

THE EFFECTS OF PARTIAL REINFORCEMENT
ON A CLASSICALLY CONDITIONED EYELID RESPONSE IN DOGS

by


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R. M. V.

This paper is dedicated to my wife, Rochelle.

R. M. V.

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INTRODUCTION

The establishment of a conditioned response (CR) requires the presentation of a certain number of reinforced training trials. A reinforced trial is defined as the occurrence of a conditioned stimulus (CS) followed by an unconditioned stimulus (US). For nonreinforced trials, the CS and US are not paired. A partial or intermittent reinforcement schedule is defined operationally as the presentation of both reinforced and nonreinforced trials in acquisition. Partial reinforcement schedules are conventionally identified by their relative frequency of reinforced trials, e.g., "50% partial reinforcement" refers to an acquisition schedule where half of the trials are reinforced. The relative frequency of reinforcement may vary between but not include 0% (extinction) and 100% or "continuous" reinforcement.

It has been established that partial reinforcement produces a reliable effect on the performance of infra-human Ss in the case of appetitive instrumental conditioning. Early in acquisition groups receiving partial reinforcement exhibit inferior performance relative to continuously reinforced Ss. Subsequently, the partial reinforcement groups perform at higher terminal levels than the groups given continuous reinforcement. Partially reinforced Ss show greater resistance to extinction than consistently reinforced Ss. This set of results is

is commonly referred to as the partial reinforcement effect (PRE) for instrumental approach conditioning.

With classical conditioning in infra-humans, partial reinforcement has produced variable results. Under certain conditions, no measureable effect may be obtained. In human eyelid conditioning, the conventional PRE is a lower level of acquisition performance for groups receiving intermittent reinforcement and greater resistance to extinction than is the case with continuous reinforcement groups.

The failure to obtain the usual PRE in certain experiments involving infra-human Ss has led some investigators to question the generality of the effect and to suggest that the PRE in classical conditioning is limited to verbal organisms (cf., Kimble, 1961; Spence, 1966). If the phenomenon is to be regarded as a fundamental property of the conditioning situation, then presumably it should be found in lower animals as well as in humans. One of the main purposes of this paper is to consider the inter-species generality of the PRE in classical conditioning. To aid in the clarification of this issue, the currently available evidence which bears on the PRE for infra-human Ss is reviewed separately from that for humans.

Because resistance to extinction has often been taken as an index of associative strength developed in

acquisition, it is understandable that the early demonstrations of an extinction PRE posed serious problems for theorists. When confronted with the phenomenon, psychologists were obliged to explain how reinforcement on only a fraction of the total number of acquisition trials could maintain performance in extinction more effectively than reinforcement on every acquisition trial--a problem of considerable theoretical and practical significance. Although a number of models were advanced to explain the PRE, only a few remain viable today. The theories that were general enough to account for the effect both in acquisition and extinction of classically and instrumentally conditioned behaviors have proved too general to be submitted to precise experimental test. Conversely, those models that were intended to deal with a limited aspect of the PRE have had little predictive power across response systems, experimental techniques, or species.

The reference experiments

Widespread interest in the PRE seems to have begun with the publication of two studies by Humphreys, one dealing with the classically conditioned eyelid response in humans (1939), and the other concerning the human GSR (1940). The major finding of these investigations was little or no difference in levels of performance during acquisition of a consistently reinforced group compared to

a random partial reinforcement group. Furthermore, it was found that the intermittently reinforced group was superior in performance to the consistent reinforcement group during extinction. These results were interpreted as a serious challenge to the then widely accepted view that level of performance in acquisition and resistance to extinction were roughly comparable indices of associative strength built up on reinforced training trials.

Pavlov described some research conducted by Podkopaev and Virjиковsky (Pavlov, 1927) who investigated partial reinforcement in the acquisition of a classically conditioned appetitive salivary response. Three schedules were employed: 100% or continuous reinforcement, 50% alternating reinforcement, and 25% regular periodic reinforcement. Extinction procedures were not included in the experimental design. No appreciable tendency for the CS to evoke conditioned salivation could be obtained under the 25% reinforcement condition even though 240 trials were given (60 reinforced). In contrast, Fitzgerald (1963) obtained reliable salivary conditioning in dogs with a 25% partial reinforcement schedule. This difference in results might be attributed to procedural factors; Fitzgerald used an aversive US (dilute acetic acid) and the 25% reinforcement schedule was random. It was noted that the schedule employed by Fitzgerald included sequences of consecutive reinforced trials, whereas the

regular periodic schedule of Podkopaev and Virjиковsky did not. The 50% dogs responded at a level comparable to that of Ss given continuous reinforcement. Pavlov seemed at a loss to explain these results and stated only that there remained much to be done on his theory of cortical excitation and inhibition. This reticence to theorize may explain why the data attracted less attention from American workers than did the experiments of Humphreys despite the fact that Pavlov's studies antedated Humphreys' by a number of years.

Pointing out that Pavlov's general theory demands that a CR be weakened whenever the US is omitted, Brogden (1939) cited some preliminary data obtained in his laboratory indicating that this is not always the case. An unusual set of experiments was conducted in an attempt to determine how the frequency of CRs varies with frequency of the US. One study with dogs involved the conditioning of foreleg flexion (produced by pawshock) to the sound of a bell. All dogs were trained to asymptotic performance with 100% reinforcement following which each S was given 80, 60, 40, and 20 per cent reinforcement. A slight increase in response level was observed as frequency of reinforcement decreased except for the 20% condition which resulted in depressed performance. However, none of these effects were statistically significant. In a second experiment, original training conditions were as in the first

study, but when asymptotic levels of performance were reached, Ss could avoid the US by making a CR. In addition, whenever an avoidance CR occurred, a food reward was substituted for the aversive US. The dogs were brought to 100% performance under the new conditions and given the same series of reinforcement schedules used in the first experiment. With these procedures, the only condition resulting in performance inferior to the 100% treatment was 20% partial reinforcement. The third experiment consisted of standard salivary conditioning to the sound of a bell and switching reinforcement schedules as before. In this case both 20% and 40% reinforcement resulted in slightly depressed performance although the differences were not statistically significant. No extinction data were reported for these studies. Brogden concluded from the results of the experiments that a high level of responding can be obtained with extremely low frequencies of reinforcement. He suggested that the US is necessary only to maintain drive or to motivate performance in the manner of an incentive. Viewed in perspective, the interpretation of Brogden's three experiments seems greatly complicated by introducing avoidance training and changing from aversive to appetitive reinforcement. In addition, an order effect is confounded with the acquisition PRE in all experiments, i.e., Ss were always

switched from high frequencies of reinforcement (100%) to some lower frequency.

PRE in human classical conditioning

1) Eyelid conditioning. An early demonstration of what has come to be accepted as the standard PRE for human eyelid conditioning was provided by Grant and Schipper (1952). Acquisition and extinction of eyelid CRs were studied under conditions of 0, 25, 50, 75, and 100 per cent reinforcement. It was found that the frequency of CRs in acquisition increased with the percentage of reinforcement. During extinction the 50% and 75% groups performed at higher levels than the continuous reinforcement group. In a similar experiment (Grant, Schipper, & Ross, 1952) where percentage of reinforcement and intertrial interval were varied, partial reinforcement produced inferior acquisition performance and greater resistance to extinction relative to 100% reinforcement.

The standard PRE was also obtained by Reynolds (1958) in an investigation where, for half the Ss, nonreinforcement was defined as a trial with a 2400-msec. CS-US interval. Under all conditions, 100% reinforcement resulted in higher performance levels during acquisition than partial reinforcement. In extinction, the performance of the 50% groups was superior to that of continuously reinforced Ss.

In an attempt to determine the relationship between frequency and patterning of reinforcement, Grant, Rioppelle, and Hake (1950) conducted an experiment where the effects on acquisition and extinction of 50% single alternation, 50% double alternation, 50% random reinforcement, and 100% spaced reinforcement were studied. Early in conditioning the 50% random group was superior in performance to the others, but as training progressed, the 100% and 50% random groups were at approximately the same level. At the beginning of extinction, the 50% random group showed more response strength than the other groups but extinguished rapidly thereafter and reached a final asymptote which was lower than the other terminal performance levels. Throughout the course of acquisition and extinction, the performance of the alternating partial reinforcement groups was inferior to that of the groups receiving random and continuous reinforcement.

In another investigation of the effects of patterned reinforcement, Hake and Grant (1951) studied resistance to extinction of the human eyelid CR as a function of the number of transitions from reinforcement to nonreinforcement and the average length of a block of reinforced trials. Extinction performance increased to a maximum with six transitions and then declined with further transitions. A similar trend was obtained for

nonreinforced block size. In this experiment, extinction performance became worse as the number of transitions approached the limiting case of 50% alternating partial reinforcement.

In a recent discussion of factors influencing extinction of the eyelid CR, Spence (1966) pointed out that extremely rapid extinction is usually observed with human Ss. In contrast, infra-humans often extinguish at roughly the same rate as they learn. It was suggested that the rapid decrement in humans may result from an inhibitory "set" which is adopted when extinction procedures are begun. Some data that bear on this aspect of human eyelid conditioning were provided by McAllister (1953). More gradual decrements were obtained under conditions where the US was present on extinction trials and the 500-msec. CS-US interval in acquisition was extended to 2400 msec. in extinction. Training involved an 80% partial reinforcement schedule. The relatively slow extinction was interpreted in terms of the US maintaining general motivational levels on nonreinforced trials. Subsequently, Reynolds (1958) found that using an extended CS-US interval decreased the rate of extinction only after partial reinforcement in acquisition. Subjects who had received continuous reinforcement during acquisition extinguished at the usual rapid rate. These findings were substantiated in a more recent investigation by

Spence, Rutledge, and Talbott (1963). It has been suggested that a simple drive interpretation of the effects on extinction of the delayed-US technique is unsatisfactory (Spence, 1963), since rapid extinction is obtained with this procedure if the conditioning history involves continuous reinforcement. Using a probability learning task and the long CS-US interval to mask changes in the experimental situation when extinction was initiated, Spence and Rutledge, (1964) found that approximately one third of the Ss did not extinguish at all whereas the others stopped responding after the second or third extinction trial. It was concluded that the delayed US is reinforcing for some Ss and therefore is not a satisfactory method of maintaining drive in extinction. Three methods of providing nonreinforcement in extinction were compared in an experiment by Spence (1966). Two of the techniques were intended to maintain motivational levels in extinction (delayed US and randomized presentations of CS or US) while the third involved the usual presentations of CS-alone trials. All conditioning procedures were imbedded in a probability learning situation. Subjects receiving CS-alone trials in extinction extinguished very rapidly. Some Ss who were given trials with the US delayed showed little or no decrement while others receiving this

treatment extinguished immediately. Randomized presentations of CS or US proved to be the most effective method for producing gradual decrements in all Ss during extinction.

2) Autonomically mediated conditioning. An important area of research on classical conditioning in humans involves responses mediated by effector organs that are controlled primarily by the autonomic nervous system. The effects of partial reinforcement on the acquisition and extinction of CRs in these systems are of particular interest with regard to determining the inter-response generality of the PRE.

The role of patterning in reinforcement schedules was investigated by Longnecker, Krauskoff, and Bitterman (1952). They conducted an experiment where the effects of alternating reinforcements and random partial reinforcement on the classically conditioned human GSR were studied. The two reinforcement conditions did not affect the overall acquisition performance differentially. However, in extinction the random partial reinforcement group performed at a higher level than the alternating reinforcement group. The form of the acquisition function for the alternation group approximated a "sawtooth" shape after the first few trials, suggesting that these Ss became aware of

the pattern of reinforcements and responded accordingly. Verbal reports from the Ss substantiated this inference. No such configuration of responding was evident in the acquisition curve for the group receiving random partial reinforcement. Unfortunately, a continuous reinforcement condition was not included in the design so that the conclusions which may be drawn from these data with respect to the PRE are somewhat limited.

Notterman, Schoenfeld, and Bersh (1952) studied the effects of partial reinforcement on the conditioned heart-rate response in humans. The experimental protocol involved habituation, conditioning, extinction, reconditioning, and re-extinction. During acquisition, half the Ss received continuous reinforcement while the others were given 50% random reinforcement. The total number of reinforced trials was the same for both groups. The conditioned response proved to be a deceleration of heart rate. There were no significant differences in level of responding during initial training or reconditioning for the two treatment groups. The partial reinforcement Ss showed greater resistance to extinction than the regularly reinforced Ss. Only a negligible amount of response decrement was observed during extinction in the case of intermittent reinforcement.

