procedures, but they fail to indicate the variables that determine whether an optimum point will occur in a given situation, and that determine the value of the optimum intensity. It seems likely that difficulty of task does have some role, but it is as yet impossible to specify that role.

An approach that might help to clarify this confused situation is to relate the specific contingencies involved in the delivery of the aversive stimulation to the experimental findings on the effects of variation in the intensity of aversive stimulation. On this basis these experiments can be divided into two categories. Two of the experiments (Annau, 1963; Hammes, 1956) showed only decreases in performance as shock intensity was increased. Both of these were experiments which varied the intensity of the shock from which the rat escaped. The remaining experiments showed a variety of effects in comparisons between groups trained at different intensities of aversive stimulation. Increased aversive stimulation intensity resulted in one or more of the following: (a) improved performance (Cole, 1911), (b) improved performance at medium intensities followed by a decrement at higher intensities (one group in Yerkes & Dodson, 1908; one group in Broadhurst, 1957), (c) no effect on performance (two groups in Yerkes & Dodson, 1908; two groups in Broadhurst, 1957). With one exception (Broadhurst, 1957) these latter experiments were in the escape-punishment category and varied the intensity of the punishing stimulus. Although the explicit procedure in the Broadhurst experiment involved varying the intensity of the anoxia from which the rats escaped, the delay in escape from the underwater maze resulting from an incorrect response would mean that a response to S- would be followed by an increase in the intensity of the aversive stimulation. Thus the Broadhurst experiment, as well, could be classed as an escape-punishment procedure in which both intensity of the aversive stimulus from which the rat escaped, and the intensity of the punishing stimulus were varied.

This division in terms of results and procedures indicates that the relationship between aversive stimulation intensity and performance depends on whether one varies the intensity of the aversive stimulus from which the subject escapes, or varies the intensity of the punishing stimulus, or both. Therefore the escape and escape-punishment procedures cannot be regarded as equivalent, as was apparently done by some authors (Broadhurst, 1957, 1959). This lack of differentiation between procedures may have occurred because it was assumed that the only important effects of variations in aversive stimulation intensity were in terms of general motivation. That this is not the case has clearly been demonstrated in the research reviewed earlier on the effects of punishment in appetitively motivated discrimination. Aversive stimulation has multiple functions, whose effects on performance differ with the contingencies between responses and the aversive stimulation, as well as with the intensity of the motivating stimulation and the difficulty of the discrimination.

The two experiments which varied the intensity of the shock from which the rats escaped were consistent; the remaining experiments which varied punishment intensity were not. The unpredictable nature of the relationship between punishment intensity and performance in experiments dealing with the Yerkes-Dodson Law could be a result of interaction among the different effects of motivation level, escape contingencies, and punishment contingencies. For example, performance might be a decreasing function of the shock intensity from which a subject escapes because of the interfering effects of high motivation on performance, as suggested by Annau (1963) and Hammes (1956), and an increasing function of intensity of punishment for errors, as suggested by the appetitively based experiments. If this were so, a combined escape and punishment procedure in which both escape and punishment intensities were varied might show optimum performance at some middle aversive stimulation intensity value, depending on the relative importance of the motivational and escape components of the procedure on the one hand, and the punishment components on the other. Therefore, clearer specification of functions of aversive stimulation in discriminative escape procedures than has been typical in the past will be necessary to determine whether or not such interactive processes were the basis of the results of previous experiments. In addition, different functions were obtained over the same range of shock intensities in a given experimental situation when discrimination tasks which differed in difficulty were employed. Therefore it is necessary to deal with the interaction between the properties of the discriminative stimuli and aversive stimulus manipulations in more detail.

Stimulus Effects in Escape and Escape-Punishment Discrimination Learning

Difficulty of discrimination appears to be a determinant of the relative importance of the suppressive and cue functions of punishment for correct responses in appetitively based discrimination. Also, the Yerkes-Dodson Law assigned discrimination difficulty a role in the determination of optimum aversive stimulus intensity, and the shape of the function relating aversive stimulus intensity and performance. In all of the experiments considered to this point, brightness discrimination tasks were used, and discrimination difficulty was defined in terms of the difference in brightness between S+ and S-. A recent experiment (Annau, 1963) on discriminative escape conditioning provided evidence that properties of the discriminative stimuli, other than simply the degree of difference between them, determine the way in which they affect discriminative control by aversive stimulation.

Annau employed a brightness discrimination task, as had all the earlier experiments, but unlike any of the earlier experiments, he used a control for possible stimulus preferences. One half of his animals were trained to respond to the brighter of the two stimuli as S+, while the other half were trained to respond to the dimmer stimulus as S+. *In all of the earlier experiments the brighter of the two stimuli was S+*.

Annau trained his rats in a black discrimination apparatus equipped with two grey escape doors separated by a barrier. A light above one door or the other provided the discriminative cue. Between trials the apparatus was diffusely illuminated, but during a trial the stimulus light provided the only illumination. Difficulty of the discrimination was varied by using two different intensities of illumination over the lighted door. For half the rats the lighted door was the positive stimulus, while the unlighted door was the positive stimulus for the other half of the rats.

He found that the light-positive animals made fewer errors during the early stages of training than did the dark-positive animals in all shock intensity and discrimination difficulty conditions. This stimulus effect, however, was restricted to the first 20 training trials, after which there was no further significant difference between stimulus conditions until after 60 training trials. At the 60-trial point a stimulus effect reappeared in certain groups of animals, but this time in the opposite direction to that found early in training. Light-positive animals now made more errors than dark-positive animals, and continued to do so until training was terminated at 120 trials.

These results make it clear that the effect of the discriminative stimuli is much more complex than has been suggested by previous experiments. More than the simple difference in intensity between the S+ and the S- is involved. Not only is the difficulty of discrimination, as determined by this difference important, but also the choice as to whether the more intense stimulus is the S+ or the S-. Because this latter issue has not been considered before, the possible explanation for this effect will be discussed next.

Annau had no convincing explanation for these stimulus effects. He suggested that the initial superiority of light-positive animals may have been a result of generalization from the presence of a light during the "safe" intertrial interval. Since the stimulus light was always present during shock, there seems no reason why the light stimulus should be more of a sign of safety than a sign of danger.

Since the later superiority of the dark-positive rats was significant only in the groups with the most intense stimulus light, Annau suggested that the smaller number of errors by the rats for whom the light was the S- may have resulted because of inherent aversiveness of bright lights. Considering the early superiority of light-positive animals in both light intensity conditions, this hypothesis also seems unlikely.

Although there has been no other evidence published on the role of stimulus characteristics in aversively motivated brightness discrimination tasks, there have been a number of experiments analyzing stimulus effects in appetitively motivated brightness discrimination tasks. Of these, the ones most directly relevant to the present discussion have dealt with the stimulus intensity dynamism effect (see review by Gray, 1965). The term stimulus intensity dynamism was first used by Hull (1947, 1949) to describe a positive correlation between the intensity of a stimulus and the magnitude of a resulting response. As examples Hull (1949) cited a number of unpublished experiments by students in his laboratory, one of which produced results quite similar to those obtained by Annau during early trials of training. In an experiment by Spence (Hull, 1949), rats were trained in a food reinforced black-white discrimination, using an apparatus similar to that used by Annau. It was found that rats responding to the more intense white stimulus made fewer errors than those responding to the black stimulus, which is the same result observed during the early trials of training by Annau. Replication of these conditions by Nygaard (1958) produced identical results.

Although the initial superiority of the light-positive animals in Annau's experiment seems to be an example of what has previously been termed a stimulus intensity dynamism effect, the later reversal in performance that led to the relative superiority of the dark-positive animals late in training did not occur in any of the appeitively based experiments on this phenomenon. This suggests that the superiority of dark-positive animals late in training was a consequence of Annau's use of aversive control of discrimination.

As we pointed out earlier, none of the previous experiments on stimulus intensity dynamism in discrimination learning involved contingencies of aversive stimulation, but a possible interpretation of Annau's results is suggested by another series of experiments which led to an account of a similar reversal in differential response tendencies early and late in training in terms of an aversive stimulation contingency. As one of a series of experiments intended to test predictions of the Pavlovian theory of generalization gradients, Lashley and Wade (1946) trained rats on a jumping stand to respond to a white circle, 8 cm in diameter, in preference to a black square. This same white circle was then used in a second discrimination, as either the S+ or the S- when compared to a second white circle 5 cm in diameter. Lashley and Wade argued that according to a Pavlovian theory of generalization, the animals for which the same stimulus was the S+ in both discriminations should show most rapid learning. As it turned out, those animals which were trained in the second discrimination with the initially positive stimulus used as a negative stimulus learned most rapidly, a result apparently inconsistent with either the presence or absence of generalization gradients.

Grice (1948, 1951) argued that Lashley and Wade's findings were a consequence of the use of a correction procedure with a jumping stand. With a correction procedure the animal must make a correct response to terminate a trial, so that more than one error is possible per trial. Also, with the type of jumping stand used by Lashley and Wade, errors resulted in the rat crashing into a locked door and falling into a net, presumably an aversive consequence. Assuming that the rats start the second discrimination stage with a tendency to respond to the formerly positive stimulus, those animals for which that stimulus is now negative would make a greater number of errors and receive more punishment, and so would learn more quickly to inhibit responses to the negative stimulus.

As support for this interpretation, Grice repeated the Lashley and Wade experiment in a runway apparatus with a non-correction procedure and no source of punishment for incorrect responses. With these changes the findings were reversed, and the second discrimination was learned more rapidly by those animals for which the same stimulus was positive in both stages, as would be predicted from the concept of generalization of excitation.

The points of resemblance between Annau's experiment and that of Lashley and Wade are that both involved a correction procedure, and errors in both cases had potentially aversive consequences. Although Annau used no specific punishment contingency, it was pointed out previously that the continuation of aversive stimulation after an incorrect response may be punitive to some degree. In Annau's experiment the group that eventually showed superior discrimination performance initially made more errors, and the same is assumed to be true for the Lashley and Wade experiment. It therefore seems possible that the dark-positive rats in Annau's experiment made fewer errors late in training because they learned to inhibit responses to light early in training. Although the initial superiority of the light-positive animals may have been an example of a stimulus intensity dynamism effect, in combination with the use of aversive stimulation, the eventual consequence of stimulus intensity may have been superior performance of dark-positive animals late in training.

Three hypotheses have been advanced in the literature to account for the stimulus intensity dynamism effect. They will be outlined briefly here, and discussed more fully in Chapter II after the presentation of the relevant data from the present research. For identification they will be referred to as the stimulus intensity hypothesis (Hull, 1949), the contrast hypothesis (Logan, 1954; Perkins, 1953), and the attention hypothesis (Nygaard, 1958).

Hull (1949) attributed the superiority of animals with the brightest stimulus as S+ in a discrimination task as being due to an energizing effect of stimulus intensity on a response to that stimulus. He postulated stimulus intensity dynamism (V) as a theoretical construct which interacts in a multiplicative fashion with habit strength and drive to determine response strength.

According to the contrast hypothesis (Logan, 1954; Perkins, 1953), the more rapid learning by animals with the brighter stimulus as S+ is due not to the intensity of the stimulus per se, but to its greater contrast to the dark background of the apparatus. Responses to the background are quickly extinguished, and the resulting inhibition should generalize more to the dimmer of the two discriminative stimuli, leaving a greater net response strength to the brighter stimulus. This should facilitate learning with a bright S+, and interfere with learning with a bright S-.

The attention hypothesis (Nygaard, 1958) also considers contrast the important aspect of a bright stimulus, but as a determinant of attention rather than response tendencies.[1] Attention theories (see review by Mackintosh,

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[1] Actually, Nygaard did not use the term attention, but referred to an orienting response (Wycoff, 1952). This is a more "conservative" concept than attention, implying peripheral receptor adjustment rather than a central process as is usually implied by the use of the term attention. Recent authors (e.g. Hilgard & Bower, 1966) suggest the distinction is unimportant, since it can seldom be maintained on empirical grounds.

1965) view learning as a two-stage process, wherein animals must learn to attend to the relevant stimulus dimension (i.e. brightness) before they can develop differential response tendencies to values along the dimension. Attention presumably is strengthened through reinforcement, just as any other response. A bright stimulus as S+ would increase the likelihood of an animal attending to the brightness dimension during reinforcement, so attention to the relevent dimension would develop rapidly. With a bright S- and a dim S+, the animal would be more likely to attend to brightness during a non-reinforced response to the S- and so attention to brightness, and consequently discrimination, would be relatively slow to develop.

While all three of these hypotheses appear consistent with the initial superiority of the light-positive animals in the Annau experiment, they differ in their compatibility with the interpretation suggested for the final superiority of dark-positive animals. The interpretation of later superiority of dark-positive animals as resulting from rapid early inhibition of errors, appears readily compatible with either the stimulus intensity hypothesis or the contrast hypothesis, since it would simply mean that initial differential response tendencies must be overshadowed by more rapid learning to inhibit errors in one group. However, the attention hypothesis does not appear to be readily compatible with the hypothesis of more rapid inhibition of errors by the dark-positive animals. If the dark-positive animals perform poorly during early trials because they fail to attend consistently to the relevant stimulus dimension, it does not seem likely that they could learn to inhibit responses to one value along that dimension during the same period of time. Either the attention hypothesis is inaccurate, or the later superiority of dark-positive animals did not result from the greater number of errors made by these animals during the early trials of training.

Although it appears reasonable to assume that the initial superiority of animals in the light-positive groups in Annau's experiment is an example of a stimulus intensity dynamism effect, his results provide no basis for choosing among the alternative hypotheses offered to account for this effect. As well, the interpretation offered for the later superiority of the dark-positive in terms of their performance during the first few trials, must be regarded as highly tentative.

It is clear from the discussion of the data, that a number of questions must be answered in order to understand discrimination learning controlled by aversive motivation and reinforcement. The functions relating shock intensity to performance in experiments which varied the intensity of the shock from which the animals escaped are consistent. Optimum performance occurred just above threshold values. The experiments which varied the intensity of a punishing shock were not consistent. A variety of functions relating punishment intensity to performance was found. One purpose of the experiments described in this thesis was to determine more precisely the factors which control the shape of the latter function. In this respect it is interesting to note that the one recent experiment which found an inverted U-shaped function (Broadhurst, 1957) relating aversive stimulus intensity to performance employed a procedure in which the aversive stimulus from which the subjects escaped increased over time on each trial (anoxia). Yerkes and Dodson (1908) may have carried out a similar procedure inadvertently, if they pushed rats to the choice point more vigorously as the trial progressed. An attempt was made to provide an analogue for these procedures in the first experiment by the following method. Each subject was trained to escape from a shock which gradually increased in intensity. Additional increases in intensity were given following errors in some cases.

In this procedure the intensity of the shock from which the subject escaped was not controlled by the experimenter. It depended on the latency of the correct response. Therefore, the procedure also permitted us to obtain data on the intensity of the shock which the rats required before they made a correct response under different punishment conditions. We could ask, for example, whether high punishment led to higher or lower escape intensities than low punishment. This provided some preliminary data on the interaction between punishment and escape intensities, a problem which is obviously important but has hardly been considered.

The second area in which we were interested was the analysis of the role of the discriminative stimuli. Although attention has been focused on the difference in intensity between S+ and S-, Annau's data indicate the choice as to whether the more intense stimulus is S+ or S- is also important. As was pointed out above, the basis for this latter effect is not clear. One purpose of the present research was to attempt to analyze this effect. Annau carried out research which demonstrated this effect in an experiment in which the intensity of the shock from which rats escaped was varied. As a first step in attempting to deal with this issue we asked whether this stimulus intensity effect would be found in procedures in which punishment for errors is administered, and the intensity of the punishment is varied. Data on these questions are described in the next chapter.

CHAPTER TWO

Experiment I

In this experiment the effects of different intensities of punishment in an escape-punishment situation were explored. In addition, the stimulus characteristics in the development of a brightness discrimination were studied by comparing the effects of having a brighter stimulus as S+ with the effects of having the brighter stimulus as S-.

Method

Since the procedure in this and the following experiments was basically the same, it will be described in detail only for Experiment I. In subsequent experiments changes in this basic procedure will be described.

Subjects: The subjects in this experiment were 24 naive male hooded rats supplied by Quebec Breeding Farms, St. Eustache, Quebec. (The same source of rats was employed in subsequent experiments.) At the time of testing, all rats were at least three months of age, and weighed between 250 and 400 g. During the experiment the rats were kept in single cages and were fed ad lib.

Apparatus: Training was conducted in a perspex box, 9 1/2 in. wide by 12 in. long by 8 1/2 in. deep, with a grid floor of 1/8 in. stainless steel rods set 1/2 in. apart. The walls of the box were lined with aluminum, painted flat black. In the center of one long wall there was a retractible response lever, which was used for simple escape pretraining. On the opposite wall of the box there were two response levers mounted immediately beneath two translucent plastic stimulus display windows, 3 in. high by 2 1/4 in. wide. The stimulus display windows were 4 1/2 in. apart, and midway between them an aluminum barrier projected out 1 1/4 in. from the wall, to prevent the possibility of an animal responding to both levers simultaneously by leaping at the wall sideways.

Escape behavior was maintained by intermittent scrambled AC shock delivered to the grid floor and walls of the apparatus by a Grason Stadler E7110B shock generator. The shock was delivered in one per second pulses of 100 msec duration. Intermittent shock was used because pilot work had shown that it minimized the tendency of animals to freeze in positions which were apparently less painful. Before the start of each escape trial the shock intensity was set to zero, from which point it gradually increased until either a correct response terminated the trial, or a maximum intensity of 1.6 ma was reached.[1] The maximum intensity was reached in

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[1] Shock intensity values given in this thesis were obtained by measuring the voltage drop across a 10,000 Ohm series resistance. A load resistance of 52,000 Ohms was placed across the shock grids while these measurements were made. This load resistance value was selected on the basis of the results of

100 seconds, and shock was then maintained at this level until a correct response occurred.

Annau (1963) and Hammes (1958) reported that optimum performance in a discriminative escape procedure was obtained with shock intensities close to the lower response threshold. However, initial pilot studies with the lever-press escape procedure indicated that response thresholds varied widely during different stages of training, with quite intense shock required to maintain responding during early discrimination trials. The gradually increasing shock allowed the rats to set their own response thresholds, which typically dropped back to relatively low intensities after the first few discrimination trials. The intensity of the shock was controlled and recorded by a Grason Stadler E7110A recording attenuator, with which it was possible to vary the source voltage of the shock between 0 and 350 v (nominal).

In this experiment the rats were trained to discriminate between a rectangle, produced by illuminating a whole stimulus display window, and a vertical line, produced by illuminating a strip 1/8 in. wide down the center of the display window. A criticism (Gray, 1965; Nygaard, 1958) has been made of some of the experiments on stimulus intensity dynamism (Bragiel & Perkins, 1954; Hull, 1949) which

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Campbell and Teghtsoonian (1958), as well as observations from pilot studies, as being representative of the resistance offered by rats to the typical current values operative in these experiments.

used light-dark discrimination tasks. Nygaard (1958) suggests that animals may be unable to discriminate the dark discriminative stimulus from the background and the apparent stimulus intensity effects may simply be due to inappropriately directed responses to the dark stimulus. The line-rectangle discrimination in the present experiment assured that both discriminative stimuli were discriminable from the background, and yet maintained the brightness differential between the stimuli. The line discriminative stimulus was produced by illuminating a 28 v DC light bulb, which was screened so as to shine only on a vertical strip down the center of the stimulus display panel. The rectangle discriminative stimulus was produced by illuminating the center bulb plus one on either side of it, so that the whole stimulus display panel was illuminated. The line and rectangle stimuli varied between the left and right display windows according to a Gellerman series (Gellerman, 1933). The room was darkened except for a 25 w red bulb in a ceiling fixture, so that the discriminative stimuli were clearly visible.

The experiment was programmed through a five channel tape reader, relay switching circuits, and timers. The responses were recorded on counters, and response latencies were recorded on running time meters and print-out counters.

Training: Discrimination training was preceeded by 90 trials of simple escape pretraining distributed over five days. In simple escape pretraining the start of a trial was signalled by the movement of the lever into the cage, accompanied by the sound of the shock scrambler and the gradual increase of the shock intensity. A lever press ended the trial, producing termination of the shock and retraction of the lever out of the apparatus until the start of the next trial. The intertrial interval was 90 sec. On the first day of training 10 trials were given, during which the rat was shaped to escape by pressing the lever. At first successive approximations of the escape response were reinforced by manual termination of a trial. All rats learned the lever-press escape response in from five to ten trials. On each of pretraining days 2 through 5, 20 simple escape trials were given.

On the sixth day of training, a discrimination requirement was introduced on alternate trials, in which the animal was required to respond to the appropriate one of the two levers on the wall opposite the retractible lever, in order to terminate the trial. A discrimination trial was signalled by the presentation of the two visual stimuli accompanied by the onset of the gradually increasing shock. Simple escape trials intervened between each discrimination trial to force the rats to move to a position where both stimuli were visible at the start of the next discrimination trial. Pilot work had shown that without this procedure, rats tended to remain close to the lever to which they had responded to terminate the last trial, and respond to it first at the start of the next trial.

A correction procedure was used in discrimination training. A trial could be terminated only by a response to the correct stimulus (S+), so more than one response per trial to the incorrect stimulus (S-) was possible. Three different outcomes could follow a response to S-. For one group, an incorrect response was followed by immediate delivery of a 100 msec pulse of high intensity shock (2.6 ma). For a second group, an incorrect response was followed by a pulse of lower intensity shock (1.6 ma). For a third group, incorrect responses had no programmed consequence. Each of these groups was further divided into two subgroups on the basis of which discriminative stimulus was assigned as S+. In one subgroup the rectangle was S+ and the line was S-, while in the other subgroup, the line was S+ and the rectangle was S-.

A total of 170 discrimination training trials were given over 9 days. On the first day of discrimination training, 10 discrimination trials were given, along with 10 simple escape trials. On the succeeding 8 days, 20 trials of each type were given per day.

Design: In summary, 24 rats were randomly assigned to one of six groups in a two by three factorial design. One main factor was the intensity of punishment for errors, and involved the comparison among three punishment conditions. The other factor was the comparison between line-positive and rectangle-positive reinforcement arrangements.

Results

Three measures of performance were recorded. The main index of discrimination learning was the number of correct trials per day, that is, the number of trials per block of 20 discrimination trials on which the first response of the trial was correct. In a correction procedure more than one wrong response can occur on a given trial. Therefore, the number of errors per error trial was recorded, in order to provide an indication of the extent to which the rats persisted in responding to the S-. The third measure recorded was the mean latency of correct responses per day. Because the shock intensity gradually increased on each trial, this measure provided an indication of the highest intensity of the shock that was reached on any given trial. These three measures will be described in the order listed.

Correct trials per day: Learning curves, in terms of percent correct responses per day, for rectangle-positive and line-positive animals are shown in Figure 2, plotted separately for each punishment condition. The two aspects of the stimulus effect reported by Annau are evident in these curves. On the first day of training, those rats for which the S+ was the brighter stimulus (the rectangle) had more correct trials, and later in training those rats for which the S+ was the dimmer stimulus (the line) had more

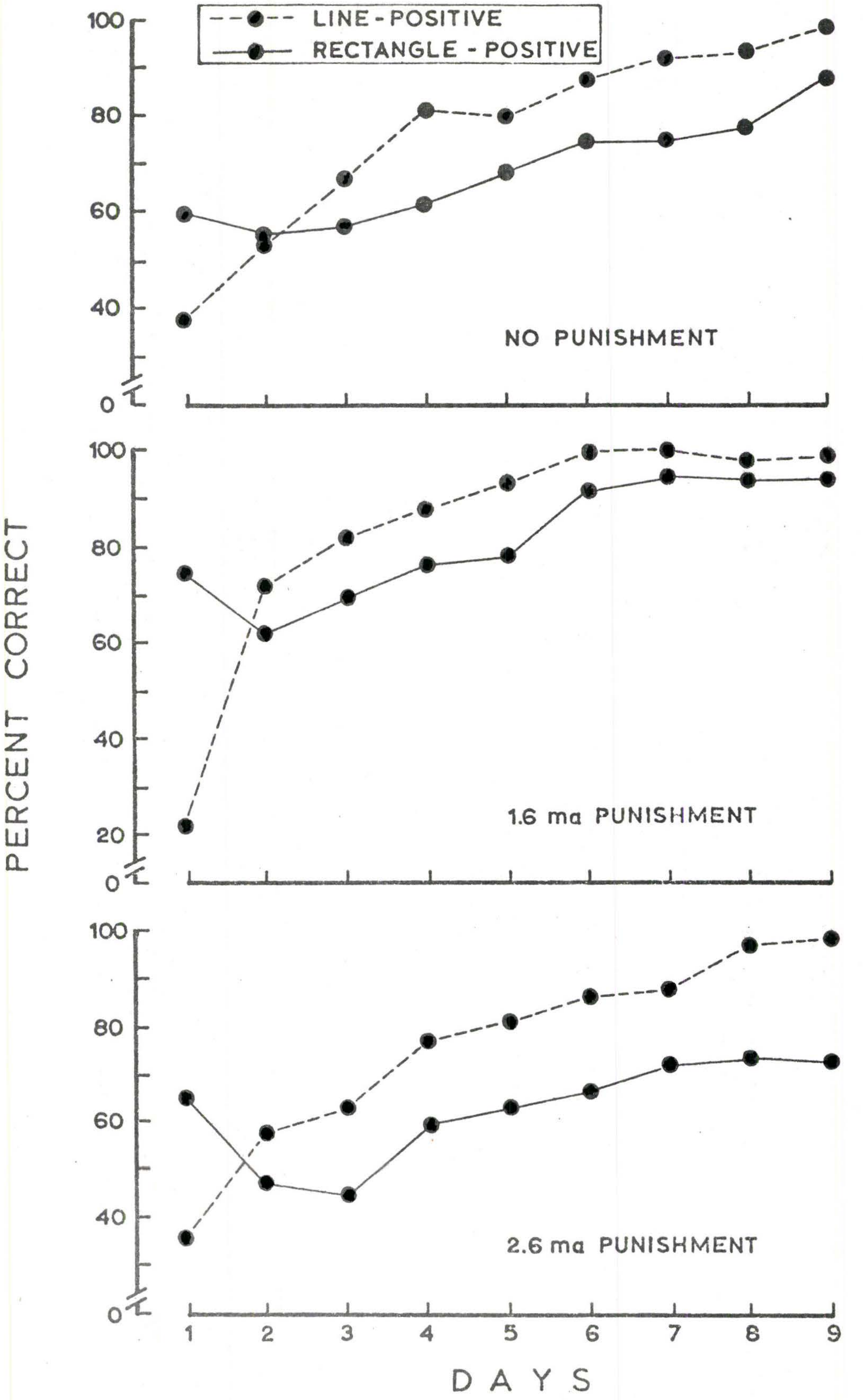

Figure 2. Percent correct discrimination trials over days of training.

correct trials.

The effects of punishment conditions on overall discrimination performance are shown in Figure 3. In both stimulus conditions the highest percentage of correct trials was made by the animals in the 1.6 ma punishment condition, while the performance of animals in the no-punishment condition and the 2.6 ma punishment condition was much the same.

In order to assess the reliability of these effects an overall analysis of variance was performed. The analysis employed a 2 x 3 x 9 factorial design with two stimulus conditions and three punishment conditions over nine days of training. The results of the analysis are summarized in Table 1. The effects due to stimulus conditions and punishment conditions were both significant, as was the effect due to days of training. There was also a significant interaction between the effect due to stimulus conditions and the effect due to days of training, indicating that the development of the discrimination differed between stimulus conditions.

In order to interpret this interaction, the simple main effects of stimulus conditions were calculated for each day of training. It was found that on day 1 the rectangle-positive animals had significantly more correct trials than the line-positive animals ($F = 38.59$, $df = 1/18$, $p < .01$), while by day 3 the line-positive animals had significantly more correct trials than did the rectangle-positive animals ($F = 6.25$, $df = 1/18$, $p < .05$).

Additional analyses on the effects due to stimulus conditions were suggested by detailed examination of the

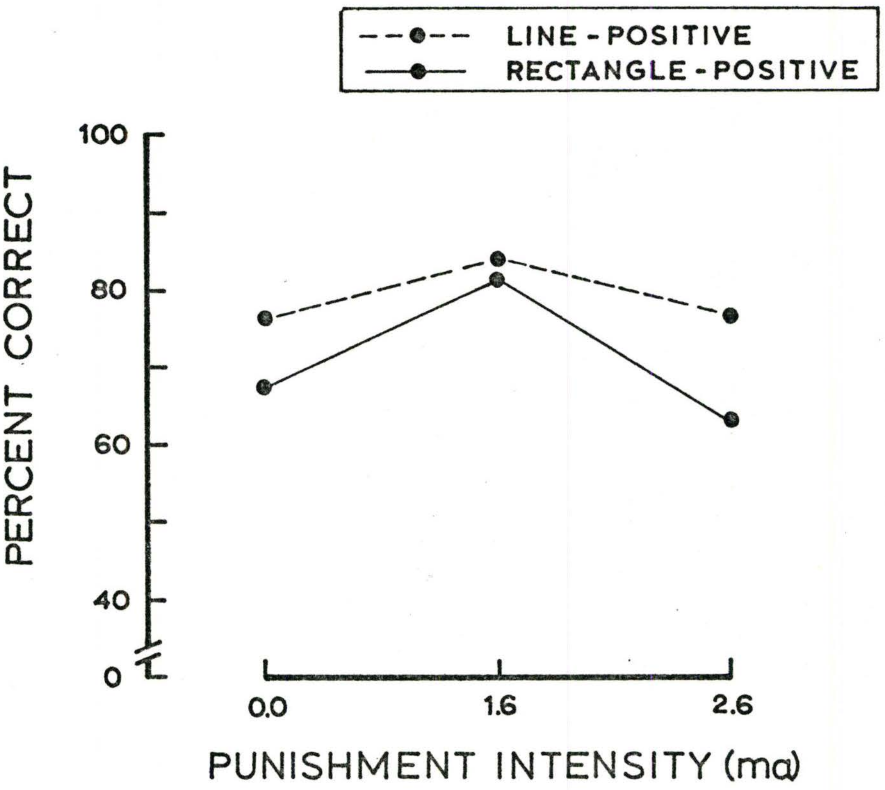

Figure 3. Overall discrimination performance as a function of punishment intensity.

Table 1

Analysis of variance on number of correct trials per day as a function of stimulus and punishment conditions.

Source	SS	df	MS	F	P
Between Ss	942.89	23			
Stimulus	140.16	1	140.16	5.21	< .05
Punishment	268.36	2	134.18	4.99	< .05
Stimulus x Punishment	50.2	2	25.1	< 1	
Between Error	484.17	18	26.9		
Within Ss	3006.44	192			
Days	1680.75	8	210.09	43.77	< .01
Stimulus x Days	499.42	8	62.42	13.0	< .01
Punishment x Days	76.22	16	4.76	< 1	
Stimulus x Punishment x Days	58.72	16	3.67	< 1	
Within Error	691.33	144	4.80		

learning curves in Figure 2. The relative superiority of the rectangle-positive animals on day 1 did not result simply from deviation from chance performance by one or another of the groups alone; rather the rectangle-positive animals performed better than chance and the line-positive animals performed worse than chance. This observation was confirmed by t tests. On day 1 the rectangle-positive animals made significantly more correct responses than would be expected by chance ($t = 4.02$, $p < .01$ two-tailed), while line-positive animals made significantly fewer correct responses than would be expected by chance ($t = 4.47$, $p < .001$ two-tailed).

Also, the later superiority of the line-positive animals was not simply the result of more rapid learning by this group than by rectangle-positive animals. Examination of the learning curves for the two stimulus conditions shows that while line-positive animals showed a consistent improvement over days of training, the rectangle-positive animals had fewer correct trials on day 2 than they did on day 1. In short, their performance deteriorated before it began to improve. To confirm this observation the simple main effects of training between day 1 and day 2 for the line-positive and rectangle-positive animals were calculated from the overall analysis of variance. Discrimination performance of line-positive animals improved significantly between day 1 and day 2 ($F = 4.25$, $df = 1/44$, $p < .05$), while performance of rectangle-positive animals declined significantly ($F = 5.89$, $df = 1/44$, $p < .05$).

In order to further localize the source of the significant punishment effect found in the overall analysis of correct trial scores, multiple comparisons were made among the mean correct scores for each punishment condition using the Newman-Keuls procedure. At the .05 level of significance it was found that the no-punishment and the 2.6 ma punishment conditions did not differ from one another, while the 1.6 ma punishment group made significantly more correct responses than either of the other two groups. Thus, with increased intensity of punishment for errors, there appears to be an inverted U-shaped function relating punishment intensity and discrimination performance.

Although the interaction between stimulus and punishment effects was not significant in the overall analysis of variance, a more detailed examination of the relationship between these two variables appeared warranted because of the theoretical role of punishment in the stimulus effect. Consequently, the simple main effects of stimulus conditions were calculated separately for each punishment condition. It was found that the effect due to stimulus conditions was not significant for the no-punishment condition ($F = 1.78$, $df = 1/18$, $p > .05$) or the 1.6 ma punishment condition ($F < 1$), but was significant for the 2.6 ma punishment condition (F, 5.16, $df = 1/18$, $p < .05$). These results suggest the possibility of variation in the magnitude of the stimulus effect at different punishment intensities, and examination of the terminal stages of performance gives clearer indication of this. Figure 4 shows the percent correct trials during the last two days of training for line-positive and rectangle-

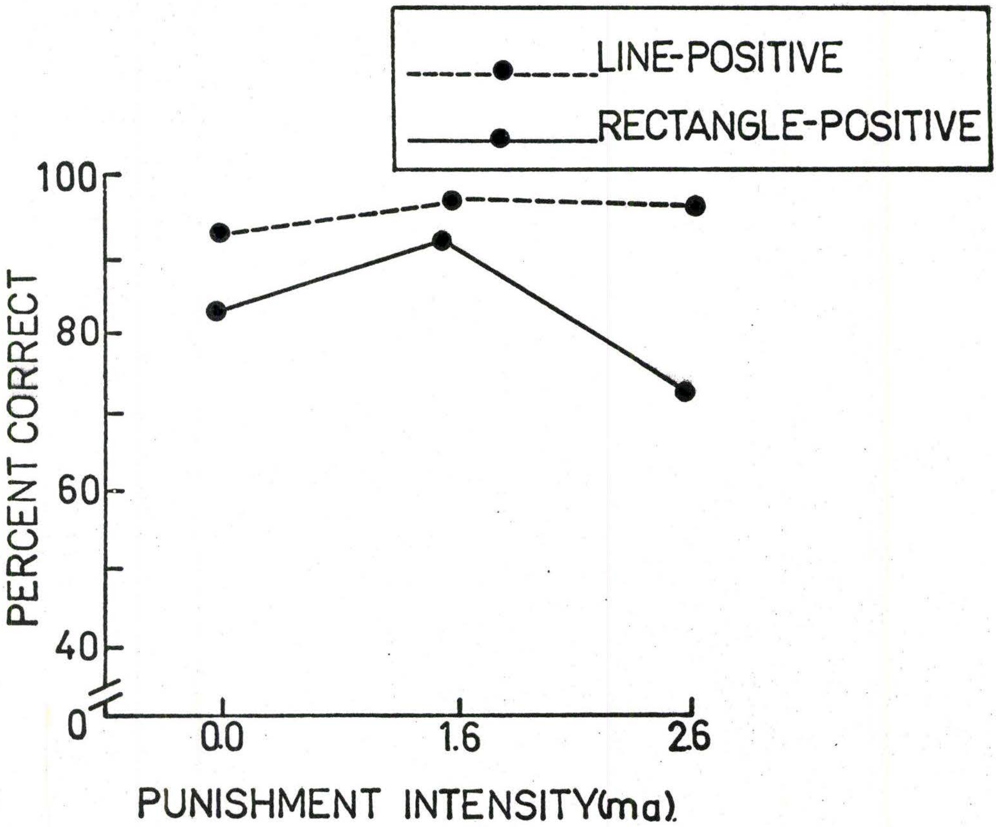

Figure 4. Terminal discrimination performance as a function of punishment intensity.

positive animals in the different punishment conditions. Mean performance by the line-positive animals was uniformly high, and while mean performance of all rectangle-positive groups was below that of the line-positive groups, the largest difference between stimulus conditions was in the 2.6 ma punishment group. However, as in the analysis of overall performance, statistical support for this observation was weak. An analysis of variance was performed on the total correct trials scores for days 8 and 9 using a 2 x 3 factorial design with two stimulus conditions and three punishment conditions. A summary of this analysis is presented in Table 2. As in the overall analysis, the effect due to stimulus conditions was significant, but neither the effect due to punishment nor the interaction between stimulus and punishment effects was significant. The lack of a significant interaction, in spite of the apparent difference in the form of the functions in Figure 4, can probably be attributed to the variability in the rectangle-positive, 2.6 ma punishment group. Two of the animals in this group had reached a high level of performance by the end of training (both 95% correct) while the remaining two were performing at no better than chance, considerably poorer than animals in any of the other groups. The simple main effects of stimulus conditions at different punishment intensities were calculated sepately, as had been done in the analysis of overall performance. Again it was found that the effect due to stimulus conditions was not significant for the no-

Table 2.

Analysis of variance on total correct trials on days 8 and 9 as a function of stimulus and punishment conditions.