An investigation of partial reinforcement of the salivary CR in humans was reported by Razran (1955). For this study, the CS was a flashing light and the US was eight small pretzels. The intermittently reinforced group was found to be more resistant to extinction than a 100% reinforcement group. The continuous reinforcement group performed at higher levels during acquisition.

Yarczower, Vlases, and Friedman (1960) conducted an experiment on the classically conditioned human GSR that included six experimental treatments: three percentages of reinforcement (10%, 30%, 100%) and two levels of training (10 and 30 trials). With ten acquisition trials more extinction responses were obtained for 30% reinforcement than for 10% reinforcement, but there were no differences between the 30% and 100% conditions. For the groups receiving the larger number of training trials, 100% reinforcement led to fewer extinction responses than 30% reinforcement, although there were no significant differences between extinction performance levels for 30% and 10% reinforcement. No acquisition data were reported. Therefore, the extinction results might be questioned on the grounds that reliable conditioning may not have occurred for the 10% reinforcement groups and the groups given only 10 acquisition trials.

PRE in infra-human conditioning

1) Eyelid conditioning. The effects of partial reinforcement on the classically conditioned eyelid response in rabbits were investigated by Thomas and Wagner (1964). One group of 10 Ss received 220 acquisition trials of which 100% were reinforced. A second group was given 440 acquisition trials with 50% random partial reinforcement. The CS was a 600-msec. tone and the US was a 4-psi air puff. On reinforced trials these stimuli were paired such that the US overlapped the last 100 msec. of the CS. Nonreinforced trials consisted of presentations of the CS alone. The rate of acquisition of the 50% group was reliably slower than that of the continuously reinforced group, although both groups reached approximately the same asymptote. However, 60 trials of extinction revealed no differences in CR frequency between the two groups. No reliable between-group differences in CR latency were obtained in acquisition or extinction. A detailed analysis of the acquisition data revealed significantly lower CR percentages on trials following nonreinforcements.

2) Conditioned gross body movements. Classical conditioning in many infra-mammalian organisms presents special problems for attaching electrodes, detecting movements of appendages, or maintenance in alien environments. As a result, it is sometimes

necessary to present the US as a shock across a volume of water in a tank or to use electrodes placed so that a relatively large proportion of the body is stimulated. The UR to such stimulation is usually characterized by gross movements of the entire body. Adequate techniques have been developed for quantifying conditioned "agitation" and "body contraction". These developments have facilitated the investigation of classical conditioning in lower phyla. Studies using infra-mammalian species as Ss can provide valuable information concerning the phyletic generality of the PRE.

Gonzalez, Longo, and Bitterman (1961) made objective measures of the conditioned agitation response in goldfish with three conditions of reinforcement. During acquisition a reinforced trial consisted of a forward pairing of CS and US using a 4.5-msec. CS-US interval. A nonreinforced trial for one group involved the omission of the US while for another group the US was presented 30 sec. after the onset of the CS. A 100% reinforcement group performed slightly better than the 50% groups throughout acquisition, although this difference was not statistically significant. Similarly there were no reliable differences in extinction. The two nonreinforcement procedures had no differential effects during acquisition or extinction. A second experiment by these authors involved a 2 X 2 factorial

design in which two percentages of reinforcement and two amounts of training were compared. The various treatments produced no differences in performance among the groups during acquisition and extinction or in a series of retrainings followed by extinction.

Another study of partial reinforcement in the classical conditioning of fish (mouthbreeders) was conducted by Gonzales, Eskin, and Bitterman (1963). A 100% reinforcement group received 100 pairings of light and shock during acquisition, while a 50% group was given 200 trials, half of which were presentations of the CS alone. A second random partial reinforcement group received 40 trials of continuous reinforcement followed by 60 trials with partial reinforcement. Extinction consisted of 35 CS-alone trials for all groups. The acquisition procedures resulted in significantly lower performance levels for the 50% groups. Both partial reinforcement groups showed greater resistance to extinction than the consistently reinforced group. This PRE is consistent with the result that is usually obtained for human Ss in aversive conditioning situations.

A series of seven studies of partial reinforcement in goldfish was reported by Berger, Yarczower, and Bitterman (1965). The effects of intermittent reinforcement were investigated with equated reinforcements and with equated trials, with constant and with variable

CS-US intervals, with long and with short runs of non-reinforcement, with balanced and with biased patterns of partial reinforcement, and with two different extinction procedures. The only differential effects on extinction performance were produced under conditions of long runs of nonreinforced trials that tended to occur early in acquisition (early-biased partial reinforcement schedule). This effect was reflected in a Treatments X Trials interaction, with the continuous reinforcement group extinguishing more rapidly than the partial reinforcement group that received long runs of nonreinforced trials early in acquisition.

A conditioned agitation response in pigeons was studied by Longo, Milstein, and Bitterman (1962). Here all Ss were trained to asymptotic levels of performance with continuous reinforcement, after which half the Ss were given 50% partial reinforcement. Comparison groups for matched trials and matched reinforcements were included in the design. Following the shift to partial reinforcement, performance levels rose above those of the 100% reinforcement group. During the 180 trials of extinction, the 50% group performed at a slightly higher level than the 100% group and this difference was significant. In a second experiment, training conditions were similar, except that the groups were given either 50% or 100% reinforcement from the

start of acquisition. This resulted in superior performance for the 100% reinforcement group in acquisition and extinction.

Wyers, Peeke, and Hertz (1964) used a tactile CS and an intense light as the US to condition a retraction or withdrawal response in earthworms. A continuous reinforcement group received 150 reinforced trials, while a partial reinforcement group first received 20 reinforced trials and then 130 trials involving 50% partial reinforcement. The reinforcement procedures produced no differences in acquisition performance, but the 50% group performed at a higher level than the 100% group during extinction.

A subsequent study by these authors (Peeke, Hertz, Wyers, 1965) involved the same specie of S and a similar experimental design. Three levels of training (50, 100, and 150 acquisition trials) were made orthogonal to two reinforcement schedules (100 and 50 per cent). In addition, separate control conditions were provided for sensitization and pseudo-conditioning. The results of their previous investigation with earthworms were substantiated; for all levels of training, Ss given partial reinforcement responded at levels comparable to the groups receiving consistent reinforcement during acquisition and showed greater resistance to extinction than consistently reinforced Ss.

Crawford, King, and Siebert (1965) investigated the effects of partial reinforcement on classical conditioning in 20 planaria. The CS was a 3-sec. light and a 1-sec. shock was the reinforcer. For reinforced trials, these stimuli were paired using a 2-sec. CS-US interval. The experimental design included four treatment groups. A continuous reinforcement group received 120 light-shock trials in acquisition, while a sensitization control group was given the same number of trials with the CS and US unpaired (separated by 30 sec.). A 50% partial reinforcement group had CS-US pairings on 60 acquisition trials and 60 presentations of the CS alone. The second sensitization control group received 120 acquisition trials where the US was present but not paired with the CS on half the trials. All groups were given 32 CS-alone trials in extinction. The performance of the partial reinforcement group did not differ from that of the 100% group in acquisition. A significant Treatments X Trials interaction was obtained in extinction, with the 100% group extinguishing more rapidly than the intermittently reinforced group.

Three groups of 6 planaria received 48 presentations of a photic CS and 48 shocks per day for 5 days in a study by Kimmel and Yarenko (1966). On conditioning trials, light and shock were paired using a 2-sec. CS-US interval. The minimum intertrial interval

was 15 sec. A CR was defined as cephalic turning, curling, or contraction during the first 2 sec. of the CS. These CRs were scored visually. For one group, acquisition involved pairing light and shock on 100% of the trials. Another group received 50% paired presentations of light and shock, while 50% of the trials consisted of the CS alone. A third group was given 0% reinforced trials in order to provide an estimate of sensitization and pseudo-conditioning levels. All groups received 50 extinction trials on the sixth day of the experiment. Both the 100% and the 50% groups performed at levels that were significantly higher than the control group during acquisition. There were no reliable differences between the acquisition performance levels of the two conditioning groups. In extinction, the 50% group exhibited higher response percentages than the 100% and control groups. However, there was no significant difference between the performance of the 100% group and the control group in extinction.

Slivka and Bitterman (1966) investigated classical appetitive conditioning in the pigeon with continuous and partial reinforcement. The CS was a change in illumination and the US was a small quantity of grain. On reinforced trials these stimuli were presented with a 10-sec. CS-US interval. Conditioned

responding was measured as the difference between mean activity occurring in the CS-US interval and that observed for an equal period of the intertrial interval. During acquisition, Ss were given 150 reinforced trials and then either 100% or 50% reinforcement for 225 trials. All Ss received 90 trials of extinction with the US omitted. Frequency of reinforcement had no reliable effect in acquisition. There was no significant overall difference in performance levels of the two experimental groups during extinction, but a statistically significant Groups X Trials interaction was obtained.

3) Conditioning of autonomically-mediated responses. An experiment by Fitzgerald (1963) dealt with an aversive conditioned salivary response in dogs. The reinforcement schedules employed were 25%, 50%, and 100%. The CS was a tone and the US was dilute acetic acid. In this study, the acquisition performance levels of both partial reinforcement groups were lower than those of the continuously reinforced group. In extinction, a significant Groups X Trials interaction was obtained. No reliable differences between acquisition or extinction performance were observed for the two partial reinforcement groups.

Wagner, Siegel, Thomas, and Ellison (1964) investigated the effects of partial reinforcement on

an appetitive conditioned salivary response in dogs. An auditory CS was paired with a food pellet using a 20-sec. CS-US interval on reinforced trials. A 50% reinforcement group tended to perform at lower levels than a continuously reinforced group in acquisition. A significant Groups X Trials interaction was obtained during extinction, but there were no differences in overall performance for the two reinforcement groups.

Two experiments involving a conditioned heart-rate response in dogs were reported by Fitzgerald (1966). A tone was the CS and reinforcement was provided by a shock. The reinforcement schedules employed were 0%, 50%, and 100%. In the first experiment, no PRE was obtained in acquisition or extinction. The second experiment, where the number of reinforcements was equated for the two experimental groups, produced a Treatments X Trials PRE in extinction. No overall differences between the performance levels of the experimental groups were obtained in acquisition or extinction. The lack of evidence for a PRE in the first experiment was explained in terms of the relatively small number of reinforced trials (six) occurring in the partial reinforcement schedule. It was suggested that 6 reinforced and 6 nonreinforced trials established only a minimal amount of response strength. In the second experiment, where both the 100% and the 50% group received 12 reinforcements,

conditioning levels were sufficient to reveal an interaction PRE.

Fitzgerald, Vardaris, and Teyler (1966) studied the effects of partial reinforcement followed by continuous reinforcement on a classically conditioned heart-rate response in dogs. In one condition a group received partial reinforcement on the first day of acquisition and was then switched on the next day to continuous reinforcement. Another condition provided partial reinforcement on both days. A group receiving continuous reinforcement on both days was also included. In this experiment, partial reinforcement produced a decrement relative to a 100% group on the first day of acquisition. During extinction, a group that received only partial reinforcement in acquisition showed greater resistance to extinction than did a continuously reinforced group. Ss given partial reinforcement and then continuous reinforcement before extinction tended to extinguish more gradually than the 100% reinforcement group, although the difference was not statistically significant. Switching from partial to continuous reinforcement presumably made the extinction situation less similar to acquisition, and therefore extinction should have been rapid as compared to the unswitched group. It was concluded that this evidence did not support explanations of the PRE that postulate differential discrimination

of extinction from acquisition as the mechanism underlying the effect.

Fitzgerald, Vardaris, and Brown (1966) conducted an experiment in which classical conditioning of heart-rate was studied in rats. For this investigation, three different groups of SS received either 100%, 50%, or 0% reinforcement. All groups were given 42 acquisition trials and 24 trials of extinction. The CR observed for the 100% and 50% groups was a deceleration in heart rate. In acquisition, frequency of reinforcement had no differential effect on performance. Because the extinction procedure failed to produce performance decrements, it was not possible to assess the effects of partial reinforcement in extinction.