Source	SS	df	MS	F	P
Stimulus	198.37	1	198.37	9.29	< .01
Punishment	69.74	2	34.87	1.63	n.s.
Stimulus x Punishment	68.26	2	34.13	1.60	n.s.
Error	384.25	18	21.35		
Total	720.62	23			

punishment condition ($F = 2.83$, df = 1/18, $p > .05$) or the 1.6 ma punishment condition ($F < 1$), but was significant for the 2.6 ma punishment condition ($F = 9.37$, df = 1/18, $p < .01$). Because of the lack of significant interactions between stimulus and punishment effects, these results must be assessed cautiously, and can only be regarded as suggestive that a high intensity punishment could lead to a greater relative superiority of line-positive animals.

Errors per error trial: An analysis of variance was performed on the errors per error trial scores, using a 2 x 3 x 9 factorial design, identical to that used for the correct trial scores. A summary of this analysis is presented in Table 3, along with group mean scores. The effect due to punishment and the effect due to days of training were significant, as was the interaction between stimulus and training effects.

The significant effect due to days of training indicates that the number of multiple errors per incorrect discrimination decreased with training, but the significant interaction term indicates that the slopes of the learning curves resulting from this change differed between stimulus conditions. Separate calculations of the simple main effects of stimulus conditions for each day of training revealed the source of the significant interaction. On day 1 of training, the line-positive animals made significantly more errors per error trial than did the rectangle-positive animals, while

Table 3

Mean number of errors per error trial on days 1 through 9 as a function of punishment intensity and stimulus condition

Punishment intensity in ma	0.0	1.6	2.6
Rectangle-positive	2.47	1.79	1.68
Line-positive	2.55	1.88	1.73

Analysis of variance of the number of errors per error trial for rectangle-positive and line-positive animals

Source	SS	df	MS	F	P
Between Ss	90.52	23			
Stimulus	.29	1	.29	< 1	
Punishment	26.74	2	13.37	3.79	<.05
Stimulus x Punishment	.01	2	.005	< 1	
Between Error	63.48	18	3.53		
Within Ss	329.67	192			
Days	156.29	8	19.54	19.54	<.01
Stimulus x Days	17.31	8	2.16	2.34	<.05
Punishment x Days	12.89	16	.81	< 1	
Stimulus x Punishment x Days	10.52	16	.66	< 1	
Within Error	132.66	144	.92		

on succeeding days the stimulus groups did not differ significantly. Taken together with the correct response measures, this means that on day 1 the line-positive animals not only made more incorrect discrimination choices, but they also made more multiple errors per incorrect choice. However, although the rectangle-positive animals made relatively more incorrect discrimination choices during the remainder of training, they did not differ significantly from the line positive animals in the number of multiple errors per incorrect choice.

The effects of punishment on the errors per error trial measure also differed from its effects on overall discrimination performance. While the total number of correct trials appeared to be an inverted U-shaped function of punishment intensity, examination of the group means in Table 3 suggests that the number of errors per error trial is a decreasing monotonic function of punishment intensity. Multiple comparisons were made among the mean scores for each punishment intensity condition using the Newman-Keuls procedure. At the .05 level of significance both the 1.6 ma punishment group and the 2.6 ma punishment group made significantly fewer errors per error trial than did the no-punishment group, while the 2.6 ma and the 1.6 ma punishment groups did not differ significantly from each other.

The main difference between the effects of punishment intensity on the correct trial scores and the errors per error trial scores was in the 2.6 ma punishment group. While the 2.6 ma punishment group made significantly fewer correct trials (and therefore more incorrect discrimination choices) than the 1.6 ma punishment group, and did not differ in the number of correct trials from the no-punishment group, they made fewer errors per error trial than either the no-punishment group or the 1.6 ma punishment group, although they differed significantly only from the former.

Response latency: The third measure of performance examined was correct response latency. Mean response latencies for rectangle-positive and line-positive animals at each punishment level were transformed into response speed measures $(\frac{1}{\text{latency}})$ to make them comparable to the correct response learning curves, and are plotted in Figure 5 (day 9 was excluded due to loss of data from some animals). Since speed of responding determined the intensity of the shock from which the rat escaped, equivalent shock intensities are shown on the right hand vertical axis of Figure 5.

The response speed measures showed the same relative differences between rectangle-positive and line-positive animals as did the correct trial scores. On day 1 rectangle-positive animals responded correctly more rapidly than line-positive animals, while later in training this relationship was reversed and the line-positive animals responded correctly more rapidly than the rectangle-positive animals.

An analysis of variance was performed on the mean response latency scores, using a 2 x 3 x 8 factorial design similar to that used on the other two performance measures. A summary of the results of this analysis is presented in Table 4. The reversal in the relative response speeds of

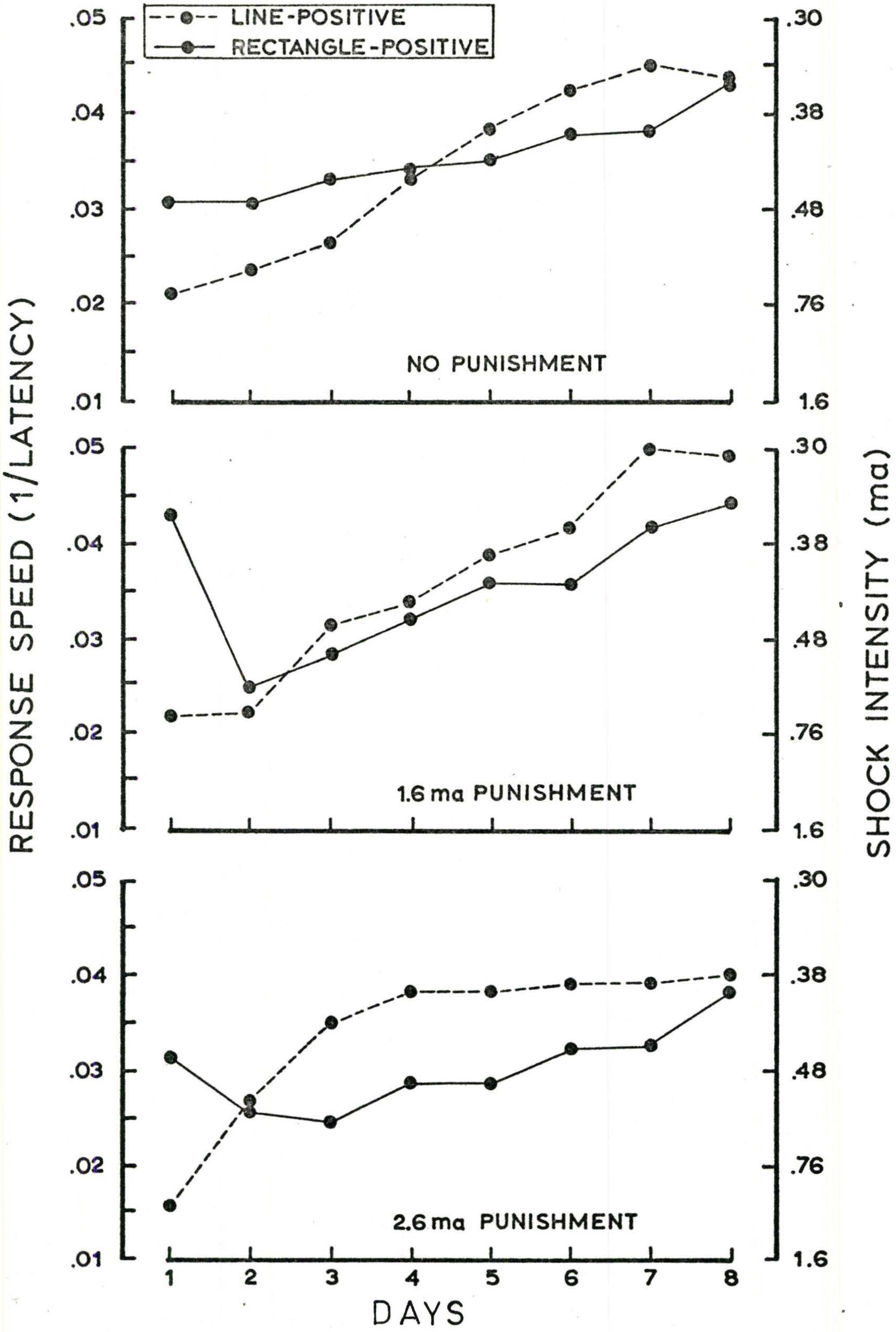

Figure 5. Mean correct discrimination response speed and escape shock intensity over days of training.

Table 4

Analysis of variance on mean response latencies per day as a function of stimulus and punishment conditions

Source	SS	df	MS	F	P
Between *S*s	13,109.84	23			
Stimulus	31.85	1	31.85	<1	
Punishment	442.64	2	221.32	<1	
Stimulus x Punishment	225.5	2	112.75	<1	
Between Error	12,409.85	18	689.43		
Within *S*s	18,636.2	168			
Days	7,082.63	7	1,011.80	19.51	<.01
Stimulus x Days	3,575.10	7	510.72	9.85	<.01
Punishment x Days	695.28	14	49.66	< 1	
Stimulus x Punishment x Days	748.86	14	53.49	1.03	n.s.
Within Error	6,534.33	126	51.86		

rectangle-positive and line-positive animals early and late in training may be seen in the significant interaction between the effects due to stimulus conditions and days of training. There was also a significant increase in response speed over days of training, but main effects due to either correct stimulus or punishment intensity were not significant.

Discussion

There were three main findings in this experiment. The first concerns the effect of punishment intensity. There was an inverted U-shaped function relating punishment intensity to overall performance. The 1.6 ma punishment groups were superior to the no-punishment and the 2.6 ma punishment groups. The second main finding concerns the effects of the discriminative stimulus. During the first 10 trials of training, the rats that were required to respond to the brighter of the two discriminative stimuli (rectangle-positive) were superior to those required to respond to the dimmer of two discriminative stimuli (line-positive). During the remainder of training this relationship was reversed, and line-positive rats were superior to rectangle-positive rats. The third is more a suggestion than a finding, and concerns a possible relationship between punishment intensity and the magnitude of the stimulus effect. During the terminal stages of the experiment, all the rats in the line-positive groups were performing at a uniformly high level. Performance in the rectangle-positive groups was poorer on the average, and although the interaction between stimulus and punishment effects was not significant, the largest difference between line-positive and rectangle-positive animals was in the 2.6 ma punishment condition, and individual comparisons showed that only in this condition was the difference significant. The lack of a significant interaction in the terminal performance data can be attributed to the combination of a few subjects in each group, and a bimodal distribution in the 2.6 ma rectangle-positive group. The excellent performance by some animals and extremely poor performance by others in this group is interesting in itself, since it indicates that there must be some further variable (or variables) that have not yet been isolated which are crucial in determining performance in this situation.

These results will be discussed under two headings: (a) punishment effects, and (b) stimulus effects.

Punishment effects: The finding of superior performance by the 1.6 ma punishment group relative to the 2.6 ma and no-punishment groups is consistent with the part of the Yerkes-Dodson Law, outlined in Chapter One, that postulated an optimum intensity of aversive stimulation for certain discrimination tasks. Further it is consistent with the view that the inverted U-shaped relationship between discrimination learning and punishment intensity is found in escape-punishment procedures in which escape intensities increase on each trial. Also, if we assume that the line-positive task is easier than the rectangle-positive task, then the form of functions relating shock intensity to performance during the terminal stages of training are consistent with the view that the U-shaped function is more pronounced with difficult tasks.

Although these results are for the most part consistent with expectations, it still must be determined how the particular effects were produced. In this context, the poor terminal performance of some 2.6 ma rats is somewhat surprising. The errors per error trial measures indicate that punishment suppresses responses which produce it, in direct relation to intensity (see Table 3). This is consistent both with the findings from non-discriminative research (Azrin, 1956; Church, 1969), and the findings from experiments involving punishment for errors in appetitively based discrimination (Curlin & Donahoe, 1965; Wischner, Fowler & Kushnick, 1963). A question arises, however, as to why the punishment did not suppress all discrimination errors in proportion to punishment intensity so that the high punishment rats performed best of all. In short, why did some rats in the 2.6 ma rectangle-positive group perform so poorly?

One possible answer to this question is that the use of an escape procedure in combination with punishment, in some manner cancelled out any beneficial effects that punishment could otherwise be expected to have had on discrimination. Annau (1963, 1968) and Hammes (1956) both reported optimum discrimination performance in an escape procedure at the escape shock intensity threshold. Increases in shock intensity above threshold produced decrements in discrimination performance. If this mechanism were operative in the present situation, it might be expected that response speed would be lower in animals which performed poorly. The correlation between discrimination performance and response latency over the last four days of training for which latency scores were available (days 5 through 8) was -.41 ($t = 2.11$, $df = 22$, $p < .05$). The longer the latency of the response, and the higher the shock intensity, the worse the terminal performance. It may be therefore that in some cases, with a gradually increasing shock, the beneficial effects on discrimination due to higher intensity punishment, were cancelled out by decremental effects of higher intensity escape shock. According to this view any factor which leads to increased escape latencies should produce poorer performance. One such factor might be high intensity punishment, particularly with a difficult discrimination, since the punishment would tend to produce avoidance of both levers rather than just the lever associated with S-.

Another possible explanation of these results is suggested by a recent paper by Church, Wooten, and Matthews (1970). These authors demonstrate two effects of punishment. One is a response specific effect of the punishment and the other a more general conditioned emotional effect of the punishment. The former would lead to a suppression of the response that the punishment was contingent on. The latter might lead to a general emotional arousal which, in combination with the effects of the shock from which the animals escape, would disrupt discrimination behavior. If the high punishment shock tended to produce more of this general emotional effect, especially when the discrimination was difficult and more punishments were given, we would expect poorer performance in this group than in the groups given lower punishment intensity, as occurred in the present experiment.

The basic idea in both of these explanations (which are complementary rather than exclusive) is that high intensity punishment interacts with high intensity shock from which the animal escapes, and it is only when both escape and punishment contingencies are employed that high intensity punishment interferes with behavior. In short, the argument would be that both escape contingencies and punishment contingencies should lead to an improvement in discrimination as shock intensity is increased, but that this is counteracted by a general motivational effect of shock which decreases adequacy of performance, either by some direct effect of the motivation or by the elicitation of interfering responses.

Stimulus effects: To recapitulate briefly, the data indicated that during the first 10 trials of training animals required to respond to the brighter of two discriminative stimuli (rectangle-positive) were superior to those required to respond to the dimmer of two discriminative stimuli (line-positive). During the remainder of training this relationship was reversed, with line-positive animals showing superior discrimination performance. These results indicate that the effects found by Annau in a discriminative escape learning situation also occur in escape-punishment situations.

The stimulus effects during the first 10 trials provide a basis for assessing the three hypotheses that were described in Chapter One to account for similar results in appetitively based discrimination. Both the rectangle-positive and line-positive animals deviated from chance in opposite direction during the first 10 trials. While it could be argued that the better than chance performance of the rectangle-positive animals during the first 10 trials was simply due to rapid learning, this argument cannot account for the worse than chance performance by the line-positive animals, since their performance was the opposite of what would be expected if learning produced it. It appears, therefore, that this symmetrical deviation from chance by both groups indicates a performance effect due to stimulus characteristics rather than to learning. In short, it would seem that the initial stimulus effect was the result of a pre-existing bias towards the rectangle in both groups.

Both the stimulus intensity hypothesis (Hull, 1949) and the contrast hypothesis (Logan, 1954; Perkins, 1953) would predict such a bias during early trials. In terms of the stimulus intensity hypothesis, the greater physical intensity of the rectangle should energize any response tendencies towards that stimulus, thus leading to a greater probability of responses to the rectangle by all animals. According to the contrast hypothesis, any tendency to respond to the dark background should have been extinguished during simple escape pre-training, so that on initial presentation of the discriminative stimuli there would be greater generalization of inhibition to the less contrasting line stimulus. Again, the net response strength to the rectangle would be greater during early trials in both rectangle-positive and line-positive groups.

The attention hypothesis (Nygaard, 1958), however, while predicting more rapid learning by rectangle-positive animals, does not provide an explanation of the worse than chance performance by the line-positive animals. If, as the attention hypothesis suggests, contrast between a stimulus and its background is a determinant of attention, then it might be expected that the line-positive animals would be slower to develop consistent attention to the relevant brightness dimension. Line-positive animals would be relatively less likely to attend to brightness on a trial when they responded to S+ and were reinforced, and relatively more likely to attend to brightness on a trial when they responded to S- and were not reinforced. Since attention presumably develops through reinforcement, line-positive animals would be more likely to be reinforced for attending to irrelevant stimulus dimensions, such as position. The most that could be expected from such a process, however, would be chance performance by the line-positive animals, rather than the significantly worse than chance behaviour that was observed.

Although, on the basis of the results of Experiment I the possibility cannot be rejected that stimulus intensity, rather than contrast, is the determinant of the initial stimulus effect, the evidence available in the literature suggests that this is unlikely (see review by Gray, 1965). Particularly clear evidence is provided by experiments (Bragiel & Perkins, 1954; Nygaard, 1958) in which the factors of stimulus intensity and contrast are set in opposition. Nygaard (1958) trained animals on a black-white discrimination task in apparatuses with either black, white, or mid-grey walls. He found that while discrimination learning was relatively more rapid for animals with the white stimulus as S+ (as compared to animals with the black stimulus as S+) in the apparatus with black walls, animals with the less intense black stimulus as S+ showed more rapid discrimination learning in the apparatus with white walls. In the apparatus with mid-grey walls, where the contrast should be equal for black and white stimuli, performance was the same with either stimulus as S+.

While it seems reasonable to conclude that the initial superiority of rectangle-positive animals in Experiment I can be attributed to a performance effect, dependant on the greater contrast between the rectangle and the background, the basis of the relative superiority of the line-positive animals during the remainder of training is less clear. It was previously suggested that similar finding observed by Annau (1963) could have been a consequence of more rapid inhibition of responses to the S- by the dark-positive animals due to the greater number of errors made by this group early in training. Although a similar interpretation could be applied to the present results, it seems inadequate. While line-positive animals did make more errors during the first 10 trials of training than the rectangle-positive animals, this seems insufficient to account for their relative superiority during the remaining 160 trials. Such an effect should be self limiting, since the relatively greater number of errors by rectangle-positive animals on each day following the first should inhibit responses to the line S- and cancel out the difference between groups.

It seems more reasonable to conclude that the relative superiority of the line-positive animals later in training in the present research resulted from a process operative throughout training, rather than just during early trials. Since such an effect was not found in any of the previous experiments using appetitively based discrimination tasks, it is probably a consequence of the use of aversive control of discrimination.

There are a number of facts available which suggest that the later superiority of line-positive animals may be a direct result of stimulus characteristics in the same manner as the initial superiority of rectangle-positive animals. Since, as the above discussion suggests, the important difference between the rectangle and line may be some factor other than intensity (for example, contrast), the difference will be described by the more general term "salience" in the following discussion.

Although a number of alternative hypotheses are possible, the simplest explanation of the present results requires three main assumptions. First, let us assume a bias such that rats tend to respond to the most salient stimulus at the beginning of discrimination training. This would account for the initial better than chance performance in the rectangle-positive groups and the poorer than chance performance in the line-positive groups.

Second, assume that discrimination learning in escape or escape-punishment procedures develops primarily through inhibition of responses to the S-, and third, that the more salient the S-, the more quickly is the inhibitory control established. Jenkins (1965) has pointed out that in a two choice discrimination task, performance can depend on excitatory control alone, inhibitory control alone, or a combination of excitatory and inhibitory control. That is, the animal may have learned to (1) respond to S+, (2) avoid S-, or (3) respond to S+ and avoid S-. If discrimination in the present procedure depended primarily on the development of inhibitory control by the S-, then while the initial superiority of rectangle-positive rats could be characterized as an excitatory stimulus salience effect, the later superiority of line-positive rats could be characterized as an inhibitory stimulus salience effect.

The first of these three assumptions has already been discussed. There is evidence that suggests that the second and third are reasonable. Consider the assumption that discriminative escape conditioning develops mainly via inhibitory control by the S-. Although the popular Hull-Spence (Hull, 1952; Spence, 1936) theory of discrimination learning assumed that excitatory control by the S+ and inhibitory control by the S- develop concommitantly in discrimination learning, a number of recent authors have provided evidence to indicate that this is not necessarily true. Recent experiments (Biederman, 1967; Gardner and Coates, 1965; Jenkins and Sainsbury, 1970; Mandler, 1968; Suter, 1970) have demonstrated greater control by either the S+ or the S- in appetitively motivated discrimination tasks, and some (Biederman, 1967; Mandler, 1968; Suter, 1970) have suggested that the degree of control by one or the other stimulus may shift at different stages of training.

Similarly, the assumption that more salient stimuli lead to the more rapid development of inhibitory control, does have some experimental support. Other research using aversive stimulation has demonstrated a stimulus effect on the magnitude of a conditioned emotional response (CER) (Kamin, 1965) and on a conditioned avoidance response (Kessen, 1953). Kamin (1965) reported a series of experiments which demonstrated that the amount of suppression of food reinforced lever pressing by a stimulus (noise or light) paired with shock was a direct monotonic function either of an increase in the intensity of the stimulus, or of a decrease in the intensity of a continuously present stimulus. Kessen (1953) found that the effectiveness of avoidance conditioning in a wheel turning apparatus was directly related to the intensity of a light used as a CS.

Conclusion: In summary, then, the present results suggest that the punishment and escape contingencies tend to improve performance, while general motivating effects of either escape shock or punishing shock tend to deteriorate performance. Furthermore, they suggest that the role of the salience of the stimulus is more complex than indicated by previous authors. More is involved than the difference along some intensity dimension between S+ and S-.

In the next experiment an attempt was made to deal with some of the questions that arose from the results of this experiment. First, there is the question of the basis of the stimulus salience effect. Can it be attributed to stimulus intensity, to contrast, or so some other variable? Second, is the assumption tenable that discriminative control in the present situation depends primarily on avoidance of the S-? This question is especially important since one could argue that punishment was present in all groups in this experiment, because the escape shock intensity gradually increased on each trial. Perhaps if groups were included which received no punishment for responses to S-, discriminative control would have appeared to be under the control of both S+ and S-.

CHAPTER THREE

Experiment II

The present experiment was intended to answer three questions. First, does inhibitory control predominate in discriminative escape conditioning? Second, if inhibitory control predominates, does the effect depend on explicit punishment contingencies? Third, do the stimulus effects that were observed in Experiment I depend necessarily on either stimulus intensity or stimulus-background contrast along an intensity dimension.

A typical procedure to determine the presence of inhibitory or excitatory control is the use of transfer tests, where a neutral stimulus is substituted for either the S+ or the S-. If inhibitory control predominates, discrimination should be disrupted greatly by substituting a neutral stimulus for the S-, but should be affected relatively little by substituting a neutral stimulus for the S+. If excitatory control predominates, the converse relationship should be observed, while if both excitatory and inhibitory control are operative, removal of either the original S+ or S- should decrease performance but not eliminate the discrimination.

However, as Mackintosh (1965) points out, transfer tests are insensitive at best, since the testing procedure tends to extinguish whatever differential response tendencies are present. It was felt that this would be particularly true with a discriminative escape procedure, since testing during extinction (that is, without reinforcement) is not possible. Accordingly, an alternative procedure was adopted, which provided an indication of the relative importance of excitatory versus inhibitory control for the development of discrimination, through the use of stimuli in which the distinguishing characteristic could be attributed to either the S+ or the S- alone.

The procedure was adapted from a series of experiments by Jenkins and Sainsbury (1970), in which they demonstrated what they called a "feature-positive effect". Pigeons were trained on a successive visual discrimination, using stimuli which were identical except for the presence of a distinguishing feature on either the S+ or the S-. One example of the type of task, involved alternate presentations of two evenly illuminated stimulus displays, one of which was blank, while a black dot was superimposed on the other. If the black dot was on the S+, birds had to learn to respond to it and withold responses to the blank stimulus. Conversely, if the dot was on the S-, birds had to learn to respond to the blank stimulus and withold responses to the black dot. Jenkins and Sainsbury described the task with the dot on the S+ as a feature-positive discrimination, and the task with the dot on the S- as a feature-negative discrimination.

They found that birds learned the feature-positive discrimination readily, but were unable to learn the feature-negative discrimination. Apparently the birds could learn to respond to the presence of a distinctive stimulus and withold responses in its absence, but they could not learn to respond to the absence of a distinctive stimulus and withold responses in its presence.

It cannot be concluded from these findings that inhibitory control was not operative in the Jenkins and Sainsbury experiments, but they do indicate that, in the procedure used, a discrimination is not readily learned on the basis of an inhibitory stimulus in the absence of any other means of distinguishing the S+ from the S-. Since it has been argued that the superior performance later in training of the line-positive group in the first experiment was due to the presence of a distinctive or salient feature as S-, it seemed probable that the use of stimuli similar to those used by Jenkins and Sainsbury might lead to the opposite results to theirs, that is, a feature-negative effect. Accordingly, in Experiment II the discriminative stimuli consisted of two illuminated rectangles with a black dot projected on one or the other. For half of the animals the black dot was on the S+ (dot-positive), and for the other half of the animals the dot was on the S- (dot-negative).

The question of the importance of punishment in the development of predominantly inhibitory control proved difficult to answer. The fact that the stimulus effect in Experiment I was found in both punishment and no-punishment groups suggested that the results were simply typical of the discriminative escape procedure. However, the use of gradually increasing intermittent shock raised the possibility of effects due to adventitious punishment in the nominally no-punishment condition. In order to eliminate adventitious punishment, the logical solution appeared to be the use of continuous shock of fixed intensity to maintain escape responding.

Two pilot studies, which are briefly described in Appendix A, were conducted to test the feasibility of this procedure with the dot-positive and dot-negative discrimination tasks. In the first pilot study, gradually increasing continuous shock was employed, and in the second, intermittent shock fixed at the maximum intensity of the increasing shock (1.2 ma) was employed. In the first pilot study there was no indication of discrimination learning over 15 days of training in either stimulus condition. In the second pilot study there was no indication of discrimination learning over 14 days of training, and moreover, a considerable number of animals stopped responding when the discrimination requirement was introduced.

Since on the basis of these pilot studies it appeared unlikely that a continuous fixed intensity shock procedure would provide an adequate test of the inhibitory control hypothesis, it was decided to continue the use of gradually increasing intermittent shock in Experiment II, and attempt to minimize any possible punitive effects of shock onset by delaying the start of the next pulse of shock following an error. It has been demonstrated (Kamin, 1959; Misanin, Campbell & Smith, 1966) that a delay-of-punishment gradient can be measured, analogous to the commonly accepted delay-of-reinforcement gradient (Grice, 1948). Misanin, Campbell, and Smith tested the effects of punishment on the resistance to extinction of a shuttle-box avoidance response and obtained a relatively steep delay-of-punishment gradient. Using a .15 sec pulse of shock as punishment, they found that following a delay of 10 sec after a response, the punishment produced no suppression whatsoever.

Two no-punishment groups were included in the present experiment. In one group, onset of the next pulse of shock following an error was delayed for 1 sec, and in the second group shock onset was delayed for 3 sec. While neither of these delay conditions could be considered to completely eliminate the possibility of adventitious punishment effects, longer delays in shock onset were not deemed practical, since the procedure amounted to a Sidman avoidance schedule, and the animals could learn to postpone shock indefinitely by repeatedly responding to the S-.

Finally, the use of dot-positive and dot-negative discrimination tasks provided evidence on the third of the questions listed at the beginning of this chapter. If stimulus effects similar to those reported in Experiment I were found in this experiment, one could reject hypotheses in terms of absolute stimulus intensity or stimulus-background contrast along an intensity dimension. A feature-negative effect, with superior discrimination performance by dot-negative animals would imply a more general concept of a perceptual salience effect.

Method

Subjects and apparatus: The subjects were 48 naive male hooded rats, weighing between 250 and 350 g at the start of the experiment. Due to equipment failure and sickness, 8 animals were lost during training, leaving unequal groups ranging in size from 4 to 6 animals.

The apparatus was basically the same as that used in Experiment I, was with several modifications. Training was done in two identical perspex boxes, of the same dimensions as that used in Experiment I. The walls were lined with unpainted aluminum, and the two long walls of each box were removable and could be interchanged for differently equipped walls at different stages of training. During pretraining on simple escape responding, one long wall was blank and the second had a retractable response lever mounted in the center. Before the first day of discrimination training both long walls were replaced by walls equipped with two response levers and stimulus display windows each. During discrimination training the rats responded to opposite walls on alternate trials. The locations and dimensions of response levers and display windows were the same as in Experiment I.

Gradually increasing intermittent shock was again used to maintain escape responding, but the maximum intensity was lowered from 1.6 ma to 1.2 ma, and this level was reached in 76 sec from the start of a trial. The shock sources were modified Grason Stadler E1064GS shock generators, from which the source voltage could be varied between 0 v and 700 v.

The stimulus display windows were made of Kodak rear projection screen, and the stimuli were produced by two Kodak Carousel 650 slide projectors for each box. One slide projector was positioned on either side of the apparatus, so that it projected on both display windows in one wall at once. Slides were made up with one stimulus on one half and the second stimulus on the other half. Shutters were mounted in front of the projector lenses to control presentation of the stimuli. The voltage across the projector bulbs was dropped from 120 v and 35 v, in order to produce stimuli of approximately the same brightness as those used in Experiment I. The discriminative stimuli consisted of two illuminated rectangles with a black dot superimposed on one of them. The rectangles were produced by completely illuminating both display windows in one long wall of the apparatus with the slide projector. The black dot was a circle, 1 in. in diameter, projected on one display window, with its center falling on the midline 3/4 in. from the bottom.

Training: The training procedure was a somewhat simplified version of that used in Experiment I. Pretraining consisted of 40 simple escape trials on the retractible lever, given in two blocks of 20 trials per day. Discrimination training consisted of 300 training trials, given in blocks of 20 trials per day alternating between the two walls of the apparatus.

The animals were divided into four groups differing in the consequences of incorrect responses. Two of these groups employed explicit punishment contingencies (1.2 ma and 3.8 ma), while in the remaining two groups there was no explicit punishment and incorrect responses delayed the onset of the next pulse of shock. In one delay group an error postponed the next pulse of shock for 1 sec, and in the other an error postponed the next pulse of shock for 3 sec. For half of the animals in each group the black dot was on the S+ and for the other half the black dot was on the S-.

Results

Correct trials per day: In this experiment, as in the previous one, the main measure of discrimination performance was the number of correct trials per day. The learning curves for dot-positive and dot-negative animals are shown in Figure 6 plotted separately for each of the four punishment conditions. With the exception of the 1 sec delay group, the discrimination performance of the dot-negative animals was

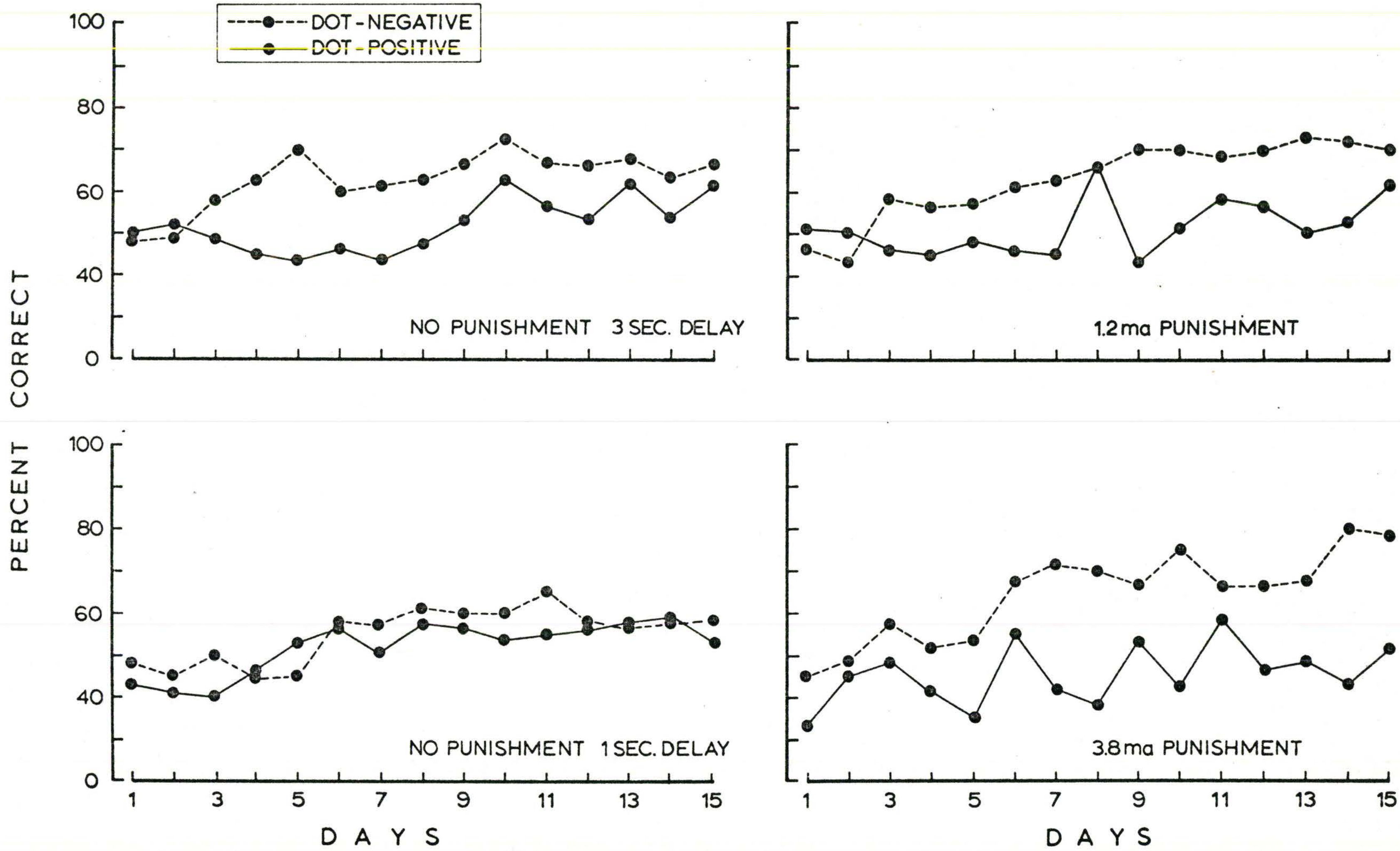

Figure 6. Percent correct discrimination trials over days of training.

superior to that of the dot-positive animals, as would be predicted from the hypothesis of predominantly inhibitory control.

The effects of the punishment conditions on overall discrimination performance by dot-positive and dot-negative animals are shown in Figure 7. Punishment conditions appeared to have different effects on dot-positive and dot-negative animals, although the differences between groups were small. In the dot-negative condition the 1 sec delay group appeared to have fewer correct trials relative to the remaining groups, while in the dot-positive condition the 3.8 ma punishment group appeared to have fewer correct trials relative to the remaining groups.

An analysis of variance was performed on the correct trial scores, using a 2 x 4 x 15 factorial design, similar to that used in previous experiments. Because of the unequal numbers of animals in the different conditions, unweighted cell means were used in the analysis. A summary of the analysis is presented in Table 5. The effect due to stimulus conditions was significant, as was the effect due to days of training. The interaction between stimulus conditions and days of training was also significant. The main effect due to punishment was not significant, nor were any of the interactions involving the punishment factor.

One possible basis of the significant interaction between stimulus conditions and days of training could have been a lack of improvement over days in the dot-positive

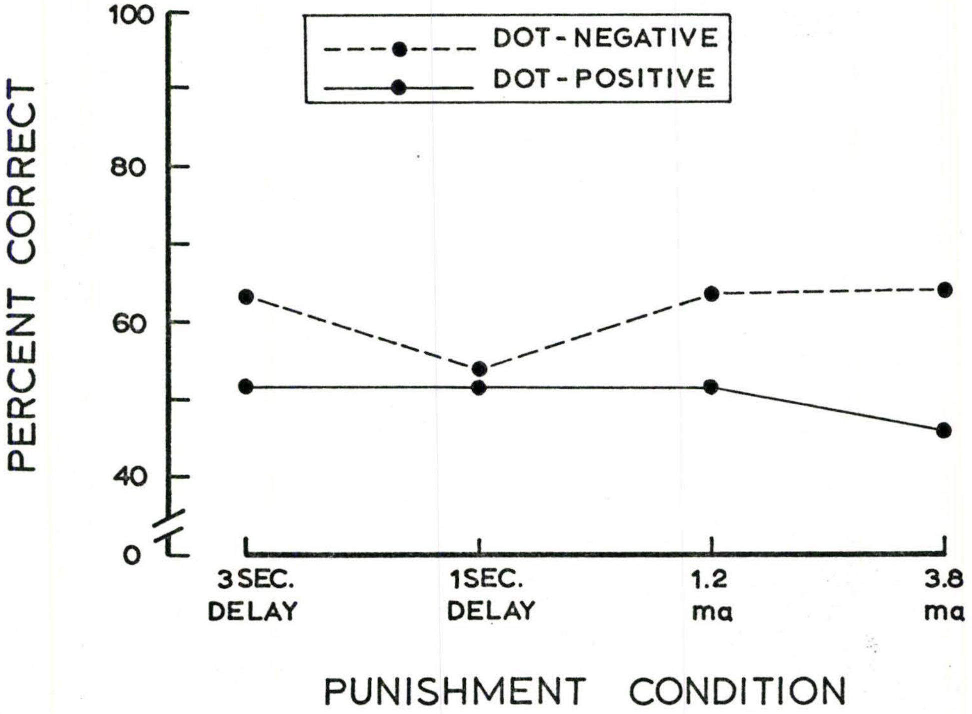

Figure 7. Overall discrimination performance as a function of punishment conditions.