Summary of results in the literature

It has been stated that the great majority of studies concerned with partial reinforcement of the classically conditioned eyelid response in humans have found that intermittent reinforcement produces inferior performance in acquisition and more resistance to extinction. The PRE in such investigations takes the form of a significant difference between treatment-group means, with a 100% group performing at higher levels than a partially reinforced group during acquisition and a 50% group performing above a continuous reinforcement group

in extinction

The results for infra-human Ss are much more variable. Effects of partial reinforcement may be reflected in overall mean differences, or Groups X Trials interactions. In some experiments no differential effects of reinforcement schedule have been observed. Table 1 has been included to provide a convenient summary of the various types of experimental findings for infra-human Ss. The main headings of this table refer to columns in which the investigators, Ss, and type of CR are given. The sub-headings under "Response system" provide three classes to which the CR observed in a given study may be assigned. Further subdivisions under each class of response systems identify results as having occurred in acquisition or extinction.

Entries in Table 1 are intended to describe the major types of findings in studies of the PRE with infra-humans. The entry $P = C$ refers to a situation where the performance level of a group receiving partial reinforcement (P) was not different from that of a group given continuous reinforcement (C). In a case where performance of a partial reinforcement group was superior to that of a group receiving continuous reinforcement, $P > C$ is used. $P < C$ symbolizes lower overall performance of a partial reinforcement group relative to a group given continuous reinforcement. The entry "interaction" refers

Table 1. Summary of experimental findings
for the PRE in infra-human Ss. Explanations of headings
and symbols are in the text.

Response system

Experiment	<u>S</u>	Discrete skeletal		Gross skeletal		Autonomic	
		Acqui- sition	Extinc- tion	Acqui- sition	Extinc- tion	Acqui- sition	Extinc- tion
Pavlov, 1927	Dog					P = C	Not re- ported
Brogden, 1939	Dog	P = C	Not re- ported			P = C	Not re- ported
Fitzgerald, 1963	Dog					P < C	Inter- action
Wagner, <u>et al.</u> , 1964	Dog					P < C	Inter- action
Fitzgerald, 1966	Dog					P = C	Inter- action
Fitzgerald, <u>et al.</u> , 1966	Dog					P < C	P > C
Thomas & Wagner, 1964	Rabbit	Inter- action	P = C				
Fitzgerald, <u>et al.</u> , 1966	Rat					P = C	P = C

(Table continued on next page)

Response system

Experiment	S	Discrete skeletal		Gross skeletal		Autonomic
		Acqui- sition	Extinc- tion	Acqui- sition	Extinc- tion	
Longo, et al., 1962	Pigeon			P = C	P > C	
Slivka & Bitterman, 1966	Pigeon			P = C	Inter- action	
Gonzalez, et al., 1961	Goldfish			P = C	P = C	
Gonzalez, et al., 1963	Mouth- breeder			P < C	P > C	
Berger, et al., 1965	Goldfish			P = C	Inter- action	
Wyers, et al., 1964	Earthworm			P = C	P > C	
Peeke, et al., 1965	Earthworm			P = C	P > C	
Crawford, et al., 1965	Planarian			P = C	Inter- action	
Kimmel & Yarenko, 1966	Planarian			P = C	P > C	

to the finding of a significant Groups X Trials interaction. As an example of the use of these symbols, the standard PRE for human eyelid conditioning could be expressed as $P < C$ in acquisition and $P > C$ in extinction.

From inspection of Table 1, it is evident that the most common result in acquisition is one of approximately equal performance levels for partial and continuous reinforcement groups. Frequency of reinforcement did not affect acquisition performance differentially in the majority of experiments using infra-humans, whereas partial reinforcement ordinarily produces a decrement during acquisition with humans. Two studies obtained a result similar to the PRE in acquisition and extinction for humans. Although the acquisition findings for infra-humans are relatively consistent from experiment to experiment, the extinction results are not. In general, the type of result obtained for extinction does not appear to be systematically related to the response system investigated or the species serving as Ss. Increased resistance to extinction after partial reinforcement was obtained in some of the experiments with animals, but other findings such as interactions or no differences are relatively more common for infra-humans than for humans.

Theoretical formulations

It is clear that any comprehensive theoretical

explanation of the PRE in classical conditioning must be able to predict a number of replicable findings in a variety of experimental situations. It may be stated that at present no single theory is capable of encompassing all the results obtained in studies of classical conditioning with partial reinforcement. The more recent theoretical attempts have tended to be directed at specific conditioning situations and are not intended to be applied to all the PRE data.

Humphreys' "expectancy" hypothesis is an example of the early general theories. His view is that an expectation of consistent reinforcement is acquired during conditioning trials involving regular presentations of US following CS. Humphreys assumed that it is easier to change from an expectation of this kind to one of regular nonreinforcement (extinction) than it is to change from an expectation of irregular (partial) reinforcement to regular nonreinforcement. The difficulty in changing expectancies after partial reinforcement presumably would produce the increased resistance to extinction exhibited by groups receiving this treatment. It will be noted that this conception is general enough to explain the extinction PRE in some conditioning situations, but by the same token, it is so general as to be not susceptible to precise experimental test.

The stimulus-generalization decrement hypothesis, which was developed by Hull and later extended by Sheffield (1949), provides another general explanation of the PRE. According to this conception, the stimulus aftereffects of a reinforced trial become part of the CS complex acting at the start of the subsequent trial. Similarly, the perseverative stimulus traces of nonreinforcement become part of the CS complex operating during the following trial. Such persisting cues of nonreinforcement are regarded as being exactly those which follow the usual extinction trial where the US is omitted. In partial reinforcement, the response becomes conditioned to a combination of reinforcement and extinction-like cues. According to the principle of stimulus generalization, the partial-reinforcement CS is then more similar to the extinction CS than is the continuous reinforcement CS. Therefore, there is less generalization decrement and more resistance to extinction following partial reinforcement.

Another formulation which considers the similarity of conditions in extinction to those in acquisition is the discrimination hypothesis that was advanced by Mowrer and Jones (1945). Essentially, it was contended that extinction may be prolonged by procedures in acquisition which make it difficult for the S to discriminate between training and extinction.

Some of the conditions that were regarded as making this discrimination relatively easy are continuous reinforcement, regular patterns of partial reinforcement, and changes in the stimulus (CS) complex from acquisition to extinction. Therefore, extinction would progress relatively rapidly after such procedures.

Recently, Spence (1963, 1966) has extended and modified the discrimination hypothesis to account for certain results obtained in the human eyelid conditioning situation. It has been mentioned that extinction of the human eyelid CR normally progresses at an inordinately high rate. If nonreinforcement in extinction is accomplished by using a long CS-US interval instead of omitting the US, the rate of performance decrement may be retarded. Apparently, the extended CS-US interval is effective in retarding extinction only after partial reinforcement in acquisition. It was hypothesized that partial reinforcement provides Ss with the experience of nonreinforcement in acquisition and, therefore, makes the extinction procedures less discriminable from acquisition. Subjects not receiving partial reinforcement in acquisition easily discriminate the extinction procedures and adopt an inhibitory "set". This set factor is assumed to result from self-instructions on the part of Ss and explains the precipitous

course of extinction after continuous reinforcement. Certain masking procedures such as the probability learning situation have been effective in making extinction less discriminable from acquisition. This is revealed by relatively slow extinction in Ss trained under such conditions. Spence's theoretical formulation differs from other versions of the discrimination hypothesis in that it introduces an inhibitory "set" factor and is specifically limited to conditioning situations involving Ss with verbal capabilities.

Another specific model for the PRE has been developed by Fitzgerald (1966). Although this conception was advanced to explain certain results obtained for heart-rate conditioning in dogs, its applicability may be extended to other organisms and response systems. Since punishment is invoked as the essential factor, the model is best suited for experimental situations employing an aversive US. According to this notion, a partial reinforcement schedule in acquisition provides an opportunity for extinction-like responses to be conditioned to the CS on nonreinforced trials. In conditioning situations where the reinforcer is aversive, these extinction-like responses are punished by the US when they occur on reinforced trials. Therefore, partially reinforced groups would be expected to show

greater resistance to extinction because responses assumed to produce performance decrements in extinction would have been suppressed by punishment in acquisition.

Purpose of the present experiment

The experiment to be reported in subsequent sections of this paper was designed to assess the effects of partial reinforcement on performance during acquisition and extinction of a classically conditioned eyelid response in dogs. It may be recalled that a PRE for the conditioned heart-rate response in dogs has been demonstrated (Fitzgerald et al., 1966). Therefore, the present investigation, by employing the same type of Ss and similar experimental conditions, provides a test of the inter-response generality of the PRE. Since infra-human Ss were used, this study can yield further information concerning whether or not the PRE is species-dependent. In addition, the experimental design includes conditions where the "discriminability" of extinction from acquisition varies. This was accomplished by selecting partial reinforcement schedules that differed in regularity of the reinforcement pattern.

METHOD

Subjects

Thirty-four mongrel dogs ranging in weight from 18 to 35 lb. served as Ss for this experiment. The animals were housed and maintained in the University of Oregon Medical School animal care facility and had experienced no experimental treatment prior to this investigation. Six of the 34 Ss had to be eliminated from the experiment; two of the animals having died from undetermined causes, and four having struggled excessively in the restraining stock.

Apparatus

Conditioning and habituation sessions were conducted in a commercially manufactured sound-proof room with an air-conditioner and a one-way screen through which the Ss' general behavior could be observed. The system for recording eyeblinks consisted of a micro-torque potentiometer obtained from a Hunter Model 311 Headpiece, a wheatstone bridge circuit, a dc preamplifier, and a pen-writing channel of a Grass Model V polygraph. The potentiometer served as a variable resistor in a 10 K-ohm bridge. A movable arm on the potentiometer was linked to the S's right eyelid by means of a length of silk thread having a small hook at one end that was

attached to a loop of suture in the eyelid. The other end of the linking thread was fastened to the arm of the potentiometer with a small lump of clay. In this way, movements of the eyelid changed the electrical resistance of the bridge circuit and produced a pen deflection on the polygraph. The nominal sensitivity setting of the preamplifier was 1 mv./cm. All responses were recorded at a paper speed of 100 mm./sec.

Stimulus presentations were accomplished by Hunter interval timers and Grayson-Stadler programming equipment located outside the sound-proof room. The conditioned stimulus (CS) was a 0.6-sec., 500-Hz. tone of moderate intensity delivered through a speaker mounted approximately 24 in. above S's head. The unconditioned stimulus (US) was a 0.1-sec., 2-psi (104 mm. Hg) puff of compressed air presented to the S's right eye through a 0.5-mm. nozzle located approximately 1 in. in front of the cornea. Presentation of the air puff was accomplished by means of a solenoid valve which was activated by the US timer. Puff intensity was monitored continuously by a U-tube mercury manometer. The CS-US interval was 0.5 sec., with the US overlapping the final 0.1 sec. of the CS.

Subjects were restrained in a wooden stock with an adjustable headpiece, neckpiece, and canvas sling. The headpiece consisted of a wood platform with aluminum

uprights and crossbars on which were mounted the air puff nozzle and eyeblink transducer. This system of supports permitted adjustments in the orientation of the nozzle and blink transducer in relation to S's eye. The S's head was securely positioned on the wooden platform by means of a leather strap that was passed over the bridge of the nose and through slots in the platform located on either side of the muzzle. When this strap was pulled tight, the chin was held down on the platform and vertical head movements were prevented. Adjustable padded blocks that were clamped against the muzzle and cranium bilaterally prevented lateral head movements. The wood neckpiece was in two sections, each with a semi-circular cut-out. The sections were mounted one above the other on metal brackets across the front of the stock. Adjustments in height of the neckpiece were accomplished by means of vertical slots in the brackets. A canvas sling held the Ss suspended above the base of the stock. Four canvas straps with buckles were attached to the base of the stock and fastened to S's legs. An additional strap passed over S's back and helped hold the body in place in the sling.

Procedure

All Ss were given one 2-hr. period of habituation to restraint in the stock on each of two consecutive

days. During the initial habituation period, the E remained in the sound-proof room for the first hour, leaving the S alone for the second hour. At the start of the second day, a loop of thread was sutured in the S's eyelid to allow recording of the eyeblink. Following this minor surgery, the S was left alone for the balance of the 2-hr. period. On the third experimental day, all Ss received 200 acquisition trials preceded by a test for sensitization which consisted of the following series of stimuli: 5 CS alone, 5 US alone, and 5 CS alone. On the fourth experimental day, the Ss were given 100 acquisition trials followed by 100 extinction trials. Two types of trials were administered during acquisition: reinforced (RF) and nonreinforced (NRF). A RF trial consisted of a paired presentation of CS and US while a NRF trial was a presentation of the CS alone.