Table 5

Analysis of variance on the number of correct trials per day as a function of stimulus and punishment conditions

Source	SS	df	MS	F	P
Between *S*s					
Stimulus	724.00	1	724.00	22.58	<.01
Punishment	65.30	3	21.77	< 1	
Stimulus x Punishment	183.59	3	61.20	1.91	n.s.
Between error	1,025.86	32	32.06		
Within *S*s					
Days	701.51	14	50.11	10.14	<.01
Stimulus x Days	124.45	14	8.89	1.80	<.05
Punishment x Days	181.41	42	4.32	<1	
Stimulus x Punishment x Days	250.21	448	5.96	1.21	n.s.
Within error	2,213.26		4.94		

animals. In order to determine whether or not there was significant learning in the dot-positive condition, the simple main effects of training were calculated separately for each stimulus group. The effect of training was significant for both the dot-negative animals (F = 8.52, df = 14/448, p < .01) and the dot-positive animals (F = 3.42, df = 14/448, p < .01). Thus, although the slopes of the learning curves differ in the two stimulus conditions,both dot-positive and dot-negative animals improved over trials.

Further analyses were suggested by detailed examination of the learning curves in Figure 6. During approximately the first half of discrimination training the difference in performance between stimulus groups appeared to have depended not merely on more rapid learning by dot-negative animals, but also on a tendency to worse than chance performance by the dot-positive animals. The number of correct trials by each animal over the first seven days of training were totaled, and t-tests were performed on these scores to determine if dot-positive or dot-negative animals deviated significantly from chance during this period. It was found that the number of correct trials by dot-positive animals was significantly less than what would be expected by chance (t = 8.87, df = 19, p < .002 two-tailed), while the number of correct trials by dot-negative animals was significantly greater than what would be expected by chance (t = 13.48, df = 19. p < .002 two-tailed). The better than chance performance of the dot-negative animals is what would be expected from the development of discrimination learning, but the worse than chance performance by the dot-positive animals is counter to what might be expected from discrimination learning.

This raised the possibility that there may have been some pre-existing tendency to respond to the blank stimulus display in preference to the display containing the dot. Consequently, a count was made of the number of correct trials by dot-positive and dot-negative animals during the first 10 discrimination trials, and t-tests were performed to determine if either group deviated significantly from chance. During the first 10 discrimination trials dot-positive animals averaged 5.05 correct trials and dot-negative animals averaged 5.3 correct trials. Neither of these means differed significantly from chance ($t < 1$ in both cases). On the basis of these results, it would appear that the worse than chance performance of the dot-positive animals, as well as the better than chance performance of the dot-negative animals, developed during the course of training.

Although neither the main effects due to punishment conditions nor any of the interactions involving the punishment factor achieved significance in the overall analysis, the theoretical importance of punishment again warranted more detailed examination of its role in the results. Since the magnitude of the stimulus effect might be expected to vary with punishment conditions, the simple main effects due to stimulus conditions were calculated from the analysis of variance separately for each punishment condition. The difference between dot-positive and dot-negative animals in the 1 sex delay group was not significant (f =.43, df = 1/32, $p > .05$), while the effects due to stimulus conditions were significant in each of the remaining three punishment groups (3 sec delay - F = 6.87, df = 1/32, $p < .05$; 1.2 ma punishment - F = 5.89, df = 1/32, $p < .05$; 3.8 ma punishment - F = 13.16, df = 1/32, $p < .01$). The basis of these results may be seen in Figure 6, in the lack of separation between the learning curves in the 1 sec delay condition as compared to the remaining punishment conditions.

As in Experiment I, examination of the terminal stages of discrimination performance provided more indication of a relationship between punishment intensity and the magnitude of the stimulus effect. Figure 8 shows the percent correct trials during the last two days of training for dot-positive and dot-negative animals in the different punishment conditions. In general, the terminal discrimination performance was poorer than it was in Experiment I, but again the largest difference between stimulus groups was at the highest punishment intensity. In the dot-negative group the best discrimination performance was at the 3.8 ma punishment intensity, while in the dot-positive group the poorest discrimination performance was at the same punishment intensity.

Statistical analysis provided some support for these observations. In order to provide a design more comparable

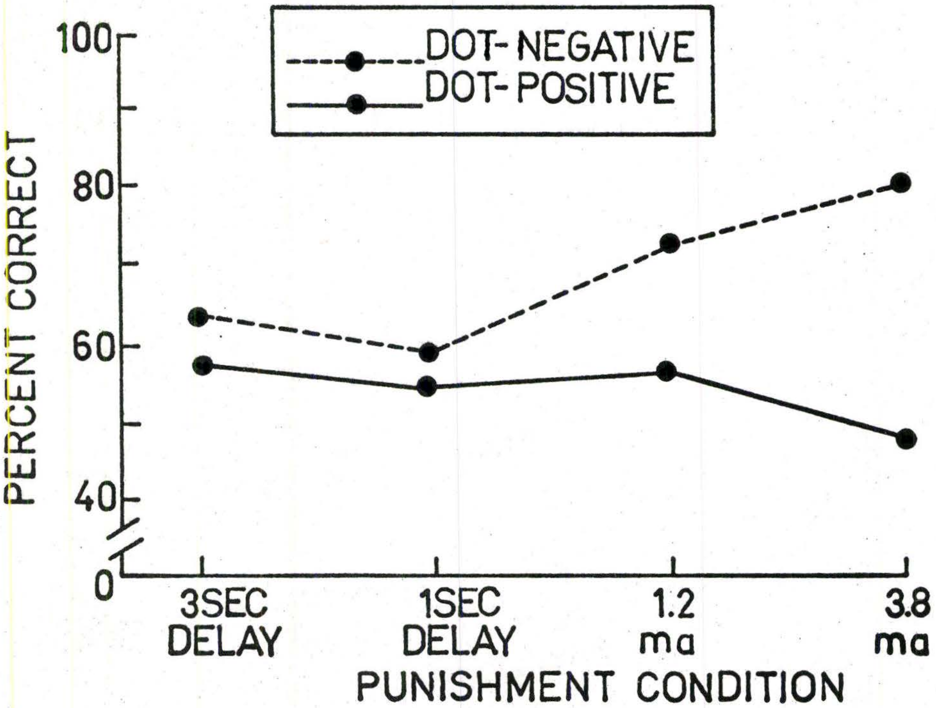

Figure 8. Terminal discrimination performance as a function of punishment conditions.

to that used in the terminal performance analysis of Experiment I, the 3 sec delay condition was excluded and the remaining data were subjected to a 2 x 3 factorial analysis of variance, with two stimulus conditions and three punishment conditions. Because of the unequal group sizes, unweighted cell means were used in the analysis. A summary of the analysis is presented in Table 6. The effect due to stimulus conditions was again significant, and although the effect due to punishment conditions was not significant, there was a significant interaction between stimulus and punishment effects. In order to determine the source of this significant interaction, the simple main effects of stimulus conditions were calculated separately for each punishment condition. The difference between dot-negative and dot-positive groups was not significant in the no-punishment 1 sec delay condition ($F = .09$, $df = 1/22$, $p > .05$) or in the 1.2 ma punishment condition ($F = 2.99$, $df = 1/22$, $p > .05$), while there was a significant difference in the 3.8 ma punishment condition ($F = 13.68$, $df = 1/22$, $p < .01$).

As well as influencing the magnitude of the stimulus effect, punishment should influence the rate of discrimination learning, and this influence may depend on whether or not a distinguishing feature is present on the S-. Therefore, the simple main effects of training were calculated separately for dot-negative and dot-positive animals in each punishment condition. Again the 1 sec delay group differed from all others. In the 1 sec delay group the effects of

Table 6

Analysis of variance on total correct trials on days 14 and and 15 as a function of stimulus and punishment conditions, omitting the 3 sec delay condition.

Source	SS	df	MS	F	P
Stimulus	282.02	1	282.02	11.87	<.01
Punishment	44.79	2	22.40	< 1	
Stimulus x Punishment	162.81	2	81.40	3.43	<.05
Error	522.83	22	23.76		

training were not significant for either the dot-negative animals ($F = 1.66$, df = 14/448, $p > .05$) or the dot-positive animals ($F = 1.58$, df = 14/448, $p > .05$). The effects of training were significant beyond the .05 level of significance for dot-negative and dot-positive animals in each of the other three punishment conditions.

Because of the lack of significant effects due to punishment in the overall analysis of variance, these comparisons involving the punishment factor must be interpreted cautiously, but they would seem to support the suggestion from Experiment I that the effect of punishment differs in the two stimulus conditions, with the result that the magnitude of the stimulus effect is greatest with high intensity punishment.

Errors per error trial: Finally, the number of errors per error trial was again calculated for each animal on each day of training, and an analysis of variance was performed on these scores using a 2 x 4 x 15 factorial design with unweighted cell means. Group mean scores and a summary of the analysis are presented in Table 7. As in the analysis of this measure in the previous experiment, the main effect due to stimulus conditions was not significant. Unlike the previous experiment, however, the main effect due to punishment conditions was also not significant, nor were any of the interactions involving the punishment factor. Again, the main effect due to days of training was significant, indicating that the number of errors per error trial decreased

Table 7

Mean number of errors per error trial on days 1 through 15 as a function of stimulus conditions and punishment conditions

	Punishment condition			
	3 sec delay	1 sec delay	1.2 ma	3.8 ma
Dot-positive	2.90	2.53	2.31	2.51
Dot-negative	2.65	2.04	2.38	1.84

Analysis of variance of the number of errors per error trial for rectangle-positive and line-positive animals

Source	SS	df	MS	F	P
Between Ss					
Stimulus	16.39	1	16.39	2.80	n.s.
Punishment	30.59	3	10.20	1.74	n.s.
Stimulus x Punishment	11.34	3	3.78	< 1	
Between Error	187.56	32	5.86		
Within Ss					
Days	229.99	14	16.43	11.57	< .01
Stimulus x Days	42.18	14	3.01	2.12	< .01
Punishment x Days	34.37	42	.82	< 1	
Stimulus x Punishment x Days	44.21	42	1.05	< 1	
Within Error	638.04	448	1.42		

over days of training, while the significant interaction between stimulus conditions and days of training indicated that the form of the function describing this decrease differed for dot-positive and dot-negative animals.

In order to determine the basis of the significant stimulus by days interaction, the simple main effects due to stimulus conditions were again calculated separately for each day of training. These calculations showed much the same change in the relative performance of animals in the two stimulus groups early and late in training as had been observed in the previous experiment. During the first two days of training, the animals that eventually showed superior discrimination performance (dot-negative condition) made relatively more errors per error trial than did those animals which eventually showed inferior discrimination performance (dot-positive condition). This difference between stimulus groups was not significant on day 1 ($F = 2.09$, $df = 1/32$, $p > .05$), but was significant on day 2 ($F = 6.04$, $df = 1/32$, $p < .05$). During the remainder of training the dot-positive animals made relatively more errors per error trial than the dot-negative animals, although this difference was significant only on day 5 ($F = 5.48$, $df = 1/32$, $p < .05$).

Discussion

The results of this experiment appear to support the hypothesis of predominantly inhibitory control of discriminative escape conditioning, in that the animals with the distinctive feature on the S- showed relatively superior discrimination performance. Animals appear to form a discrimination in an escape or combined escape and punishment procedure more by learning which stimulus to avoid than by learning which stimulus to approach.

This conclusion must be qualified somewhat because of the observation that significant improvement over trials did occur in the dot-positive group. There are at least two ways that this could occur. Learning by the dot-positive animals could indicate that excitatory control by the dot may develop, albeit more slowly than inhibitory control. Alternatively, the learning could indicate that perceptual reorganization occurs in some, or all, of the animals with repeated exposure to the stimuli, so that the rectangle plus dot is perceived as a unitary stimulus, distinct from the rectangle alone. Animals could then learn to inhibit responses to the rectangle alone, and not to the rectangle plus dot. If an effective transfer test could be devised for a discriminative escape procedure, it would be possible to test these alternatives to determine whether or not excitatory control does eventually develop, or whether animals in the dot-positive condition also learn by inhibitory control of discrimination.

The second aim of Experiment II was to determine whether explicit punishment contingencies were necessary for the development of inhibitory control of discrimination, or whether an escape procedure alone would suffice without any increase in aversive stimulation following errors. Because the procedure adopted did not eliminate the possibility of adventitious punishment of errors, the lack of a significant punishment effect in the overall analysis cannot be taken as conclusive evidence that inhibitory control does not require punishment. However, there was suggestive evidence against the necessity of punishment in the ordering of results from the different conditions. If punishment for errors is necessary for the development of predominantly inhibitory control then the smallest stimulus effect should have been found in the 3 sec delay group, followed in order by the 1 sec delay group, and then the 1.2 ma and 3.8 ma punishment groups. The fact that the magnitude of the stimulus effect in the 3 sec delay group was roughly as great as that in the 1.2 ma punishment group, while the stimulus effect in the 1 sec delay group was relatively small, does not appear consistent with an effect requiring punishment for its production.

The poor performance of animals in the 1 sec delay group, relative to the remaining three conditions probably indicates that in a discrimination as difficult as the present one, any stimulus feedback following an error, whether it is a punishment or a 3 sec omission of shock, enhances discrimination learning. Since lever press responses in the present procedure typically occurred immediately after a pulse of shock, incorrect responses in the 1 sec delay procedure did not greatly alter the time between pulses of shock. By comparison either a 3 sec delay, or punishment, could act as an additional cue enhancing the distinctiveness of the S-.

The data on the terminal performance of the 1.2 ma and 3.8 ma punishment intensity groups as compared to the no-punishment 1 sec delay group, are interesting when considered in relation to the Yerkes-Dodson Law. The optimum performance for dot-negative rats was at the highest punishment intensity, while the worst performance for the dot-positive rats was also at the highest punishment intensity. Since the results suggest that the dot-positive discrimination is the more difficult, this could be taken as support for that aspect of the Yerkes-Dodson Law which postulates a lower optimum aversive stimulation intensity for a more difficult discrimination. However, comparison of the present results with those of Experiment I indicates that this interpretation is inadequate. On the basis of terminal discrimination performance, one would have to conclude that the rectangle-positive discrimination task in Experiment I was less difficult than either the dot-positive or dot-negative discrimination tasks in the present experiment, and should therefore have a higher optimum punishment intensity. Yet the rectangle-positive discrimination produced an inverted U-shaped function relating punishment intensity and performance, while the dot-negative condition showed an optimum at the maximum punishment intensity (3.8 ma), even higher than the maximum in Experiment I (2.6 ma). It is evident that the punishment intensity function is determined by more complex factors than absolute difficulty of discrimination. This issue is given further consideration in the General Discussion in Chapter Four.

The third question which was posed in the introduction to this chapter was whether the stimulus effect is necessarily an intensity or a contrast phenomenon. There is, of course, a possibility that intensity and contrast were involved. Although the rectangles were equal in illumination per unit area, the addition of the dot to one rectangle reduced the total light transmitted by that rectangle by approximately 10 percent. It was therefore theoretically possible for the animals to form a discrimination on the basis of brightness or contrast alone. However, the results do not appear consistent with such an interpretation. In Experiment I the animals with the brightest stimulus as the S- showed superior discrimination performance over all but the first 10 trials of training. In the present experiment the animals with the dimmer stimulus as the S- (dot-negative group) showed superior performance. The dot-positive animals, which had the brightest stimulus as the S-, actually performed worse than chance over a large part of training in the present experiment. Thus, while it is possible that rats could form a discrimination on the basis of a 10 percent difference in brightness, given the appropriate conditions, this does not seem likely as an explanation for the present results.

It would seem that the basis for the stimulus effect, in the present experiment at least, is neither intensity nor contrast, but rather the distinctiveness of the feature which controls responding (avoidance in this case) with respect to the other properties that are shared by the S+ and S-. As long as this distinctive feature is associated with the stimulus which controls the response, learning will occur.

This stimulus effect would account for the worse than chance performance of the dot-positive rats. The dot may have functioned as a salient stimulus in the same way as the rectangle did in the first experiment. The presence of the dot on the S+ may have amplified the tendency to avoid that stimulus. If this in fact was the case, one might have expected some evidence of a stimulus salience effect due to the dot during the early trials of training, analogous to the better than chance performance by the rectangle-positive animals and worse than chance performance by the line-positive animals during the first 10 trials of Experiment I. There was no indication of any difference between stimulus conditions, in terms of the number of correct trials during the early trials of the present experiment, but there was some indication of a stimulus salience effect due to the dot in the errors per error trial results. The relatively greater number of errors per error trial by dot-negative animals during the first two days of training may have been due to an amplifying effect of the dot on approach tendencies, prior to the development of strong tendencies to inhibit responses to the dot. It is not clear, however, why such an effect should be observed in the number of multiple errors and not in the overall discrimination performance.

The superior performance by the dot-negative animals also indicates something about how the animals perceptually organized the stimuli. As Sainsbury (1969) points out, describing the discriminative stimuli as identical rectangles differing in the presence or absence of a dot implies a form of perceptual organization that the makeup of the stimuli does not guarantee. For example, the stimuli could be described as a homogeneous area (the blank rectangle) vs. a heterogeneous area (the rectangle with the dot). If the animals used such a holistic analysis of the stimuli there would be no grounds for predicting a difference between the dot-positive and dot-negative conditions, since the distinguishing characteristic could not be attributed to one or another of the stimuli alone. The observed effects suggests that the rats react to the stimuli as displays differing in the presence or absence of a unitary feature, at least during the initial stages of discrimination learning.

CHAPTER FOUR

General Discussion

The following are the main findings of the experiments described in this thesis. First, that the inverted U-shaped function relating discrimination performance and aversive stimulation intensity, which was found in previous escape-punishment procedure experiments, was also found under certain conditions in the present research. However, the conditions which lead to such inverted U-shaped functions, and determine the optimum aversive stimulation intensity, cannot be described as simply as suggested by previous authors. While it has previously been proposed (Yerkes & Dodson, 1908; Broadhurst, 1959) that optimum stimulation intensity is inversely related to discrimination difficulty, the present research indicates that, at least for terminal discrimination performance, optimum punishment intensity was determined less by discrimination difficulty than by the presence of a salient stimulus on the S+ or the S-. Second, the stimulus effect which Annau (1963) had described in an escape procedure involving simple maze learning, was shown to occur in an escape-punishment procedure involving a lever-press response. Third, this effect was most readily interpreted as a stimulus salience effect indicative of a discrimination based primarily on inhibitory control. Fourth, such inhibitory control by the S- did not depend on punishment, although there was indication that the magnitude of the effect was greater with punishment. Fifth, the stimulus salience effect was not simply a stimulus intensity or a contrast effect. Rather it appears more similar to what Jenkins and Sainsbury (1970) have called a feature-positive effect, wherein discrimination performance is controlled by the S+ and successful learning occurs only with a distinguishing feature on the S+. In the present case, discrimination performance appeared to be controlled by the S-, and a distinctive feature on the S- functioned to facilitate discrimination performance (feature-negative effect).