Before handling, the Ss were randomly assigned to four different groups: three experimental groups (8 Ss each), and one control group (4 Ss). One experimental group (100%) received all RF trials in acquisition. A second experimental group (R-50%) received a schedule of 50% random reinforcement consisting of an equal number of RF and NRF trials from a Gellerman order (Hilgard, 1951, pg. 533). The random partial reinforcement schedule contained three instances

of single alternation in RF and NRF trials. The third experimental group (A-50%) was also given 50% partial reinforcement except that in this case RF trials alternated with NRF trials for the entire schedule. Group C, which was included in the experimental design to provide a control for pseudo-conditioning and sensitization, received backward US-CS presentations on 100% of the acquisition trials. The US preceded the CS by 10 sec. during acquisition for this control group. For all groups, extinction consisted of NRF trials. The inter-trial interval in acquisition and extinction was 30, 45, or 60 sec. with a mean of 45 sec.

Definition and measurement of responses

1) Historical considerations. The problem of developing an objective and meaningful definition of the conditioned response (CR) has received considerable attention from investigators in the field of classical conditioning (Kimble, 1961). Ideally, such a definition should provide operational criteria for assigning observed behaviors to separate classes of responses such that one class contains only CRs. Needless to say, this ideal situation has not been realized because of a variety of factors such as the variability of the biological system being observed, inter-experimental differences in procedures used to elicit the

behavior in question, and the difficulty of obtaining a response that has a relatively low base-rate of occurrence.

Perhaps the most common and consensually validated criterion for the definition of a CR is that the response be anticipatory. This criterion stipulates that in order for a response to be counted as a CR it must occur during the CS-US interval. That is, the CR must be a response to the CS that anticipates the time of US onset. In practice, however, the CR scoring interval employed may not be identical to the CS-US interval because of various empirical considerations of response latency. For example, certain systems such as the GSR may exhibit response latencies long enough to preclude their being recorded in the CS-US interval. This situation would be particularly likely to occur with the shorter interstimulus intervals (e.g., 500 msec.) thought to be optimal for conditioning. Similarly, it is common to use a scoring interval longer than the CS-US interval on nonreinforced trials (Moore & Gormezano, 1963). It is generally presumed that the extended interval will include a certain number of long-latency CRs that were not scorable on reinforced trials due to the occurrence of the unconditioned response (UR).

Another criterion for conditioning frequently adopted by investigators working in this area is that

the occurrence of a given response to the CS should follow a time-course commensurate with certain well-established laws of learning for it to be regarded as a CR. As an example, a CR would be expected to increase either in frequency of occurrence or amplitude, over the course of training trials. In addition, response latency might be expected to change systematically with conditioning. Applying this criterion to data generated in an experiment presumably would permit distinguishing learned behavior from a variety of other responses in the CS-US interval that may occur with some unchanging frequency, amplitude, or latency.

Additional improvements in identifying CRs in a conditioning experiment may be achieved by providing rules for the deletion of responses in the CS-US interval that, from independent evidence, are known to be unlearned. In the eyelid conditioning situation, for example, it has become common to eliminate original reflex responses to the CS and light-sensitized blinks to the CS (cf., Grant & Adams, 1944; Grant & Norris, 1947). It has been found that these responses exhibit a characteristic latency which is somewhat shorter than that of the eyelid CR, and therefore it is relatively simple to obtain an estimate of their rate of occurrence.

The problem created by a high base rate of random responding has been mentioned previously. Such

random responses could conceivably inflate estimates of CR frequency. One can determine the basal blink rate by sampling eyeblink behavior during the intertrial interval for a period equal in length to the CS-US interval. As a statistical control, the values obtained by this procedure may be compared with CR frequencies.

Some investigators have observed a type of human eyelid response that is considered to be voluntary (Spence, 1956; Kimble, 1961). Operationally, these eyeblinks can be distinguished reliably from conditioned eyelid responses on the basis of the difference in the form of the recorded tracings and response latencies. When instructed to blink at the onset of a given stimulus (CS), Ss' responses may have a characteristic form and latency which differs from that of most responses generated by Ss who have not been instructed to blink voluntarily. In experimental situations where voluntary-form blinks occur spontaneously, it is usually assumed that a verbally-mediated process such as self-instruction is involved. A number of methods for quantifying the form of eyeblinks have been suggested (Spence & Ross, 1959; Hartman & Ross, 1961; Gormezano & Moore, 1962; Pennypacker, 1964), but as yet there appear to be little agreement with respect to which method of quantification is most appropriate. It is evident that the efficiency of detecting voluntary responses will vary with the criteria

used to identify them.

Given that the distinction between voluntary and conditioned responses has been made, there is the additional problem of how the voluntary responses should be treated. Often the responses in question are simply deleted from the CR data. Alternatively, the data of Ss whose conditioning records show a proportion of voluntary-form blinks that exceeds some arbitrary level are eliminated from the analysis. With either procedure, the outcome of the experiment may be altered markedly (Gormezano, 1964).

The use of infra-human Ss would appear to diminish the importance of the voluntary-involuntary dichotomy. It is obvious that voluntary blinks under the control of instructions cannot be produced experimentally with this type of S because the appropriate instructions cannot be administered. Therefore, there would appear to be no generally accepted rule for detecting voluntary responses in infra-humans. Presumably to circumvent this problem, it has been suggested that the criteria developed for identifying voluntary responses in humans be applied directly to infra-human Ss (Kimble, 1961, Pp. 58-59), i.e., animal eyeblink tracings having the form of human voluntary responses would not be considered CRs. One implication of this technique is that the same set of processes underlies human and infra-human

voluntary responding. However, it has been indicated that certain investigators regard self-instructions to be important in determining the occurrence of voluntary blinking when no explicit instructions to respond voluntarily are provided by the E. Because infra-humans do not have verbal capabilities, the procedure suggested by Kimble seems unwarranted. Nevertheless, if the factors underlying human voluntary responding were reduced to specific stimulus-response relationships, it is conceivable that similar behavior in animals could be identified and treated accordingly.

2) Preliminary response-scoring procedures.

The preceding discussion has presented many of the considerations that influenced the selection of criteria defining the eyelid CR in the present investigation. For the acquisition and extinction phases of the experiment, the CR was defined as a downward pen deflection of at least 1 mm. In order to satisfy the requirement that the CRs be anticipatory, only responses occurring in the 500-msec. CS-US interval were scored during acquisition. For extinction the scoring interval was extended to 600 msec. As previously noted, the extended scoring period permitted the inclusion of long-latency CRs in extinction which were not scorable in acquisition because of the presence of the UR on reinforced trials.

A 600-msec. scoring interval was not employed on non-reinforced trials during acquisition for the partial reinforcement groups in order to insure comparability among the partial reinforcement, continuous reinforcement, and control groups with regard to definition of the CR.

The base rate of blinking was monitored for each S throughout the experiment by recording for a standard period before the CS onset. As was suggested in an earlier section, this pre-CS measure provided an estimate of the frequency with which random blinks might have occurred in the CS-US interval. A pre-CS blink was defined as a downward pen deflection of 1 mm. or more in a 500-msec. period before the CS for acquisition and a 600-msec. period before the CS in extinction.

RESULTS

Latency data

Preliminary inspection of the data was accomplished by plotting frequency distributions of the CR latencies. These distributions are displayed in Figure 1 which gives the frequencies in latency classes for consecutive blocks of 100 acquisition trials for all groups. Examination of the figure indicates that the control group distributions are essentially rectangular throughout training. The responses of the experimental groups, by contrast, tend to exhibit peak frequencies near the middle latency range.

It is conceivable that a certain proportion of the responses occurring in the CS-US interval have latencies too short for them to be CRs. The assumption here is that the CR has a minimum latency which is determined by certain physiological characteristics of the response system. Responses with latencies shorter than this physiological limit may be either random blinks or original reflex responses to the CS. Original responses are usually assumed to have shorter latencies than CRs and typically are defined in terms of latency criteria. It may be seen from Figure 1 that there is an abrupt increase in frequency from the 0-49 msec. interval to the 50-99 msec. interval for each of the

experimental groups. In addition, it is apparent that the low frequencies in the 0-49 msec. intervals remain relatively fixed over the course of training. It was inferred from these results that the responses in the 0-49 msec. latency range probably were not CRs but were random blinks or original responses to the CS. Therefore, responses in this latency interval were deleted from the data.

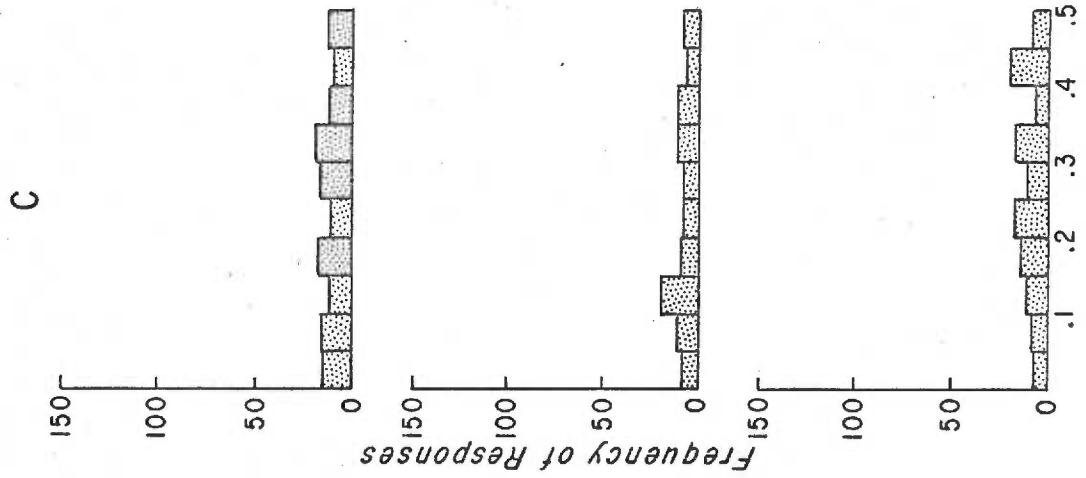
Frequency distributions of the extinction CR latencies for all groups appear in Figure 2. Examination of this figure shows that the control group frequencies are low and distributed evenly among the various latency intervals, as in acquisition. For the three experimental groups, latency classes in the vicinity of 150 msec. tend to be elevated in frequency.

In the course of inspecting the response records, it became apparent that eyelid closures of two distinct forms were represented in the CS-US interval. Figure 3 illustrates these two types of responses. The tracing depicted in the upper part of the figure can be described as a rapid closure of relatively large amplitude and short duration. Such reactions, which were typically observed in the experimental groups, are similar to those normally labelled a CR in human eyelid conditioning studies (Kimble, 1961). The response shown in the bottom half of the figure differs in form from the one above, in that

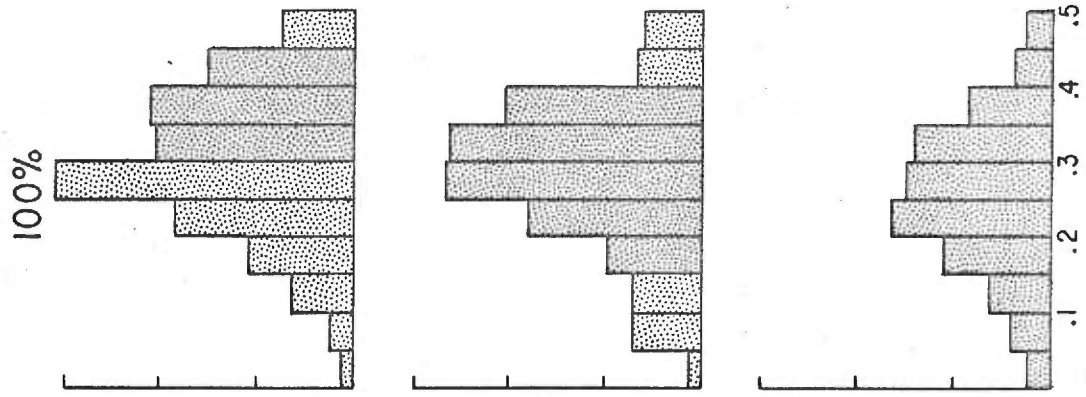
Figure 1. Acquisition CR latencies. Latency distributions of acquisition responses for the four treatment groups are given in successive 100-trial blocks.