These findings will be discussed under three headings: punishment intensity effects, stimulus salience effects, and relevance to current theories of discrimination.

Punishment Intensity Effects

The data on the effects of varying punishment intensity are unfortunately not as clear cut as one might like. Only in Experiment I was there a significant effect due to punishment intensity in the overall analysis of correct trial scores. This resulted from better discrimination performance with medium intensity punishment than with either no punishment or high intensity punishment. Examination of terminal discrimination performance, however, suggests a somewhat different conception of punishment effects. Although statistical support for individual observations was weak, a number of features recurring in both experiments indicated that the effects of variation in punishment intensity depended on whether a salient stimulus feature was present on the S+ or the S-. Where the salient stimulus feature was on the S+, the poorest terminal discrimination performance in both experiments was at the highest punishment intensity. On the other hand, with the salient stimulus feature on the S- in Experiment II (dot-negative) the best discrimination performance was in the highest intensity punishment group. In Experiment I there was near perfect terminal discrimination performance by all animals with the salient rectangle as S-, so the most that can be said is that high intensity punishment did not disrupt discrimination in this stimulus condition.

Thus it might be argued, on the basis of these observations, that high intensity punishment can facilitate discrimination performance when a salient stimulus is on the S-, or interfere with discrimination performance when a salient stimulus is on the S+. The first of these punishment effects is consistent with the findings of non-discriminative punishment experiments cited earlier, which show that punishment suppresses responses with which it is associated in proportion to its intensity. If punishment is to inhibit errors in discrimination performance it is reasonable to expect a greater punishment effect when there is a salient

S- to acquire inhibitory properties.

With respect to the second of the proposed punishment effects, that is, the adverse effect of high intensity punishment when the salient stimulus is on the S+, two possible interpretations have been advanced, both of which assume an interaction between the effects of escape contingencies and punishment contingencies. According to the first interpretation, the effect of high intensity punishment, in the absence of a salient stimulus on the S-, is to inhibit all responding, resulting in longer escape latencies and resultant higher escape shock intensities. Since previous research (Annau, 1963; Hammes, 1956) has indicated that optimum performance occurs at near threshold escape shock intensity, this could account for the adverse effect of high intensity punishment. Although response latency scores in the present research were highly variable, there was some support for this interpretation in the significant negative correlation between escape latency and discrimination performance in Experiment I. The second interpretation distinguishes between response specific effects of punishment, leading to suppression of errors, and more general emotional effects of punishment, which in combination with the effects of the shock from which the animals escape might interfere with discrimination performance. Again, the absence of a salient stimulus on the S- should reduce the response specific effects of punishment, and allow the more general disrupting effects of punishment to predominate.

A direct indication of the disruptive effects of high intensity punishment may be seen in the second pilot experiment in Appendix A. When the shock from which the rats escaped was fixed at a relatively high intensity, rather than gradually increasing throughout the trial, half of the animals in the high intensity punishment condition stopped responding completely at the beginning of discrimination training. This outcome appears consistent with the suggestion that high intensity punishment tends to suppress all responding.

In summary, the findings of the present experiments with respect to punishment intensity must be regarded as indicative of factors requiring control in future research, rather than a basis for complete resolution of uncertainty with respect to the Yerkes-Dodson Law. First, while previous research in this area has dealt with the general concept of aversive stimulation intensity (Broadhurst, 1959), the present research suggests that variation in the intensity of shock from which animals escape may produce effects on discrimination performance opposite to those resulting from variation in the intensity of punishment for errors. A major part of the variability in the results of both the present and previous experiments classified as escape-punishment procedures probably results from a lack of control over both of these factors. Second, the present research suggests that as a determinant of the effects of punishment intensity, general difficulty of discrimination is less important than the relative salience of specific features of the S+ and the S-.

Stimulus Salience Effects

The present research followed an expermient by Annau (1963) in which he found that discriminative escape performance was affected by the brightness of the visual stimuli, and that the direction of this effect differed early and late in learning. During early stages of training he found that the discrimination performance of animals with the brighter of two stimuli as S+ was superior to the performance of animals with the dimmer of the two stimuli as S+. During the last 60 trials of training he found that the discrimination performance by animals with the dimmer stimulus as S+ was superior to the performance of animals with the brighter stimulus as S+.

This reversal of relative superiority of stimulus groups early and late in training appeared similar to the results of a series of transfer experiments by Lashley and Wade (1946), in which they found that animals with a previously positive stimulus as S- in a new discrimination task learned more rapidly than animals with the same stimulus as S+. Grice (1948, 1951) argued that this finding was due to the aversive consequences of errors in the Lashley and Wade jumping-stand procedure. The animals with the previously positive stimulus as S- in a new discrimination presumably made more errors early in training and learned more rapidly to inhibit responses to this stimulus.

Since errors in a discriminative escape procedure could also have aversive consequences through contiguity with continued shock, it was felt that a similar explanation could account for Annau's observation of relatively superior performance late in training by dark-positive animals following the relatively greater number of errors by this group early in training. That is, the dark-positive animals could have learned to inhibit responses to the light S- because of aversive consequences of the large number of responses to the light early in training.

As possible explanations for the initial superiority of light-positive animals, three hypotheses were outlined which have been offered in the literature to account for the stimulus intensity dynamism effect in appetitively based discriminations. These hypotheses were identified as the stimulus intensity hypothesis, the contrast hypothesis, and the attention hypothesis.

The stimulus intensity hypothesis (Hull, 1949) postulates an energizing effect of stimulus intensity on the strength of a response to that stimulus. This would result in a greater tendency to respond to the brighter of two stimuli, and consequently superior discrimination performance by animals with a bright S+ as opposed to animals with a bright S-.

According to the contrast hypothesis (Logan, 1954;

Perkins, 1953), superior discrimination would be expected by animals with a relatively bright S+ only if the background stimuli in the apparatus were dark. In this case learned inhibition of responses to the context would generalize less to the bright stimulus than to the darker S-, thereby increasing the probability of responding to the S+.

Contrast is also the determining stimulus characteristic according to the attention hypothesis (Nygaard, 1958), but it is assumed to facilitate attention rather than determine response tendencies directly. Presumably before animals can learn a discrimination based on stimuli differing in brightness, they must learn to attend to brightness rather than to irrelevant dimensions such as position. Use of a highly contrasting bright stimulus as S+ increases the likelihood that animals will attend to brightness when a reinforced response occurs, thus strengthening attention to that dimension. On the other hand, with a less contrasting dim stimulus as S+ (and a bright stimulus as S-) animals would be less likely to attend to brightness during a reinforced response, and so the prerequisite consistent attention, and subsequent discrimination, would be slow to develop.

The results of Experiment I demonstrated that both aspects of Annau's findings regarding the effects of stimulus brightness on discrimination in an escape procedure with a maze-running response also occurred in an escape-punishment procedure with a lever-press response.

The initial superiority of the rectangle-positive animals was not simply a result of more rapid learning by these animals, as the attention hypothesis would suggest, but rather appeared to be a performance effect dependant on a pre-existing tendency to respond to the rectangle in preference to the line. Not only did the rectangle-positive animals perform better than chance during the first 10 trials, but the line-positive animals performed worse than chance. Although better than chance performance by rectangle-positive animals could have been due to learning, their performance was poorer on the second day of training than on the first, which seems inconsistent with such an interpretation, and the worse than chance performance by the line-positive animals was in the opposite direction to what would be expected from learning. Since such a performance effect would be consistent with either the stimulus intensity hypothesis or the contrast hypothesis it was labelled a stimulus salience effect.

With respect to the second aspect of the stimulus effect, however, it does not seem likely that the relative superiority of the line-positive animals late in training can be regarded as a consequence of the greater number of errors by this group early in training, as was hypothesized to account for the analogous finding in Annau's experiment. Although the line-positive animals in the present research made relatively more errors during early trials, and might therefore have learned more rapidly to inhibit responses to the S-, there appears no reason why any superiority in discrimination resulting from such a process should persist over the number of trials used in Experiment I.

The alternative explanation offered is that the relatively superior performance of line-positive animals throughout all but the early trials of training was itself a stimulus salience effect, rather than simply a consequence of the initial difference between groups. A stimulus salience effect could account for the present results if it was assumed that discrimination in the present procedure developed primarily through inhibitory control. If animals acquired the discrimination by learning to avoid the S-, then such avoidance learning should be more effective with a highly salient S-. Thus, the initial superiority of the rectangle-positive animals could be classed as an excitatory stimulus salience effect, and the later superiority of the line-positive animals could be classed as an inhibitory stimulus salience effect. The transition from one to the other would presumably be due to the aversive effects of incorrect responses, first experienced during early discrimination training trials.

In Experiment II the hypothesis of predominantly inhibitory control was tested by training animals to discriminate between stimuli that were identical except for the presence of a distinguishing feature (a black dot) on either the S+ or the S-. As predicted, the animals with the distinguishing feature on the S- (dot-negative) showed superior discrimination learning.

A second question which Experiment II attempted to answer was whether the inhibitory control observed in the present research was dependent on punishment. It has already been pointed out that there is some indication that the magnitude of the stimulus effect, which presumably is indicative of inhibitory control, varies with punishment intensity, but this does not indicate that punishment is essential. Because of the use of gradually increasing shock to maintain escape responding, it is not possible to conclude definitely that punishment, as defined as an increase in aversive stimulation following an error, is unnecessary for the development of predominantly inhibitory control. However, the fact that the magnitude of the stimulus effect in Experiment II was approximately as large as in the 3 sec delay group as in the 1.2 ma punishment group suggests that punishment is not essential. This conclusion is supported by Annau's (1963) observation of similar stimulus effects in an escape procedure where there was no increase in aversive stimulation intensity following responses to S-.

Given that both excitatory and inhibitory stimulus salience effects are possible, and that there is some evidence for both in the present research, the question remains as to the basis of the effects. Although both the stimulus intensity hypothesis and the contrast hypothesis are consistent with the excitatory stimulus intensity effect observed during the early trials of Experiment I, neither of these hypotheses are adequate to deal with the inhibitory stimulus salience effects observed in Experiment I and Experiment II.

First of all, research done with appetitive discrimination, which was cited previously, indicates that contrast rather than stimulus intensity per se is the basis of the excitatory stimulus salience effect. However, since the contrast hypothesis as stated by Logan (1954) and Perkins (1953) accounts for an excitatory stimulus salience effect on the basis of less generalization of inhibition from the background to a highly contrasting stimulus, it does not seem compatible with an inhibitory stimulus salience effect. Generalization from the background cannot account for greater avoidance tendencies with a more contrasting stimulus. Secondly, neither intensity or contrast, in the usual sense, appear relevant to the stimulus effect in Experiment II. In this case the results can best be described as superior discrimination when the S- contains a feature (a black dot) which is perceptually distinctive relative to other properties shared by the S+ and the S-. A similar analysis stressing perceptual distinctiveness can be applied to the inhibitory stimulus salience effect in Experiment II. That is, the rectangle could be considered a feature of the S- which is perceptually distinctive (perhaps as a result of contrast) relative to other properties shared by the S+ and the S-, such as spatial location.

There are two ways in which a perceptually distinctive or salient, stimulus could lead to an inhibitory stimulus salience effect. The relatively superior performance of the line-positive animals throughout most of Experiment I and the dot-negative animals in Experiment II could have resulted from more rapid learning to inhibit responses to a salient feature on the S-. Alternatively, the more salient rectangle or dot could have had an amplifying effect on tendencies to inhibit responses to the lever with which it was paired, irrespective of whether the salient stimulus was on the S+ or the S-. The first of these alternatives could be classed as a learning effect, and the second a performance effect.

There are a number of reasons why the alternative of a performance effect on inhibitory tendencies is to be preferred. Since the excitatory stimulus salience effect during the dirst 10 trials of Experiment I appeared to be a performance effect, it is more parsimonious to assume that the basis of the inhibitory stimulus salience effect is the same. Also, both the decrement in the discrimination performance of the rectangle-positive animals on day 2 of Experiment I, and the worse than chance performance of dot-positive animals during the first half of Experiment II, appear more consistent with an amplification of inhibitory tendencies in these groups than with slower learning. Finally, experiments (Heyman, 1957; Kamin, 1965) which have tested for effects of stimulus salience on learning by changing stimuli during extinction have shown no effects which could be attributed to learning.

Perhaps the most interesting question raised by the present research is whether excitatory control eventually develops in aversively controlled discrimination, or whether the discrimination is learned and maintained solely on the basis of inhibitory control. A number of authors (Biederman, 1967; Mandler, 1968; Suter, 1970) who have observed predominantly inhibitory control during the early stages of learning in appetitively based discrimination, suggest that later in training the aversiveness of the S- declines and excitatory control by the S+ comes to predominate. The present research provided no evidence for eventual development of excitatory control, although the improvement in performance over trials by the dot-positive animals in Experiment II may have been due to such a shift. If excitatory control does not develop in aversively controlled discrimination it would suggest that shock termination does not reinforce responses which produce it, as two-factor theorists (Mowrer, 1960; Schoenfeld, 1950; Solomon & Wynne, 1954) contend.

Several recent theorists (Estes, 1969; Church, 1963, 1969; Logan, 1969; Rachlin & Herrnstein, 1969) have argued that punishment acts directly to suppress responses which it follows rather than through mediated reinforcement of alternative behavior, as suggested by two-factor theory (Dinsmoor, 1954; Solomon, 1964). While Rachlin and Herrnstein (1969) have described this suppressive effect of punishment as a negative law of effect, it is relatively unusual to apply this concept to escape behavior as Bolles and McGillis (1968) have done, and suggest that escape responding is learned through the suppression by punishment of all behavior but the correct response. However, if escape learning does develop through the action of a negative law of effect, then one might expect to find persistent inhibitory control in discriminative escape learning.

Although, as Rachlin and Herrnstein (1969) point out, it is difficult to devise a test which would distinguish between a negative law of effect and a two-factor theory interpretation of the role of aversive stimulation, testing for stimulus control after extended discriminative escape training appears to be a promising method of providing such a test. Further research to determine whether transfer tests would accomplish this purpose clearly seems called for.

In summary, the investigation of the effects of stimulus characteristics in the present research has produced four main findings. First, as was the case in a previous escape conditioning procedure (Annau, 1963), both excitatory and inhibitory stimulus salience effects were found in an escape-punishment procedure. The excitatory stimulus salience effect occurred only during early trials of training and was clearly evident only in the first experiment, while the inhibitory stimulus salience effect predominated throughout most of both experiments. Second, discriminative escape conditioning appeared to develop primarily through inhibitory control. Third, punishment was not essential for development of inhibitory control. Fourth, the stimulus effect was dependant on more general perceptual variables than implied by the stimulus intensity hypothesis (Hull, 1949) or the contrast hypothesis (Logan, 1954; Perkins, 1953).

Relevance to Current Theories of Discrimination Learning

A point of terminology should first be clarified with respect to the inhibitory stimulus salience effect. The relative superiority of the dot-negative or the line-positive animals in the present research can be classed as an inhibitory effect only in the sense that lever-press responses to the rectangle or the dot are reduced. If it is assumed that the basis of this reduction is active avoidance of the S-, then the stimulus effect is excitatory rather than inhibitory. The common description of two choice discrimination learning in terms of excitatory control by the S+ and inhibitory control by the S- obscures the question of whether the control by the S- is a "passive" reduction in excitatory strength or an active suppression of responding (See Jenkins, 1965 for a discussion of this question).

At least two previous theorists have argued not only for an active response suppression by the S-, but for its predominance in discrimination learning. Amsel (1962) suggested that frustrative non-reward produces active suppression of responses to the S- and is the main mechanism of discrimination learning. Harlow (Harlow & Hicks, 1957) advocates a uniprocess theory of discrimination in which non-reward is the only basis of discrimination learning. However, both these theories deal with appetitively based discrimination, and assume prior excitatory control in opposition to the active inhibitory process. The use of aversive stimulation alone in the present research means the assumption of an opposing excitatory process is not necessary, and there is some evidence against its presence.

This illustrates a general problem in relating the results of the present research to current theories of discrimination learning. The majority of the research on discrimination learning has involved appetitively based discrimination procedures, with the result that most theorists have not directly considered the implications of aversive control of discrimination. For example, although stimulus salience has been a major concern of selective attention theorists in general (Lovejoy, 1968; Sutherland, 1964; Trabasso & Bower, 1968; Zeaman & House, 1963), making them particularly relevant to the present research, none of these theorists has dealt with the use of either escape or combined escape and punishment procedures. Although the different versions of selective attention theory vary somewhat in the rules proposed for shifting attention, all are similar to the version of attention theory previously outlined (Nygaard, 1958) in that they subscribe to what Trabasso and Bower call a "win-stay, lose-shift" principle. Attention is assumed to be strengthened by reinforcment, and weakened by non-reinforcement.

If the reinforcement in aversively controlled discrimination learning is provided by shock termination, then learning should develop most rapidly with the most salient stimulus as S+. Since the present research indicates that animals learn the discrimination more rapidly with either the salient stimulus or the distinguishing feature as S-, it would appear necessary to assume that in an aversively controlled procedure attention to the relevant stimulus dimension is strengthened by punishment or the continuation of aversive stimulation following a response. Similarly, in order to weaken attention to irrelevant stimulus dimensions, it would be necessary to assume that attention is weakened by the absence of punishment.

This seems an indefensible position, since it implies that the development of discrimination learning, with the consequent reduction in punished responses, would lead to the extinction of attention to the stimulus dimension on which the discrimination is based. If attention to brightness, for example, was strengthened by punishment, then development of discrimination based on brightness would have eliminated punishment and should then have led to extinction of attention to brightness. To some extent, this contradictory position could be avoided by postulating attention to stimulus features, rather than dimensions, so that the lack of punishment following a correct response would not directly affect attention to features present only on S-.

A further problem with attention theories, however, is that they regard stimulus salience as a determinant of attention alone, and through attention, an influence on the rate of learning. This treatment of stimulus salience as a determinant of the rate of learning is similar to that found in some stochastic learning models which do not employ mechanisms for shifting attention (Bush & Mosteller, 1955; Extes, 1959). The evidence from the present research, however, indicates that, at least the initial excitatory stimulus salience effect, resulted not from more rapid learning with a more salient stimulus as S+ but from a greater probability of responding to the salient stimulus when it was first presented.

Jenkins and Sainsbury (1970) propose a model of discrimination learning basically similar to selective attention theory, but which allows for control of discrimination performance by stimulus features rather than dimensions, and also postulates stimulus salience as a determinant of response tendencies rather than the rate of learning. Since in discrimination experiments with pigeons, the discriminative stimuli are typically projected directly on the response key at which the bird pecks, Jenkins and Sainsbury are able to avoid the use of the term "attention" as an intervening variable and deal directly with control of responses by stimulus features. They assume that responses are directed towards specific features within a compound stimulus, and that the effects of reinforcement or non-reinforcement accrue to the feature to which the response is made, rather than to the stimulus as a whole or to all its components. Reinforcement increases the probability of a response to a stimulus feature, while non-reinforcement decreases it. Also it is assumed that the probability of a response to a salient stimulus is higher than the probability of a response to a less salient stimulus.