ACQUISITION CR LATENCIES

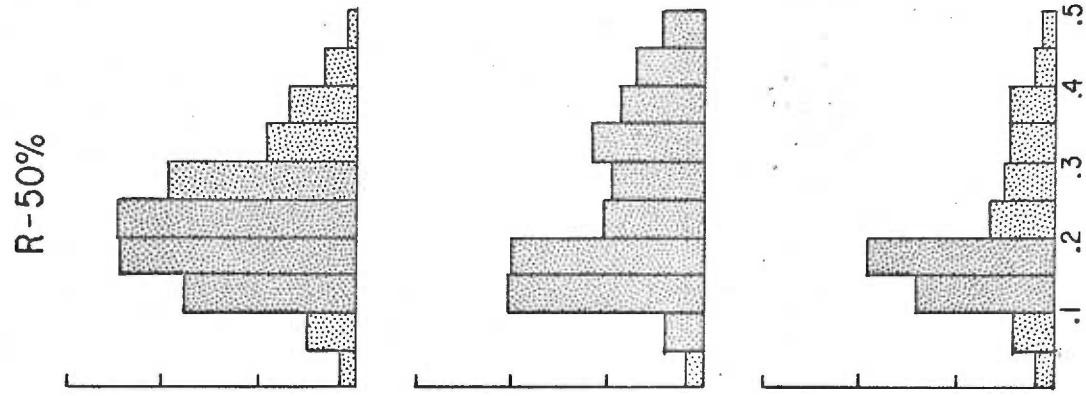
C



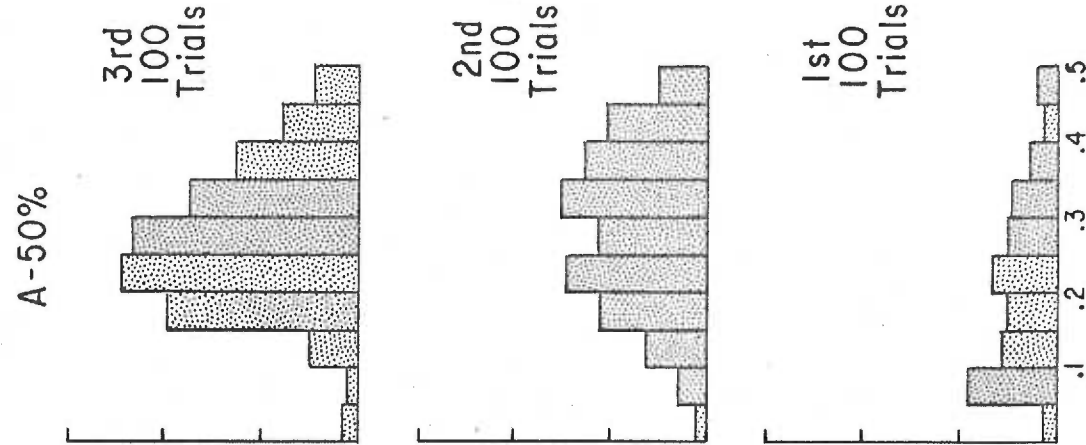
100%



R-50%



A-50%



3rd
100
Trials

2nd
100
Trials

1st
100
Trials

Frequency of Responses

Latency in Seconds

Figure 2. Extinction CR latencies. The distribution of response latencies in 100 extinction trials for the four treatment groups is given.

EXTINCTION CR LATENCIES

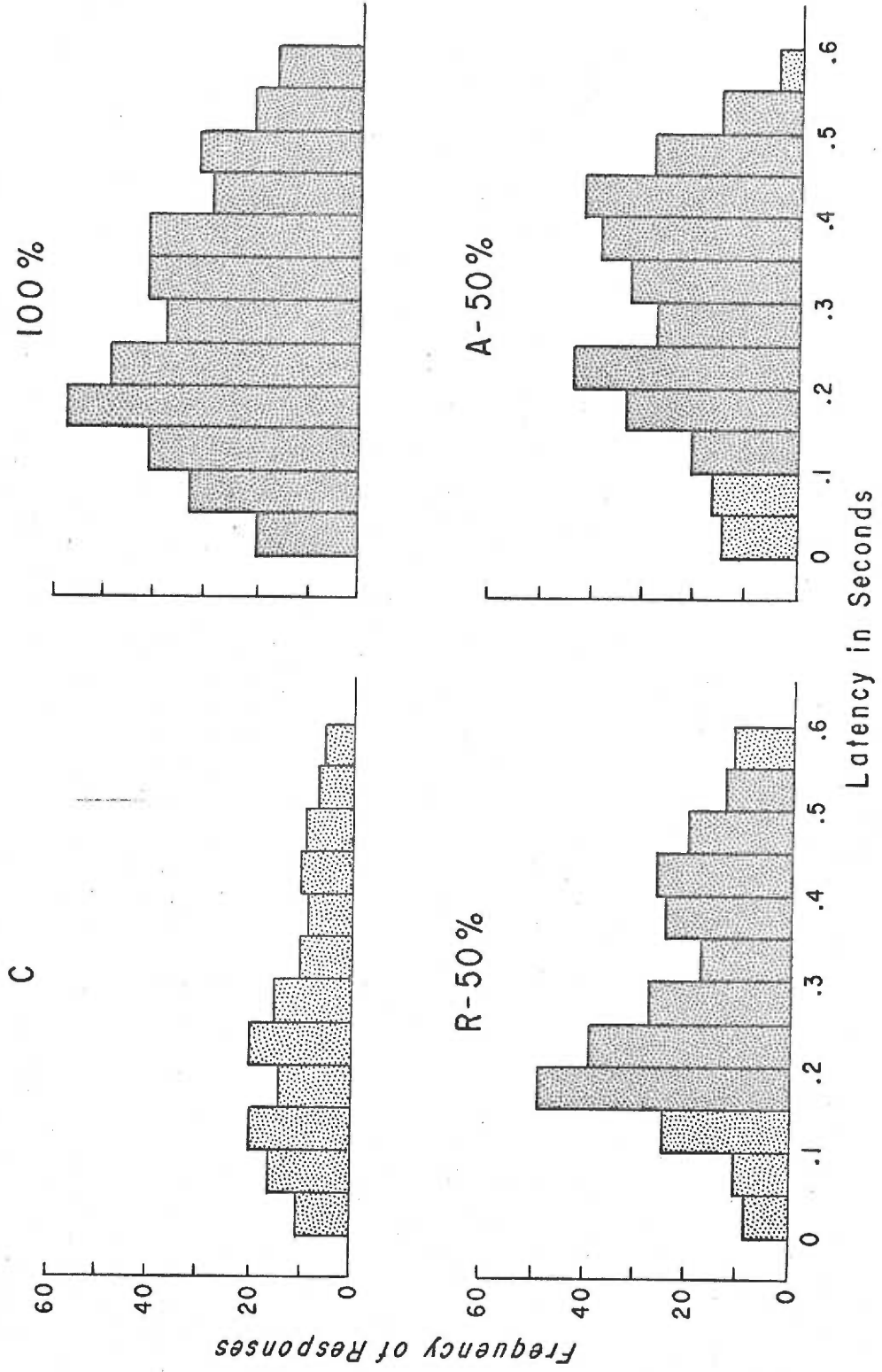
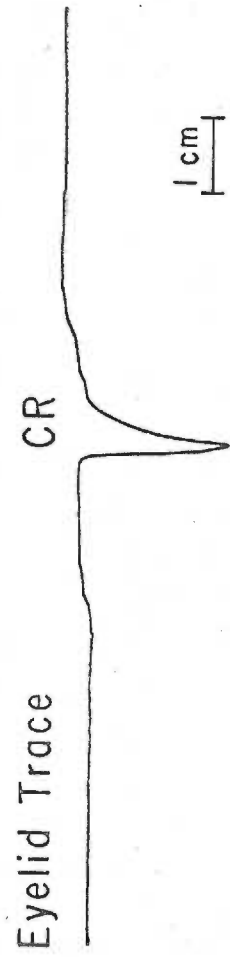


Figure 3. Two types of response to CS.
Tracings of short-duration and long-duration eyelid
responses to the CS are shown.

TWO TYPES OF RESPONSE TO CS



it has a lower amplitude and a considerably longer duration. In fact, when these responses occurred, they frequently had a duration that exceeded 500 msec. Similar long-duration eyelid closures have been observed in monkeys (Pennypacker & King, 1964). In order to distinguish between the two types of responses, all CRs obtained on the basis of the 1-mm. deflection criterion were measured in duration. This was accomplished by measuring the distance between the first downward deflection of the pen and the point at which the trace returned to 1 mm. above maximum deflection. As a result of these measurements, a judgement was made to exclude all responses from the data that had a duration in excess of 500 msec. It was felt that this criterion would be effective in detecting long-duration (L-D) responses and would have a minimal effect on CR frequencies.

It should be pointed out that these L-D reactions could not be scored in the 500-msec. CS-US interval for the 100% group during acquisition because of the occurrence of the UR. For groups R-50% and A-50%, such reactions could be scored only on NRF trials. Because the US was never paired with the CS for the control group, absence of the UR made L-D responses scorable on every acquisition trial. Therefore, it is possible that deletion of L-D closures from the CR data could spuriously elevate the performance levels of the

experimental groups relative to that of the control group. In addition, this potential scoring artifact could cause the performance of the partial reinforcement groups to appear depressed relative to the 100% group. Such a source of scoring bias did not exist in extinction because the US was omitted for all groups.

In order to obtain an estimate of the extent to which the deletion of L-D responses might influence performance differentially, the proportion of these eyelid closures occurring on nonreinforced acquisition trials was calculated for the two partial reinforcement groups and the control group. The values were: random partial reinforcement, 10.25%; alternating partial reinforcement, 4.41%; control, 11.67%. In extinction, the relative frequency of L-D responses on the first 20 trials was computed for all groups and the following proportions were obtained: continuous reinforcement, 10.63%; random partial reinforcement, 7.50%; alternating partial reinforcement, 2.50%; control, 7.50%. It may be observed that the percentages for group A-50% appear somewhat lower than those of the other groups both in acquisition and extinction. The statistical reliability of the differences among the groups was tested by analyses of variance (Winer, 1962). The data analyzed were percentages of L-D responses on blocks of 20 acquisition trials for each S, with separate analyses being performed

for Day 1 and Day 2 of acquisition. In extinction, percentages of L-D responses on four consecutive blocks of 5 trials were used in the analysis of variance. No statistically significant main effects (between-group means and trial blocks) or Groups X Trial-blocks interactions were obtained with these analyses. The results were interpreted as indicating that there were no consistent differences in L-D response frequencies among the groups and that the deletion of such responses would not influence estimates of the performance of the groups differentially.

On the basis of these considerations, the CR was redefined to include latency and duration criteria, i.e., a CR was a downward pen deflection of at least 1 mm. with a latency equal to or greater than 50 msec. and a duration less than 500 msec. All subsequent statistical analyses were carried out with the CR defined in this way.

Latencies of those CRs which satisfied the criteria specified in this new definition were inspected for systematic changes during acquisition. This was accomplished by computing the mean CR latency in milliseconds on consecutive 100-trial blocks of acquisition for each S. Examination of the group means for each block revealed a general increasing trend (100%; 262, 279, 301: R-50%; 224, 247, 237: A-50%; 244, 287, 273: C; 242, 264, 267). A trend test analysis of variance

(Winer, 1962) was performed on the latency data for all four groups. The overall trend during training was statistically significant ($F (2,48) = 3.88, p < .05$) and had a reliable linear component ($F (1,24) = 5.34, p < .05$), but the between-group and interaction effects were not significant. It was concluded from these results that there was a statistically reliable increase in mean response latency over the course of acquisition.

In order to determine the possible effects of extinction procedures on the CR latency data, a mean latency value was computed for each of four successive blocks of 25 extinction trials for every S. The results of a trend analysis with orthogonal polynomials indicated a significant overall difference between group means ($F (3,24) = 3.20, p < .05$). There was no reliable interaction effect or overall trend. The Newman-Keuls Test (Winer, 1962) was performed on the mean CR latency data in order to determine which of the two-group comparisons were significant. The statistically reliable differences were: A-50% vs. C, $q (4,24) = 10.35, p < .01$; R-50% vs. C, $q (3,24) = 8.19, p < .01$; 100% vs. C, $q (2,24) = 5.59, p < .01$; A-50% vs. 100%, $q (3,24) = 4.76, p < .01$. These results indicate that each of the experimental groups exhibited longer response latencies in extinction than the control group. In addition, the latencies for

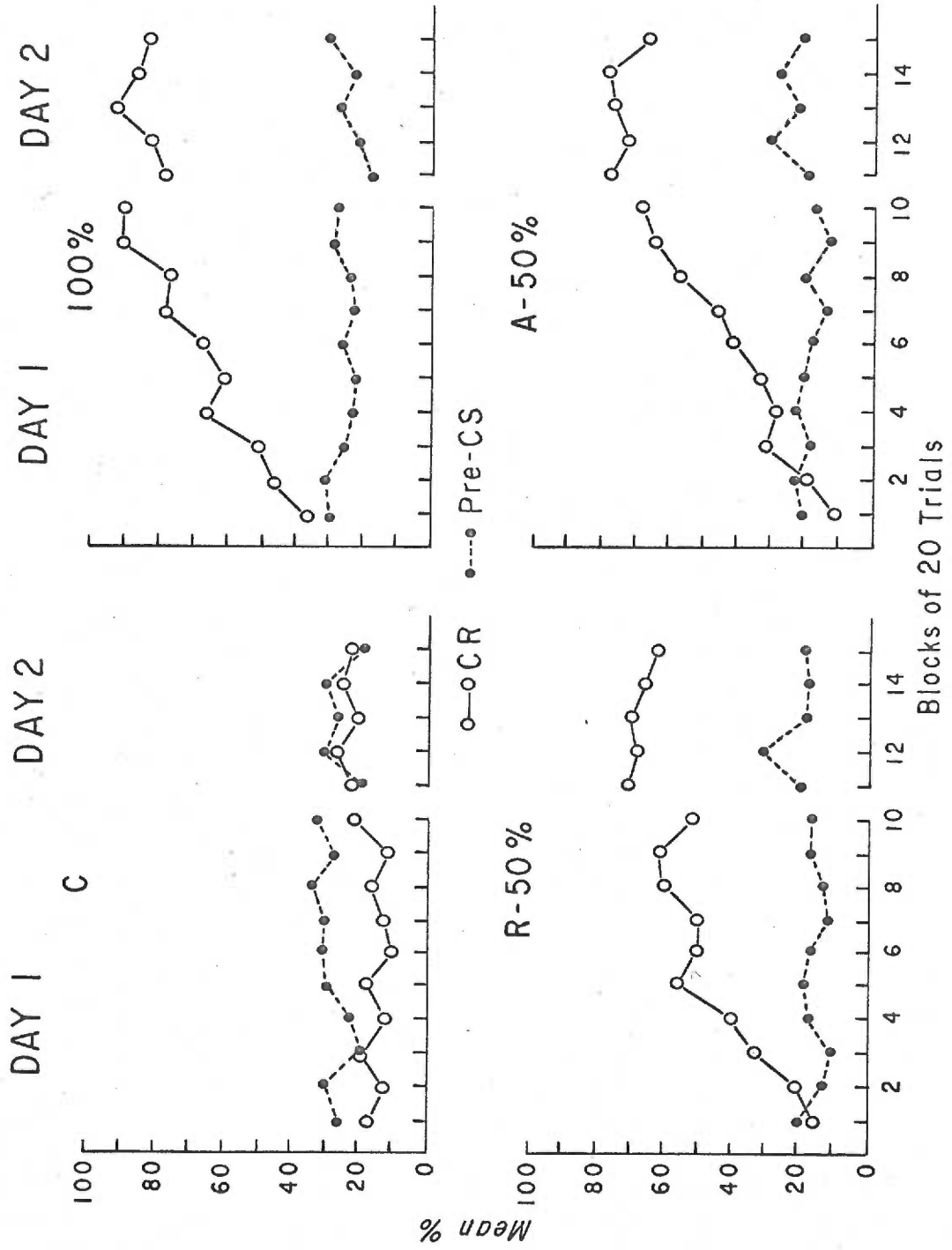
group A-50% were reliably longer than those of the continuous reinforcement group.

CR data

1) Within group comparisons. Curves of pre-CS and conditioned responding in acquisition are presented for each group in Figure 4, where the data points represent mean response percentages in blocks of 20 trials. There appears to be no consistent change with training in pre-CS response level for any of the groups on either day of acquisition. Divergence of the pre-CS and CR curves for the experimental groups reflects learning as a result of training trials. This tendency is reversed for the control group where the pre-CS responding is actually slightly higher than the CR percentages. Trend test analyses of variance comparing pre-CS and CR frequencies for each group separately were carried out for both days of training. On Day 1 of acquisition, there was a statistically significant overall increasing trend with training for the three experimental groups (100%, $F(9,126) = 4.34, p < .001$; R-50%, $F(9,126) = 5.25, p < .001$; A-50%, $F(9,126) = 2.60, p < .025$). This trend was found to be reliably linear (100%, $F(1,14) = 19.73, p < .001$; R-50%, $F(1,14) = 15.50, p < .005$; A-50%, $F(1,14) = 8.03, p < .025$). No significant trend over trials was obtained for the response levels of the control group.

Figure 4. Percentage of CR vs. percentage of pre-CS response. The acquisition percentages for all groups are plotted in 20-trial blocks.

PERCENT CR VS. PERCENT PRE-CS RESPONSE

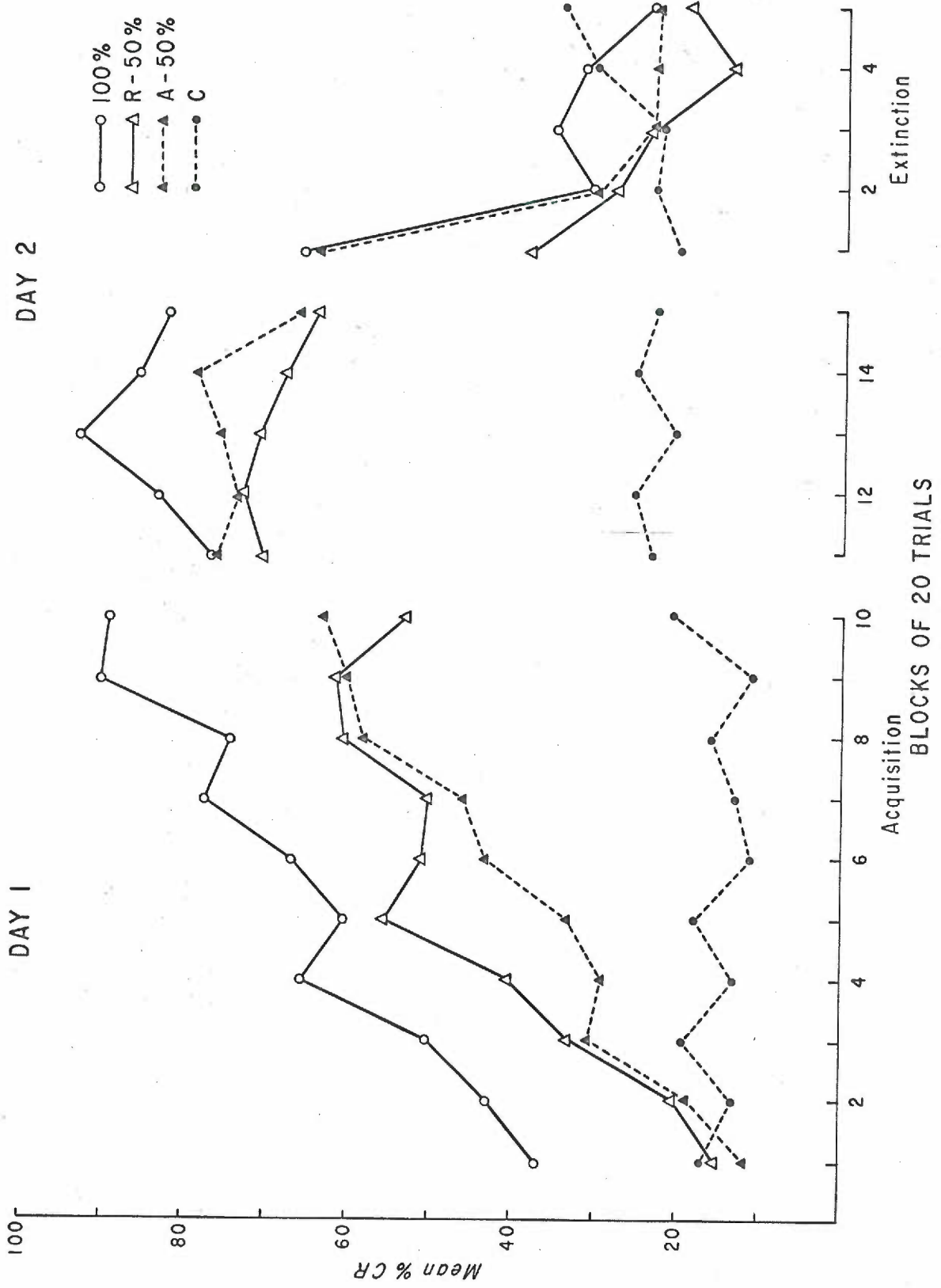


The CR means were significantly higher overall than the pre-CS means for the experimental groups (100%, $\underline{F} (1,14) = 18.50, p < .001$; R-50%, $\underline{F} (1,14) = 9.64, p < .01$; A-50%, $\underline{F} (1,14) = 7.75, p < .025$) and pre-CS responding was reliably higher than CR percentages for the control group ($\underline{F} (1,6) = 7.63, p < .05$). Significant interactions between CR and pre-CS means (100%, $\underline{F} (9,126) = 49.50, p < .001$; R-50%, $\underline{F} (9,126) = 51.64, p < .001$; A-50%, $\underline{F} (9,126) = 18.28, p < .001$) for all but the control group indicate that the divergence of the curves of the experimental groups in Figure 4 is reliable.

The analyses of Day 2 performance showed that the three experimental groups maintained CR levels that were significantly higher than the pre-CS values (100%, $\underline{F} (1,14) = 52.90, p < .001$; R-50%, $\underline{F} (1,14) = 15.26, p < .005$; A-50%, $\underline{F} (1,14) = 26.49, p < .001$). The interaction between CR and pre-CS frequency on Day 2 was statistically reliable (100%, $\underline{F} (4,56) = 157.38, p < .001$; R-50%, $\underline{F} (4,56) = 133.46, p < .001$; A-50%, $\underline{F} (4,56) = 152.04, p < .001$). For the control group, however, pre-CS performance on Day 2 was not statistically different from the CR response level.

2) Between group comparisons. Figure 5 gives the CR curves for the three experimental groups and the control group in acquisition and extinction. The acquisition CR data are the same as shown in the preceding figure

Figure 5. Percentage CRs of the experimental and control groups. The acquisition and extinction curves are plotted in blocks of 20 trials.



but they are replotted here to facilitate between-group comparisons. These curves depict the mean percentage of CRs on successive blocks of 20 trials. For Day 1 of acquisition, it may be seen that frequency of CRs is a positive function of practice for the experimental groups, whereas the control group curve exhibits little systematic change during the first day of training. The experimental group curves appear to have stabilized by Day 2, reaching an acquisition asymptote after approximately 200 trials.

A trend test analysis of variance was carried out on the CR data for all groups. Results obtained on the first day of acquisition were analyzed separately from those of the second day, the analyses being performed on mean percentage scores for blocks of 20 trials. The performance increments on Day 1 depicted in the curves of Figure 5 are statistically reliable ($F(9,126) = 14.08, p < .001$) and the variance attributable to increasing CR frequencies on day 1 had a significant overall linear component ($F(1,24) = 49.18, p < .001$). A reliable overall difference in group means was obtained ($F(3,24) = 5.63, p < .005$) and there was a significant interaction effect ($F(27,216) = 1.27, p < .05$) with a reliable linear trend ($F(3,24) = 3.13, p < .05$). On the second day of acquisition, there was no overall trend or interaction but the significant difference

between group means was maintained ($F(3,24) = 5.68$, $p < .005$).