The Jenkins and Sainsbury model of discrimination learning was formulated to account for what was earlier described as feature-positive effect, that is, superior discrimination learning by pigeons trained with a distinguishing feature only on the S+ compared to a distinguishing feature only on the S-. In the condition with the distinguishing feature on S+ (feature-positive) responses made to the distinguishing feature would always be reinforced while responses made to stimulus features common to both S+ and S- would at best be reinforced only 50 percent of the time. Consequently, over trials, responses made to the S+ should come to be directed to the distinguishing feature rather than to the common features, reducing even further the proportion of responses to the common features that would be reinforced. The result would be a positive feedback process culminating in extinction of responses to the common stimulus features, and therefore successful discrimination learning. On the other hand, with a distinguishing feature on the S- (feature-negative), responses to the distinguishing feature would never be reinforced and so should extinguish, while responses to stimuli common to both the S+ and the S- would receive partial reinforcement and so should be maintained.

Not only does this model provide an explanation for the failure of discrimination to develop in the feature-negative condition, but it is also consistent with recordings which Jenkins and Sainsbury made of the location of peck responses within the stimulus displays. Before the development of accurate discrimination performance in the feature-positive condition, peck responses came to be directed to the distinguishing feature, rather than distributed randomly about the response key as was the case early in training. In contrast, in the feature-negative condition, responses were shifted away from the distinguishing feature to the illuminated surround, and discrimination between S+ and S- did not develop.

At least two modifications would be necessary to apply the Jenkins and Sainsbury model of discrimination learning to the present data. First, since the stimulus which apparently controlled discrimination performance in the present research (the S-) was not the stimulus to which the observable response was directed, as was the case in the Jenkins and Sainsbury procedure, it is necessary to introduce some concept such as attention as an intervening variable. Second, as with other selective attention theories, it must be assumed that attention is strengthened by punishment, rather than reinforcement, and weakened by the omission of punishment.

Although, given these modifications, the Jenkins and Sainsbury model appears to be consistent with the major features of the present results, there is theoretical reason to question the validity of such an attention model, and one aspect of the results of Experiment II supports this questioning. It seems unreasonable to equate stimulus control with attention, in a situation such as the present, where the stimulus apparently controlling discrimination performance is not the one to which the observable response is made. If the rats attended to features of the S- alone, this would imply that they somehow responded to the S+ without attending to it. Also, the worse than chance performance of the dot-positive animals in Experiment II suggests that animals do not attend selectively to those stimulus features associated with punishment. Since responses made to the dot would not have been punished, while responses to stimulus features common to both S+ and S- would have been punished at least some of the time, application of the modified Jenkins and Sainsbury model of discrimination learning would predict attention to the common stimulus features rather than the dot. However, the rats apparently not only attended to the dot, but also avoided it.

Although the foregoing cannot be regarded as a comprehensive review of current theories of discrimination learning, it illustrates the general difficulty in adapting theories derived from appetitively based research to account for aversively controlled discrimination. Formulation of a detailed theory of discrimination based on aversive control is beyond the scope of this thesis, however the minimum assumptions necessary to account for the stimulus effects in the present research are; predominantly inhibitory control of discrimination learning, without selective attention, but with amplification of response tendencies, whether approach or avoidance, by a highly salient stimulus.

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APPENDIX A

Pilot Experiment I

It was previously suggested that, because the present research employed gradually increasing intermittent shock to maintain escape responding, the nominally no-punishment groups in Experiment I do not provide an adequate baseline against which to assess the effects of punishment for incorrect responses. Since punishment in a combined escape and punishment procedure has been operationally defined as an increase in the intensity of aversive stimulation following an incorrect response, there were two possible sources of punishment in the nominally no-punishment group.

First, because of the gradually increasing shock, the intensity of aversive stimulation after incorrect responses was higher than that before. Although the magnitude of this difference was small, it may have contributed to active suppression of errors. A second, and possibly more important, source of punishment derives from the intermittent nature of the shock. Although the differences in intensity between successive pulses of shock was relatively small, for any incorrect responses which occurred during the interval between pulses the onset of the next pulse of shock represented a substantial increase over the intensity of aversive stimulation present at the time of the response. Because of this increase, an intermittent shock procedure may produce more active suppression of errors than would a continuous shock procedure.

Neither of these potential sources of punishment was contingent on the occurrence of incorrect responses, but there is evidence (Church, 1969) that contiguity between a response and a source of punishment is sufficient to produce response suppression.

It was decided to eliminate the two possible sources of adventitious punishment one at a time, in an attempt to develop a procedure which would provide a clearer no-punishment baseline and still maintain effective discriminative escape learning. Accordingly, in the following pilot experiment, continuous rather than intermittent escape shock was used, but the gradual increase in shock intensity over time was retained.

Method

Subjects and apparatus: The subjects were 20 naive male hooded rats, weighing between 250 and 400 g at the start of the experiment.

The apparatus and the discriminative stimuli were identical to that used in Experiment II. Escape responding was maintained by gradually increasing continuous shock with the same maximum intensity (1.2 ma) as that used in Experiment II.

Training: The training procedures were the same as in Experiment II, with 40 simple escape pretraining trials, and 300 discrimination training trials. The animals were randomly assigned to one of two punishment conditions which differed in the consequences of incorrect responses. In one condition incorrect responses were followed by an immediate 100 msec pulse of 3.8 ma shock, while in the second condition incorrect responses had no programmed consequence. As before, half of the animals in each punishment condition had the rectangle with the black dot as S+ and the blank rectangle as S-, while the response requirements were reversed for the remaining half of the animals.

Results

There was no indication of development of discrimination learning in any of the experimental groups in this experiment. The number of correct trials per day was again used as the index of discrimination learning. An analysis of variance was performed on these scores, using a 2 x 2 x 15 factorial design similar to that employed in the previous experiments. A summary of the results of this analysis is presented in Table 8. There were no significant effects due to any of the experimental factors.

Discussion

The lack of discrimination learning in the present experiment was probably due partly to the difficulty of the discrimination task and partly to the use of continuous

Table 8

Analysis of variance on the number of correct trials per day as a function of stimulus conditions and punishment conditions

Source	SS	df	MS	F	P
Between Ss	142.88	19			
Stimulus	15.42	1	15.42	2.21	n.s.
Punishment	11.22	1	11.22	1.61	n.s.
Stimulus x Punishment	4.8	1	4.8	< 1	
Between Error	111.44	16	6.96		
Within Ss	1,117.07	280			
Days	51.35	14	3.67	< 1	
Stimulus x Days	50.18	14	3.58	< 1	
Punishment x Days	94.78	14	6.77	1.74	n.s.
Stimulus x Punishment x Days	48.2	14	3.44	< 1	
Within Error	872.56	224	3.90		

electric shock to maintain escape responding. The fact that successful discrimination learning was obtained in Experiment II with the same discriminative stimuli indicates that the present lack of learning cannot be attributed to discrimination difficulty alone.

The poorer discrimination performance with continuous shock as compared to intermittent shock is apparently analogous to the decrement in discriminative escape learning produced by increased shock intensity (Annau, 1963; Hammes, 1956). Increasing the duration of the shock from which animals escape may disrupt discrimination performance in the same way as increasing the intensity of the shock from which animals escape. Such a similarity in the effects due to duration and intensity of shock has previously been observed in research on punishment (Church, 1969; Wischner & Fowler, 1964).

Because of the lack of discrimination learning with continuous shock, the second pilot study reverted to intermittent shock, but eliminated the gradual increase in intensity.

Pilot Experiment II

As a second attempt to obtain a no-punishment baseline, the following experiment employed intermittent shock fixed at a single intensity. To further reduce the possibility of adventitious punishment of errors in the no-punishment condition, the onset of the next pulse of shock following an incorrect response was delayed.

Method

Subjects and apparatus: The subjects were 24 naive male hooded rats, weighing between 250 and 400 g at the start of the experiment. Six animals had to be eliminated because of failure to respond on the first day of discrimination training.

The apparatus and discriminative stimuli were identical to that used in the continuous shock pilot experiment. The shock from which the animals escaped was fixed at the maximum intensity to which escape shock could increase in the previous experiment (1.2 ma), and was delivered in 100 msec pulses at the rate of one per sec.

Training: The training procedure was identical to that in the previous experiment, but only 14 days of discrimination training (280 trials) were given. For half of the animals an incorrect response produced an immediate 100 msec pulse of 3.8 ma punishment, while for the remaining half incorrect responses were not punished, and instead postponed the onset of the next pulse of shock for 3 sec. For half of the animals in each punishment condition the dot was on S+, and for the remaining half the dot was on S-.

Results

On the first day of discrimination training, 6 of the 12 animals in the 3.8 ma punishment condition failed to respond and had to be eliminated. Of the remaining 6 animals in this condition, 3 were dot-positive animals and 3 were dot-negative animals.

Again there was no indication of discrimination learning in any of the experimental conditions. A 2 x 2 x 14 factorial analysis of variance was performed on the correct trial scores. Because the number of animals eliminated on the first day of training appeared to be a function of the experimental condition, the least squares method of analysis of variance was used. A summary of the results of the analysis is presented in Table 9. There were no significant effects due to any of the experimental factors.

Table 9

Analysis of variance on the number of correct trials per day as a function of stimulus conditions and punishment conditions

Source	SS	df	MS	F	P
Between Ss	105.37	17			
Stimulus	.78	1	.78	< 1	
Punishment	19.84	1	19.84	3.63	n.s.
Stimulus x Punishment	8.13	1	8.13	1.48	n.s.
Between Error	76.62	14	5.47		
Within Ss	897.57	234			
Days	38.94	13	3.00	< 1	
Stimulus x Days	85.22	13	6.56	1.85	n.s.
Punishment x Days	61.49	13	4.73	1.33	n.s.
Stimulus x Punishment x days	66.21	13	5.09	1.43	n.s.
Within Error	645.71	182	3.55		

Discussion

Two points should be noted with respect to the present results. First, the lack of discrimination learning was probably due to the disruptive effects of the higher intensity shock from which the animals escaped. In the experiments employing gradually increasing shock, the response thresholds were typically well below the maximum possible intensity except during the first few discrimination trials.

Second, the fact that half of the animals in the 3.8 ma punishment condition failed to respond during the first day of discrimination training suggests that a gradual increase in escape shock may be necessary to overcome the suppressive effects of punishment on responding. It may be, as previous authors have suggested (Hineline & Rachlin, 1969), that responding in a gradually increasing shock procedure is based at least partially on avoidance of higher intensity shock rather than simply escape from the ongoing shock.

RAW DATA FOR PILOT EXPERIMENTS I & II

Pilot Experiment I

Correct Trials Per Day

Dot Positive

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No Pun.	9	9	11	9	10	11	9	11	14	10	6	11	9	12	8	9
	10	13	8	11	11	6	11	11	8	10	11	11	12	13	7	11
	11	10	10	12	7	8	10	9	11	7	11	9	11	12	9	12
	12	10	10	11	9	12	9	12	12	13	9	10	8	11	10	11
	17	9	8	13	9	15	6	8	11	8	11	11	12	10	14	5
3.8 ma Pun.	21	7	13	10	14	10	11	10	13	8	13	10	9	10	8	11
	22	8	11	8	9	7	10	9	11	8	10	8	10	5	9	10
	5	6	10	8	10	7	10	7	7	8	8	10	9	10	11	8
	6	8	9	10	8	6	7	8	9	10	10	10	10	10	14	14
	19	7	10	12	11	9	9	8	14	9	12	12	6	10	9	10

Dot Negative

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No Pun.	13	13	8	10	9	9	8	9	11	12	10	11	9	8	14	9
	14	10	7	12	6	9	10	9	11	12	10	8	11	10	10	10
	15	12	9	10	12	14	11	13	11	11	9	13	12	9	14	12
	16	8	9	9	9	17	9	11	15	11	12	7	8	9	7	11
	18	11	11	10	10	8	11	8	10	10	11	9	10	13	11	11
3.8 ma Pun.	3	10	10	10	11	11	8	15	11	11	10	13	10	10	10	8
	4	13	12	5	11	10	13	10	10	8	10	12	11	11	10	12
	7	10	9	8	15	13	10	9	12	5	12	16	9	8	8	10
	8	11	9	10	10	12	12	10	10	10	13	11	9	12	14	10
	20	7	10	9	5	8	10	8	10	11	10	10	6	9	5	12

Pilot Experiment I

Error Responses Per Day

Dot Positive

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No Pun.	9	34	15	14	20	33	16	10	11	13	22	14	17	12	16	20
	10	45	31	28	16	18	21	13	22	15	9	13	8	11	23	11
	11	21	17	24	28	33	19	18	10	18	13	17	12	9	14	8
	12	44	18	27	19	16	18	8	14	10	12	13	19	12	12	10
	17	45	22	12	36	9	24	18	12	18	15	16	11	17	9	24
3.8 ma Pun.	21	49	16	26	22	35	21	15	11	22	20	25	18	26	29	24
	22	35	21	27	19	43	23	21	16	21	18	17	14	21	21	19
	5	45	30	30	16		25	18	15	14	18	13	14	13	16	16
	6	50	33	25	28	24	24	30	22	13	20	16	19	18	7	13
	19	26	27	13	26	16	15	22	11	16	14	11	22	16	15	13

Dot Negative

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No Pun.	13	44	43	19	21	29	20	19	15	12	14	16	16	19	8	16
	14	35	48	23	29	26	14	21	18	16	17	29	23	28	21	27
	15	27	26	17	27	20	20	13	20	11	15	9	9	20	8	10
	16	35	49	39	20	5	21	24	23	24	23	33	31	25	28	23
	18	18	21	27	21	27	19	20	15	13	12	16	14	8	15	14
3.8 ma Pun.	3	23	11	15	13	12	16	7	17	11	13	11	13	10	13	18
	4	34	18	28	11	18	8	15	33	17	20	10	16	18	13	14
	7	49	79	31	9	10	21	29	23	38	22	13	26	25	19	18
	8	28	33	25	20	15	16	12	13	14	10	14	15	9	7	10

Pilot Experiment II

Correct Trials Per Day

Dot Positive

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	1	11	12	11	11	13	12	9	10	11	12	11	13	10	12
No	2	10	10	10	11	11	12	11	14	13	10	9	12	10	13
Pun.	3	11	9	9	13	10	10	13	12	11	10	9	12	9	9
3 sec	4	11	12	10	6	8	10	11	10	7	9	6	12	8	9
Delay	22	8	13	12	12	11	11	12	10	11	9	11	11	11	12
	21	15	13	11	10	13	8	10	11	10	12	9	11	8	9
	7	11	12	8	11	10	6	10	7	11	10	12	10	11	10
3.8	17	11	9	12	10	7	10	7	8	10	11	8	9	7	7
ma	18	9	13	5	11	12	13	9	8	9	11	9	10	10	12
Pun.															

Dot Negative

	13	10	5	11	10	12	15	9	13	10	11	14	11	13	11
No	14	10	10	6	12	13	11	9	10	8	7	13	14	13	7
Pun	15	11	8	11	10	14	9	9	12	7	14	11	12	4	11
3 sec	16	11	11	9	10	11	12	12	10	9	10	11	10	12	8
Delay	29	10	11	11	9	13	8	8	13	10	14	9	11	13	11
	23	13	13	8	10	5	11	6	9	12	11	10	9	11	6
	9	13	10	7	12	6	11	14	11	13	10	8	11	13	10
3.8	10	8	6	10	14	12	10	11	6	11	7	10	11	11	10
ma	20	9	9	12	13	7	10	10	11	11	9	13	11	11	10
Pun.															

Pilot Experiment II

Error Responses Per Day

Dot Positive

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	1	81	101	43	88	21	26	37	23	13	57	17	11	19	17
No Pun.	2	37	33	30	18	16	16	21	11	10	15	20	15	12	8
3 sec	3	94	259	84	34	31	15	26	13	16	18	19	12	14	21
Delay	4	52	14	19	44	28	20	12	19	24	14	18	14	18	14
	22	110	33	50	22	26	46	35	18	19	21	12	14	9	12
	21	12	37	14	18	11	25	16	14	15	13	16	10	16	16
	7	28	19	27	13	21	24	18	21	15	15	10	25	18	27
3.8 ma	17	27	23	24	23	30	25	25	31	19	23	17	21	32	25
Pun.	18	25	18	38	38	16	11	25	30	19	17	18	18	14	15

Dot Negative

	13	173	83	39	31	21	7	27	13	21	11	7	15	8	16
No Pun.	14	139	32	25	13	11	21	24	17	17	21	7	7	17	16
3 sec.	15	59	36	17	22	14	23	27	11	16	8	17	14	9	25
Delay	16	57	27	21	21	11	13	15	19	23	24	17	14	11	13
	29	36	47	45	41	13	22	21	15	12	10	15	26	11	15
	23	26	39	47	31	25	14	25	18	13	12	11	12	13	16
	9	25	34	38	13	26	14	10	11	9	17	17	13	10	16
3.8 ma	10	34	37	34	8	15	17	18	25	19	29	16	19	19	15
Pun.	20	27	23	21	12	24	16	16	11	22	15	10	16	10	13

APPENDIX B

RAW DATA FOR EXPERIMENT I

Correct Trials Per Day

(day 1 - 10 trials, days 2 to 9 - 20 trials)

Rectangle Positive

	Subjects	1	2	3	4	5	6	7	8	9
No Pun.	1a	6	11	14	13	14	20	18	17	19
	4a	6	9	8	12	12	10	12	13	16
	2b	6	13	16	13	13	17	18	17	20
	3b	6	12	8	11	16	13	12	14	16
1.6 ma Pun.	4b	5	9	8	9	12	19	19	19	18
	5b	8	12	15	14	12	15	18	18	18
	7c	8	17	17	19	19	20	20	19	19
	9c	9	12	16	19	20	20	19	19	20
2.6 ma Pun.	3a	9	11	8	11	11	10	14	11	10
	9a	6	10	9	14	13	17	16	19	19
	3c	5	10	12	10	12	10	10	10	10
	4c	6	8	7	13	15	16	18	19	19

Line Positive

No Pun.	5a	1	8	13	20	19	18	18	19	20
	8a	5	11	13	15	15	19	19	20	20
	1b	5	11	10	12	13	14	18	16	19
	6b	4	13	18	18	17	19	19	20	20
1.6 ma Pun.	7b	3	13	12	17	19	20	20	20	20
	9b	2	14	17	16	17	20	20	20	20
	5c	2	11	18	19	19	20	20	18	20
	6c	2	20	19	19	20	20	20	20	19
2.6 ma Pun.	2a	4	11	11	16	13	14	16	19	19
	6a	3	8	12	11	14	17	17	19	20
	1c	5	13	14	20	19	20	19	20	20
	2c	3	15	14	16	19	19	19	20	20