In order to establish the source of the overall difference in group means, individual comparisons of the performance of each experimental group with the control group were made. Because the group data did not satisfy the statistical criteria for homogeneity of variance, the Mann-Whitney U Test was used (Siegel, 1956). The performance of all experimental groups was superior to that of the control group on Day 1 (100%, $U(4,8) = 0$, $p = .002$; R-50%, $U(4,8) = 3$, $p = .014$; A-50%, $U(4,8) = 3$, $p = .014$), and a similar result was obtained for the second day (100%, $U(4,8) = 0$, $p = .002$; R-50%, $U(4,8) = 4$, $p = .024$; A-50%, $U(4,8) = 1$, $p = .004$). These findings support the conclusion that performance of the experimental groups was elevated relative to that of the control group on both days of acquisition.

To provide a test for differences among the experimental groups, trend analyses of variance were performed on the CR data for groups 100%, R-50%, and A-50%. Mean percentage scores on blocks of 20 acquisition trials were analyzed separately for Day 1 and Day 2. The overall increasing trend in performance was significant ($F(9,189) = 15.02$, $p < .001$) for the first day of acquisition. This trend had a reliable linear component ($F(1,21) = 5.48$, $p < .05$), while the overall trend

was quadratic ($F(1,21) = 4.72, p < .05$) on Day 2. The quadratic trend resulted from a slight depression of performance for the 100% reinforcement group on the first block of trials of Day 2, followed by an increase for all experimental groups and a subsequent decline. Although the performance of the 100% group was higher than that of the partial reinforcement groups on both days of acquisition, there were no significant differences among the group means and no significant interactions. This indicates that the reinforcement schedules employed did not have a reliable effect on acquisition performance of the experimental groups.

Inspection of the extinction curves presented in Figure 5 reveals no consistent differences in performance for the three experimental groups. It may be seen that the control group curve exhibits a slight increasing tendency over the course of extinction. A trend test analysis of variance on these data from all four groups showed that there were no statistically reliable overall differences among mean CR values. Extinction was reflected in a significant overall decreasing trend ($F(6,144) = 10.76, p < .001$) which was reliably linear ($F(1,24) = 28.56, p < .001$). The Groups X Trials interaction was statistically significant ($F(18,144) = 4.06, p < .001$) and had a reliably linear trend ($F(3,24) = 3.12, p < .05$).

When the extinction CR data were plotted in blocks of 5 trials, it was evident that most of the performance decrement had occurred in the first 35 nonreinforced trials. Therefore, the percentages of CRs on the first 7 blocks of 5 trials in extinction were analyzed for the three experimental groups. Although the asymptotic acquisition levels of the experimental groups did not differ reliably, it was felt that the mean values for the last 40 acquisition trials were disparate enough to justify transforming the extinction data in a manner that compensated for differing initial performance levels. The transformation was carried out according to the following formula suggested by Anderson (1963):

$$\%R = 1 - (R_0 - R_n)/(R_0 - R_a) \times 100.$$

In this expression, R_0 is the mean percentage of CRs on the last 40 acquisition trials, while R_n is the raw percentage score being transformed and $R_a = 0$. R_0 represents the value taken as the acquisition asymptote, whereas R_a (zero) is a value selected as the asymptote of extinction. The ratio $(R_0 - R_n)/(R_0 - R_a)$ is subtracted from unity to provide a decreasing function. The remainder is multiplied by 100 to express the value as a percentage. When a transformation of this type is used, it is relatively common to set the extinction asymptote equal to zero (cf., Logan, Beier & Kincaid, 1956;

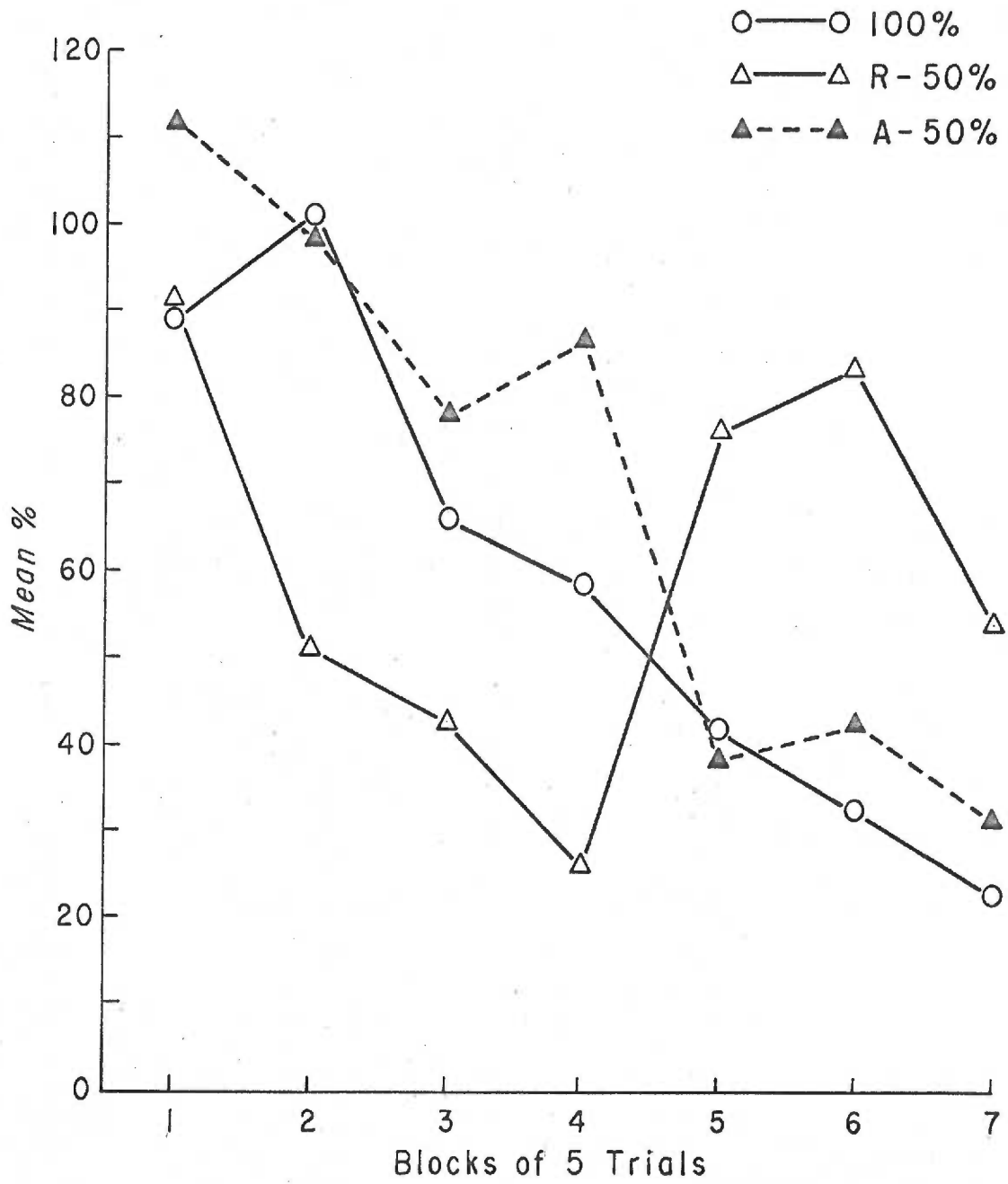
Thompson, 1966), the assumption being that performance would reach this level if extinction were carried out long enough.

For each S the terminal acquisition level was obtained and the terminal extinction performance was assigned a value of zero. Conditioned response percentages during extinction were then expressed proportionately on this scale. The transformation gives a measure of performance during extinction relative to the difference between the final acquisition level and the assumed asymptotic extinction level.

Figure 6 is a graphic representation of the mean values obtained by this transformation. This figure gives the values obtained in 35 extinction trials for the three experimental groups. The curves for groups 100% and A-50% appear to be similar in slope. In addition, the curves do not appear to differ strikingly in magnitude of the values represented. The extinction performance of group R-50% seems somewhat discrepant because the nonmonotonic function exhibits two major inflections. The results of a trend test analysis of variance for the experimental groups revealed an overall decreasing tendency that was statistically reliable ($F(6,126) = 3.75, p < .005$) and significantly linear ($F(1,21) = 6.80, p < .05$). There was no consistent overall difference between the experimental

Figure 6. Transformed percent CR in extinction.
The relative extinction curves for the three experimental
groups are plotted in blocks of 5 trials.

TRANSFORMED PERCENT CR IN EXTINCTION



group means, but a significant interaction was found ($F(12,126) = 4.18, p < .001$). In an attempt to determine which of the sets of extinction data contributed to the interaction effect, the three required simple interactions were computed and tested for significance. All three comparisons proved statistically reliable: 100% vs. R-50%, $F(6,84) = 4.77, p < .001$; 100% vs. A-50%, $F(6,84) = 5.37, p < .001$; R-50% vs. A-50%, $F(6,84) = 5.38, p < .001$. While it is not possible to state from this outcome that partial reinforcement produced more resistance to extinction than continuous reinforcement, it is clear that both relative frequency and pattern of reinforcement in acquisition had a differential effect on extinction performance.

DISCUSSION

The major findings of the experiment are summarized below. In this summary, the two primary response measures, CR latency and CR frequency, are considered separately. The results of both acquisition and extinction are indicated for each measure.

CR latency

- 1) There was an overall increasing trend in the latencies of CRs during acquisition. No reliable differences among mean CR latencies for the four treatment groups were obtained in acquisition.
- 2) During extinction, there was no trend in the latency data. The mean latency for each of the experimental groups was longer than that of the control group. The alternating partial reinforcement group had a longer mean CR latency than the 100% group.

CR percentages

1) CS and pre-CS performance

- a) On day 1 of acquisition, the CR means were higher than the pre-CS means for the experimental groups and the trends over training were linear. No significant trend was found for the control

group, but the pre-CS response levels were reliably higher than the CR percentages.

- b) The differences between CS and pre-CS performance were maintained for the experimental groups on Day 2 of acquisition. The control group CR levels were not statistically different from their pre-CS levels.

2) CR performance

- a) There was a linear increasing trend in mean CR percentages on Day 1 of acquisition. The CR levels of each experimental group were higher than that of the control group. There were no reliable differences among the performance levels of the three experimental groups.
- b) On Day 2, the trend in CR frequencies was quadratic and there were no significant differences among the experimental groups in mean CR percentages.
- c) During extinction there was a significant linear decrease in performance for the experimental groups. No consistent overall difference between the experimental group means was found. However,

there was a reliable Groups X Trials interaction in extinction.

Before discussing the principle results of this study, a consideration of the experimental controls that were employed is warranted. The pre-CS measure of random blink rates appears to have been sampling behavior that was in fact random. That is, no tendency for an increase or a decrease to occur in this measure was observed for any of the groups. It may be inferred that the base rate of responding was not influenced by potential cumulative effects of aversive stimulation to the eye. This inference is further supported by the finding that the random blink rate did not vary among groups, even though the relative frequency and total number of reinforcements differed between the continuous and partial reinforcement conditions. In view of the fact that the observed performance levels of the four treatment groups were superimposed on an essentially constant base rate of blinking, it is possible to conclude that random blinks did not affect performance differentially across groups or over training.

The backward conditioning group was included in the experiment to provide a statistical control for potential pseudo-conditioning and sensitization. Because the performance of this group did not change during acquisition, it may be assumed that the magnitudes of

the sensitization and pseudo-conditioning effects were negligible in the present investigation. Additional evidence for this conclusion is available, in that the CR frequencies of the control group were not higher than the random blink rate.

Acquisition

Reports of CR latency data in the eyelid conditioning literature are comparatively rare. Those investigators who have dealt with this response-measure in infra-humans uniformly report decreases in CR latency as a function of training (Hilgard & Marquis, 1935; Hughes & Schlosberg, 1938). Related reactions such as the nictitating membrane and eyeball retraction responses also produce decreasing CR latencies during acquisition (Schneiderman & Gormezano, 1964). In the present experiment, CR latencies increased over training. This seemingly discrepant result may be related to differential acquisition rates among the various investigations. For the current study, asymptotic levels of CR percentages were reached in considerably fewer trials than were required to achieve asymptote in previous eyelid studies with infra-human Ss. Hilgard and Marquis (1935) suggested that decreasing CR latencies reflect learning of time relationships between the experimental stimuli in the conditioning situation. If it is assumed that

such learning progresses at a slower rate than eyelid conditioning, then it is possible that the present investigation provided enough acquisition trials for CR percentages to become asymptotic but not enough trials for CR latencies to be affected by the learning of time relationships.