Error Responses Per Day

(day 1 - 10 trials, days 2 to 9 - 20 trials)

Rectangle Positive

	Subjects	1	2	3	4	5	6	7	8	9
No Pun.	1a	13	28	32	24	18	0	2	6	1
	4a	18	22	25	13	17	18	19	10	7
	2b	21	26	22	18	15	4	5	4	0
	3b	12	11	37	18	10	12	14	14	5
1.6 ma Pun.	4b	12	12	27	20	12	1	1	1	3
	5b	4	17	18	9	10	6	2	2	2
	7c	3	9	6	1	1	0	0	1	1
	9c	7	18	6	1	0	0	3	6	0
2.6 ma Pun.	3a	2	22	23	14	17	14	9	13	13
	9a	7	48	39	10	10	3	5	1	1
	3c	8	15	8	13	8	17	10	13	12
	4c	13	19	35	13	11	4	3	1	1

Line Positive

No Pun.	5a	28	51	18	0	1	5	3	2	0
	8a	14	35	26	11	8	1	1	0	0
	1b	49	59	67	28	25	14	7	6	2
	6b	25	22	3	2	5	1	1	0	0
1.6 ma Pun.	7b	49	15	16	10	2	0	0	0	0
	9b	40	31	5	6	3	0	0	0	0
	5c	22	24	5	1	4	0	0	3	0
	6c	16	0	1	2	0	0	0	0	1
2.6 ma Pun.	2a	34	21	15	7	14	8	6	1	1
	6a	29	33	15	14	8	3	3	1	0
	1c	11	11	11	0	1	0	1	0	0
	2c	34	12	17	7	1	1	1	0	0

Total Discrimination Latencies Per Day - In Minutes

(day 1 - 10 trials, days 2 to 9 - 20 trials

Rectangle Positive

	Subjects	1	2	3	4	5	6	7	8	9
No Pun.	1a	8.07	15.83	13.73	14.57	14.71	10.80	10.98	12.19	9.63
	4a	7.12	11.21	12.56	11.25	11.92	12.40	12.62	9.83	9.89
	2b	6.95	10.62	6.87	6.66	5.79	6.83	6.56	5.01	7.31
	3b	5.86	5.57	6.87	6.33	5.74	5.20	4.99	4.57	4.88
1.6 ma Pun.	4b	11.96	7.95	12.27	10.91	11.40	8.10	7.78	7.73	7.71
	5b	5.51	14.71	15.10	15.51	13.73	14.69	13.66	9.77	12.16
	7c	7.77	8.78	10.79	7.39	5.66	6.97	5.49	6.80	6.52
	9c	5.41	10.83	7.73	10.76	6.23	7.00	5.10	6.10	5.62
2.6 ma Pun.	3a	5.29	10.62	12.37	12.30	11.68	9.28	10.96	9.42	8.90
	9a	9.09	21.70	21.06	17.04	15.36	14.67	13.99	11.31	8.73
	3c	6.91	7.60	7.28	7.20	9.29	9.46	7.44	7.37	7.56
	4c	7.15	11.80	12.40	11.19	11.72	8.22	7.96	7.05	6.46

Line Positive

	Subjects	1	2	3	4	5	6	7	8	9
No Pun.	5a	12.12	15.59	12.78	11.04	8.47	7.34	6.74	9.85	7.11
	8a	8.81	14.33	11.23	7.18	5.50	6.19	5.18	5.26	
	1b	14.59	16.75	15.19	13.95	13.51	12.30	10.86	9.99	11.05
	6b	7.20	12.75	9.52	7.64	7.60	6.03	6.89	6.22	7.40
1.6 ma Pun.	7b	13.33	11.59	11.18	10.35	8.57	8.41	7.98	7.89	
	9b	16.59	15.34	9.38	9.74	6.82	7.05	6.13	4.78	
	5c	16.79	20.02	12.84	11.75	11.46	8.47	6.41	8.31	6.19
	6c	13.42	8.58	8.46	7.70	7.05	8.17	6.07	6.33	5.97
2.6 ma Pun.	2a	13.06	12.56	8.87	12.40	12.25	12.30	12.50	11.70	9.18
	6a	14.81	15.28	10.15	7.68	7.56	7.05	9.16	9.03	8.30
	1c	9.02	12.36	7.31	4.77	5.54	4.78	3.48	3.70	3.90
	2c	16.07	9.35	10.41	10.41	9.67	10.05	9.17	8.97	7.60

RAW DATA FOR EXPERIMENT II

Correct Trials Per Day

Dot Positive

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No Pun. 3 sec Delay	18	12	11	11	9	10	10	9	10	9	9	10	9	9	9	9
	19	9	6	5	8	9	10	9	10	12	14	13	10	13	12	13
	33	10	13	11	12	9	8	8	10	12	10	10	11	12	11	15
	34	11	8	9	8	11	9	10	9	11	13	8	9	13	7	10
	40	8	13	5	9	6	9	10	9	11	14	15	15	14	16	15
	41	10	12	8	8	8	10	7	9	9	15	12	10	12	9	12
No Pun. 1 sec Delay	20	1	8	7	7	9	7	8	9	9	12	9	11	12	13	12
	21	6	10	11	11	11	13	9	12	12	12	14	13	13	11	10
	22	10	7	8	10	14	9	9	11	12	7	7	10	10	8	10
	23	8	11	9	8	11	13	13	12	11	15	14	16	13	16	15
	39	9	6	8	9	10	10	10	13	9	8	10	8	10	9	8
	36	8	7	5	10	9	15	11	12	15	11	12	10	11	13	9
1.2 ma Pun.	3	10	11	5	8	5	6	7	10	9	9	13	13	6	11	11
	4	11	12	11	9	7	13	7	9	10	10	12	12	10	13	13
	11	9	8	12	13	15	11	13	17	10	13	11	12	12	10	13
	12	11	9	9	6	12	7	9	17	6	9	12	9	12	8	12
3.8 ma Pun.	7	9	11	11	11	7	15	8	6	14	12	9	10	10	7	8
	8	7	5	8	8	4	9	4	9	11	7	10	7	10	9	9
	15	6	10	9	7	7	10	9	8	11	7	13	11	12	9	13
	16	5	10	11	7	10	10	12	8	7	8	15	9	7	10	11

Correct Trials Per Day

Dot Negative

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	31	11	7	11	9	15	12	11	11	14	15	10	11	13	12	12
	32	10	15	8	11	12	10	10	13	11	12	9	11	13	15	16
No Pun.	37	10	10	14	15	15	11	16	11	13	15	13	16	10	11	10
3 sec	38	6	8	13	14	14	10	11	13	12	12	17	13	13	10	12
Delay	42	12	9	14	10	12	11	9	14	13	15	15	14	13	12	12
	43	10	10	9	16	16	18	16	14	16	18	16	14	19	16	17
	24	10	11	7	7	6	12	13	7	9	12	9	11	11	9	10
No Pun.	25	13	8	10	8	8	9	13	13	14	14	14	13	12	11	12
1 sec	28	9	7	8	9	11	12	8	14	14	12	12	9	13	14	11
Delay	29	7	9	15	10	11	13	14	13	10	12	16	10	11	12	11
	35	9	10	10	11	9	11	9	14	13	10	14	14	9	12	14
	1	9	12	14	14	15	13	14	16	19	20	19	18	20	20	18
	2	12	8	13	9	12	13	14	13	11	13	15	8	12	12	13
1.2 ma	9	9	7	9	11	9	12	11	12	14	9	10	16	13	12	9
Pun.	10	10	8	10	12	12	15	12	14	16	18	11	18	17	19	17
	18	7	9	13	14	10	8	12	11	10	10	13	10	11	9	13
	5	8	4	10	11	12	14	12	13	10	15	4	8	7	15	11
2.8 ma	6	11	12	10	9	15	15	16	16	19	17	20	19	18	15	19
Pun.	13	9	11	12	11	5	10	14	11	8	10	13	11	11	15	16
	14	8	12	14	10	11	15	15	16	16	18	16	15	18	19	17

Error Responses Per Day

Dot Positive

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	18	15	20	15	17	17	26	24	17	24	18	24	30	56	39	31
	19	36	36	36	30	57	42	36	39	13	10	11	13	10	18	9
No Pun	33	71	67	28	22	42	44	36	39	28	27	30	40	12	31	8
3 sec	34	13	41	36	27	18	37	22	20	27	28	30	32	17	33	16
Delay	40	20	15	63	51	103	136	76	47	33	19	9	13	12	7	11
	41	62	14	36	26	25	13	16	20	16	5	8	21	11	13	12
	20	23	41	35	51	54	37	39	27	33	24	43	22	18	10	10
	21	29	38	34	24	11	9	16	14	19	9	11	9	9	14	12
No Pun.	22	39	54	23	18	15	54	48	25	14	25	28	21	21	27	14
1 sec	23	46	33	31	53	19	17	19	12	18	7	15	8	13	10	8
Delay	39	58	61	60	34	34	17	28	21	30	28	18	41	33	34	30
	36	45	35	41	15	21	9	17	20	6	13	12	19	22	12	18
	3	32	12	45	30	72	32	54	29	31	48	21	28	26	13	27
1.2 ma	4	28	32	44	28	36	13	31	18	22	13	10	8	13	9	8
Pun.	11	42	40	31	16	9	28	15	5	14	11	20	15	11	18	8
	12	20	15	18	30	19	21	20	20	33	14	13	31	15	25	14
	7	25	19	40	16	35	8	36	21	15	17	21	18	20	21	18
3.8 ma	8	39	56	39	36	71	29	51	26	13	24	20	41	28	20	20
Pun.	15	51	37	32	28	49	21	22	32	17	32	14	16	19	25	14
	16	57	25	32	28	36	28	27	21	29	25	12	22	30	22	18

Error Responses Per Day

Dot Negative

	Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	31	52	42	25	19	6	25	19	18	18	16	18	16	12	9	10
	32	38	87	70	107	52	32	65	16	14	12	22	16	19	10	6
No Pun.	37	71	16	9	16	7	15	6	20	17	5	9	4	12	13	11
3 sec	38	44	33	22	14	10	32	24	16	18	18	3	11	14	18	9
Delay	42	16	41	11	28	13	16	29	11	18	9	7	10	14	9	16
	43	67	23	16	17	8	2	10	15	8	3	8	12	1	5	5
	24	54	29	31	38	30	20	13	15	12	11	11	12	18	17	13
	25	26	60	27	19	22	15	9	9	9	5	8	13	11	14	12
No Pun.	28	51	68	26	20	18	12	24	11	10	22	13	11	8	10	22
1 sec	29	34	52	16	16	10	11	6	10	17	14	4	11	12	10	14
Delay	35	31	18	26	16	34	28	31	13	16	28	10	7	12	9	6
	1	20	53	17	10	7	13	12	5	1	0	1	2	0	0	2
	2	53	50	17	28	11	13	7	16	18	14	6	17	14	5	6
1.2 ma	9	60	69	49	25	43	19	22	18	19	17	16	7	18	17	12
Pun.	10	37	75	33	9	25	10	22	8	6	3	15	4	3	5	6
	18	38	51	12	18	27	35	15	20	27	20	17	16	14	17	9
	5	31	31	22	28	18	9	15	20	14	7	25	24	22	15	20
3.8 ma	6	22	15	18	19	9	11	6	4	1	4	0	1	2	6	1
Pun.	13	21	28	24	20	30	19	12	13	18	20	8	17	14	13	4
	14	43	20	7	21	16	9	9	6	6	6	6	6	2	1	6

Total Discrimination Latencies Per Day - In Minutes
(Days 1 to 7)

Dot Positive

	Subjects	1	2	3	4	5	6	7
	18	7.62	8.91	8.85	7.95	7.21	7.48	8.22
No Pun.	19	27.72	20.52	15.05	13.91	16.29	14.64	13.35
3 sec	33	33.63	19.28	10.13	8.85	10.40	10.53	9.71
Delay	34	26.06	25.53	21.81	18.95	17.69	19.42	17.66
	40	14.89	13.35	17.29	16.20	17.78	16.16	13.20
	41	19.86	13.56	13.19	11.67	10.87	9.07	6.90
	20	27.62	25.46	15.25	16.23	20.16	17.64	13.96
No Pun.	21	16.72	12.38	9.32	7.60	6.78	6.82	9.64
1 sec	22	26.73	24.84	17.17	15.47	14.23	16.04	16.95
Delay	23	21.64	16.95	14.00	12.78	12.47	11.95	10.86
	39	23.82	25.32	19.02	18.69	17.04	17.08	19.25
	36	20.07	13.60	12.30	6.46	9.14	3.37	5.35
	3	21.54	16.17	21.71	17.89	22.96	18.92	18.23
1.2 ma	4	27.59	13.77	14.03	9.61	9.87	5.53	6.88
Pun.	11	19.67	21.94	13.97	9.89	12.00	13.66	14.73
	12	18.75	17.00	14.73	13.77	11.98	11.73	10.82
	7	33.37	21.05	21.35	20.59	18.55	16.11	16.41
3.8 ma	8	35.15	28.18	16. 6	23.12	30.88	20.79	22.46
Pun.	15	27.71	23.91	21.29	18.80	23.24	19.31	19.25
	16	32.17	28.61	30.81	23.60	27.95	24.15	17.62

Total Discrimination Latencies Per Day - In Minutes
(Days 8 to 15)

Dot Positive

	Subjects	8	9	10	11	12	13	14	15
No Pun. 3 sec Delay	18	8.09	7.97	10.34	6.54	8.31	10.57	9.99	10.04
	19	10.08	5.54	5.78	6.09	4.90	4.69	6.66	7.11
	33	9.20	9.13	8.24	8.16	8.44	9.58	9.54	7.07
	34	18.50	18.76	18.96	17.92	17.57	18.10	21.38	18.98
	40	10.18	10.12	8.78	8.15	10.31	9.15	7.42	8.80
	41	6.76	6.80	5.88	6.04	5.55	4.86	4.55	4.69
No Pun. 1 sec Delay	20	15.00	13.79	13.76	12.31	9.75	8.26	4.82	4.15
	21	7.67	5.41	5.66	7.02	6.76	5.72	7.46	8.17
	22	13.93	14.26	17.74	15.76	15.95	17.81	17.37	13.64
	23	11.91	13.73	11.43	11.26	10.31	10.79	13.13	10.22
	39	15.84	17.53	17.28	15.77	18.34	17.73	15.57	15.20
	36	4.15	3.58	4.07	3.73	4.24	3.24	3.25	4.64
1.2 ma Pun.	3	16.86	17.11	18.43	17.31	16.05	16.39	18.22	19.31
	4	7.83	6.16	4.59	3.95	4.03	3.85	2.62	3.72
	11	13.94	13.43	11.98	13.54	10.24	12.91	11.47	8.66
	12	11.57	11.38	11.74	12.06	13.94	13.59	13.92	13.40
3.8 ma Pun.	7	19.52	12.28	12.83	13.42	13.95	16.75	14.94	17.20
	8	20.27	20.95	17.13	13.69	14.45	16.91		
	15	18.72	13.92	15.03	13.69	11.04	16.15	14.83	17.38
	16	16.42	15.24	13.14	13.72	15.57	13.37	16.47	14.57

Total Discrimination Latencies Per Day - In Minutes
(Days 1 to 7)
Dot Negative

	Subjects	1	2	3	4	5	6	7
	31	25.43	19.84	16.16	12.69	10.50	11.83	11.18
	32	30.93	25.01	22.67	25.60	19.53	18.64	18.59
No Pun.	37	14.81	10.65	10.56	10.71	8.17	8.42	6.64
3 sec	38	13.81	12.05	11.83	11.64	8.87	11.48	12.15
Delay	42	24.52	21.46	16.33	14.91	12.15	12.23	12.47
	43	32.13	18.02	12.83	9.42	10.31	10.07	7.97
	24	18.98	12.14	13.05	13.88	14.02	13.10	11.33
No Pun.	25	39.38	32.64	20.99	17.29	17.46	18.32	17.63
1 sec	28	27.83	24.52	15.44	11.94	9.66	12.00	10.63
Delay	29	17.24	16.26	11.87	10.53	11.82	11.79	9.55
	35	16.97	13.54	12.58	11.57	11.37	11.55	10.12
	1	28.55	23.18	11.88	6.83	7.17	6.30	7.68
1.2 ma	2	49.14	25.18	7.46	11.95	10.15	9.39	8.64
Pun.	9	54.30	28.05	19.89	14.81	12.84	11.59	10.82
	10	43.68	22.47	12.31	8.76	8.87	6.96	9.27
	18	49.66	28.94	17.25	13.29	19.83	20.41	15.58
	5	31.66	27.58	21.67	19.18	22.05	19.88	17.89
3.8 ma	6	18.56	13.63	13.19	14.84	14.52	10.51	12.18
Pun.	13	16.89	20.31	19.88	17.45	19.25	17.16	15.39
	14	38.47	21.67	18.00	18.64	19.45	19.96	19.81

Total Discrimination Latencies Per Day - In Minutes
(Days 8 to 15)

Dot Negative

	Subjects	8	9	10	11	12	13	14	15
No Pun. 3 sec Delay	31	8.67	10.64	6.54	6.84	5.79	5.73	6.80	7.39
	32	15.72	23.17	18.97	17.44	17.73	19.85	17.61	17.22
	37	7.93	8.23	5.28	5.62	4.71	5.17	7.31	6.34
	38	8.93	9.80	8.71	6.23	6.46	8.39	9.94	9.87
	42	10.05	12.14	9.21	7.55	6.13	7.94	4.56	6.12
	43	9.12	8.14	8.22	4.86	5.89	4.11	3.59	3.98
No Pun. 1 sec Delay	24	10.05	7.73	8.48	4.38	8.28	8.24	5.79	6.28
	25	16.19	18.82	17.14	15.47	16.75	16.20	17.26	17.03
	28	9.26	10.12	11.12	9.29	12.30	14.32	9.94	11.15
	29	10.68	14.32	11.28	8.87	8.20	11.63	9.70	9.72
	35	9.40	9.66	9.09	7.14	8.64	8.73	6.31	7.54
1.2 ma Pun.	1	6.29	5.62	4.91	4.46	4.68	4.24	3.75	5.40
	2	6.21	6.20	6.57	5.41	6.48	5.19	5.76	6.02
	9	9.70	9.82	10.48	10.66	7.79	8.84	9.87	9.05
	10	9.43	7.40	6.51	7.74	7.18	6.37	6.23	8.24
	18	17.28	27.64	14.67	12.83	12.20	26.03	12.82	11.97
3.8 ma Pun.	5	17.90	16.51	16.43	18.73	21.18	19.65	17.99	21.48
	6	11.08	8.21	10.08	8.59	9.14	8.59	12.14	8.76
	13		16.47	19.00	14.92	16.72	16.33	14.73	17.65
	14		15.60	14.40	14.64	13.89	16.65	14.90	14.26