Some indirect evidence for lack of time-learning is provided by the fact that no overall mean differences in CR latency were obtained for the conditioning groups and the control group. If CR latencies were affected by learning in this study, then a reliable difference in latency between the control group and the other groups would be expected to occur. This failure to obtain between-group differences in mean latencies is consistent with the finding for rabbits reported by Thomas and Wagner (1964).

The CR percentage results are in essential agreement with those of studies where no differences in acquisition performance for 50% and 100% reinforcement were found (cf., Gonzalez, et al., 1961; Longo, et al., 1962). Here the performance curves for continuously and intermittently reinforced groups reached the same acquisition asymptote at the same rate despite the fact that the 100% group received twice the number of reinforcements that were given the 50% groups. It may be mentioned that no widely accepted reinforcement theory

can predict such a result without some modification.

The group receiving 50% alternating reinforcement did not perform differently from the group given 50% random reinforcement in acquisition. In contrast, Grant et al. (1950) found that human Ss trained with alternating partial reinforcement gave reliably lower percentages of eyelid CRs than did a random reinforcement group. The finding of Longnecker, et al. (1952) that alternating reinforcement produced acquisition performance levels comparable with those resulting from random reinforcement is consistent with the results of the present investigation. However, the human Ss in their study exhibited GSRs that varied in relative frequency according to the alternating reinforcement pattern after the first few trials. That is, the Ss tended to give more CRs after reinforced trials than after nonreinforced trials. No such pattern of responding was obtained in the present experiment. These data suggest that high-order cognitive processes may influence the conditioning performance of humans when a regular periodic reinforcement schedule is employed. In the current investigation, no results requiring the postulation of such processes were obtained with infra-human Ss trained under a similar reinforcement regimen.

Extinction

The overall difference in CR latencies between groups in extinction is difficult to interpret because no differences of this type were obtained during acquisition. Ordinarily a difference between control group performance and that of the experimental groups would be regarded as reflecting the influence of learning. However, no learning effects on CR latency were observed in acquisition, and, therefore, it is difficult to attribute the extinction results to purely associative factors. Also, it is not clear why the CR latencies of group A-50% were reliably longer than those of the 100% group during extinction when no difference was obtained in acquisition. It is possible that this result is ascribable to Type I statistical error.

The reliable interaction observed for extinction CR percentages was not of the type that would be described as a PRE. The Treatments X Trials interaction in extinction is most reasonably interpreted as reflecting multiple inversions and crossings in the performance curves rather than differential resistance to extinction among the experimental groups. However, there are circumstances where an interaction may be regarded as a PRE (cf., Fitzgerald, 1963; Wagner et al., 1964). In such cases the interaction is produced by more rapid extinction after continuous reinforcement than after

partial reinforcement. If the asymptotic levels of acquisition performance are the same for continuous and partial reinforcement groups, then the interaction PRE could consist of diverging curves, with the 100% function having the steeper slope. In a situation where terminal acquisition performance levels are different for the two reinforcement conditions and the 100% group is higher, then the interaction may be represented by crossed curves which reflects larger performance decrements for continuously reinforced Ss. The first type of interaction can be interpreted as representing greater resistance to extinction following partial reinforcement. However, for the second type where acquisition asymptotes are different, an interaction may be obtained simply because the group with the lower asymptote must exhibit less absolute decrement. Such a result should not be interpreted as necessarily indicating differential resistance to extinction. In the present experiment, neither the significant interaction for reinforcement pattern nor the frequency of reinforcement interaction appear to be classifiable as PREs.

Spence (1966), in a recent theoretical article, suggested that the rate of extinction for human eyelid conditioning is strongly influenced by complex verbal processes. It was argued that human Ss adopt an inhibitory "set" when extinction is begun and this

leads to extremely rapid performance decrements. The fast extinction in humans was contrasted with the extinction performance of infra-humans, which in certain conditioning situations may exhibit a much slower time course. It was pointed out, that extinction for infra-humans often progresses at approximately the same rate as acquisition. This inter-species difference in extinction rate, relative to that of acquisition, was attributed to the operation of a verbally-mediated inhibitory set in the case of human Ss. It may be recalled that in the present experiment asymptotic extinction performance was obtained in approximately 35 trials, whereas more than 100 trials were required for acquisition. These results indicate that, in situations where verbal processes cannot be assumed to affect performance: 1) the rates of acquisition and extinction may differ markedly; 2) relatively rapid extinction may occur.

Spence (1966) further suggested that the PRE for humans results from the influence of these complex verbal factors in extinction. It was stated that the PRE would not be observed when experimental conditions were arranged to minimize such processes. The failure to find a PRE in certain early studies with infra-human Ss was cited as evidence that verbal processes are necessary to produce the effect.

Recently, however, some investigations with infra-humans have produced an interaction PRE in extinction (cf., Fitzgerald, 1963; Slivka & Bitterman, 1966). In addition, Kimmel and Yarenko (1966) obtained a PRE with planaria that was similar to the type usually observed in humans. These authors pointed out that their finding for flatworms is inconsistent with any theory that postulates higher-order cognitive processes as a basic determinant of the PRE. These results should be viewed cautiously, however, because of the uncertainty surrounding the presence of learning in planaria. Fitzgerald, et. al. (1966) also obtained the kind of PRE usually associated with humans in a heart-rate conditioning experiment using dogs. These investigators took the position that their findings may be explained without postulating discriminative factors.

There appears to be no simple explanation of the discrepancies between the results of the present investigation and those of Fitzgerald et al. Both experiments employed dogs as Ss and used aversive reinforcers. In addition, the apparatus and general experimental procedures were rather similar. In short, conditions were such that similar results might have been expected from the two studies. It seems conceivable that the source of the discrepancies lies in the differing forms of aversive reinforcement used. Possibly the

electric shock US used in the heart-rate conditioning experiment was more noxious than the 2-psi air puff. Fitzgerald (1966) has hypothesized that the extinction PRE results from punishment by the US of extinction-like response on nonreinforced trials in acquisition. It is reasonable to assume that the suppression of these responses is a positive function of the intensity of the punishing stimulus. This set of assumptions leads to the prediction that resistance to extinction of a partially reinforced group depends on US intensity to a greater extent than does resistance to extinction of a continuous reinforcement group. That is, an interaction between US intensity and relative frequency of reinforcement may be derived from the punishment hypothesis. For the current experiment, the US may have been sufficiently intense to be reinforcing but not intense enough to punish extinction-like response in the 50% groups during acquisition. The US employed by Fitzgerald, et al., presumably being more intense, may have been effective both as a reinforcer and as a punishing stimulus.

SUMMARY

An experiment was conducted to determine the effects of partial reinforcement on a classically conditioned eyelid response in dogs. Three percentages of reinforcement, 100%, 50%, and 0% were employed in acquisition. The CS was a 600-msec., 500-Hz. tone and the US was a 100-msec., 2-psi air puff to the cornea. The CS-US interval was 500 msec. with the US overlapping the last 100 msec. of the CS. All Ss received 300 acquisition trials and 100 extinction trials. A reinforced trial was a paired presentation of CS and US while a nonreinforced trial was an occurrence of the CS alone. One group of Ss received 100% reinforced trials in acquisition. Two other groups were given 50% reinforced trials in acquisition. For one 50% group the CS-US pairings alternated with CS-alone presentations while, for the other group receiving partial reinforcement, the sequence of reinforced and nonreinforced trials was random. A control group was given 100% backward trials in acquisition where the US preceded the CS by 10 sec. Extinction consisted of nonreinforced trials for all groups.

Two response measures were obtained in acquisition and extinction: relative frequency of CRs, and latency of CRs. As a control measure, the percentage

of responses occurring in a pre-CS period was obtained. The principle findings were:

Acquisition

- 1) CR latency increased over training for all groups. There were no overall differences between groups in mean CR latency.
- 2) CR percentages for the conditioning groups increased but the control group performance did not change during training. There were no reliable differences between the performance of the conditioning groups.
- 3) Pre-CS performance did not change during acquisition for any of the groups. There were no significant between-group differences in pre-CS levels.

Extinction

- 1) No trends in CR latency were obtained during extinction. The three experimental groups had reliably longer mean latencies than the control group.
- 2) No consistent between-group differences in CR percentages occurred. However, there was a reliable Groups X Trials interaction for the three experimental groups.

3) Pre-CS levels did not vary with trials in extinction, and there were no significant differences between the four groups for this measure.

The lack of differences in acquisition performance and the rate of extinction for the conditioning groups were discussed in terms of their relevance to explanations of the PRE that postulate discriminative processes. It was concluded that certain results of the present investigation are inconsistent with such explanations. A punishment model for the PRE was considered as an alternative explanation.

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APPENDIX A

Percentages of CRs in acquisition for blocks of 20 trials.
Values followed by an asterisk are means based on less
than 20 trials due to occasional apparatus failure.

DAY 1 - ACQUISITION

Group	<u>S</u>	Trial block									
		1	2	3	4	5	6	7	8	9	10
100%	1	50	70	90	100	100	95	95	100	95	100
	2	0	5	45	65	60	35	40	10	55	80
	3	35	35	70	85	75	100	90	85	90	100
	4	15	30	30	50	75	95	95	100	100	100
	5	65	100	100	100	100	95	100	100	100	100
	6	70	40	25	55	20	80	60	80	95	100
	7	30	55	40	30	25	14*	80	90	100	84*
	8	30	30	10	45	30	20	60	30	85	50
	\bar{X}	36.9	45.6	51.2	66.2	60.6	66.7	77.5	74.4	90.0	89.2
R-50%	1	20	40	90	100	100	100	95	90	100	90
	2	11	45	40	40	85	60	70	60	80	45
	3	0	0	0	20	70	35	35	40	65	50
	4	0	5	0	20	65	55	55	70	20	40
	5	20	35	85	90	85	85	95	100	100	90
	6	50	30	50	35	30	25	25	40	45	50
	7	10	10	0	10	15	50	35	65	75	45
	8	10	10	5	5	0	5	0	20	5	20
	\bar{X}	15.1	21.9	33.7	40.0	56.2	51.9	51.2	60.6	61.2	53.7
A-50%	1	15	5	15	15	35	85	60	45	10	30
	2	45	40	25	45	90	75	100	100	95	95
	3	0	5	5	5	0	25	55	80	75	85
	4	0	5	20	15	25	55	85	70	100	90
	5	10	65	89*	67*	63*	30	5	60	75	80
	6	0	15	85	60	5	0	5	10	25	50
	7	15	5	5	5	5	15	5	10	30	5
	8	10	15	10	15	45	65	50	85	70	75
	\bar{X}	11.9	19.4	31.7	28.4	33.5	43.7	45.6	57.5	60.0	63.7
C	1	25	20	35	25	25	20	15	5	5	26*
	2	0	5	5	0	0	0	5	10	15	30
	3	30	20	37*	30	30	15	10	20	5	11*
	4	15	10	0	0	15	10	25	30	20	15
\bar{X}	17.5	13.7	19.2	13.7	17.5	11.2	13.7	16.2	11.2	20.5	

DAY 2 - ACQUISITION

Group	<u>S</u>	Trial block				
		11	12	13	14	15
100%	1	94*	100	100	100	95
	2	10	45	100	55	44*
	3	95	100	100	100	100
	4	100	95	95	100	95
	5	89*	80	95	65	70
	6	85	85	90	100	95
	7	90	90	90	80	65
	8	55	70	79*	85	95
	\bar{X}	77.2	83.1	93.6	85.6	82.4
R-50%	1	100	100	100	100	100
	2	95	80	65	30	40
	3	95	100	100	90	85
	4	35	40	45	50	45
	5	95	95	95	95	60
	6	50	50	75	65	53*
	7	95	80	90	95	80
	8	0	0	0	15	5
	\bar{X}	70.6	68.1	71.2	67.5	58.5
A-50%	1	50	45	35	55	70
	2	100	100	100	100	100
	3	100	100	100	100	100
	4	100	100	90	100	70
	5	75	70	84*	95	65
	6	65	85	90	85	70
	7	47**	20	20	20	25
	8	85	65	90	75	35
	\bar{X}	77.7	73.1	76.1	78.7	66.9
C	1	50	50	30	35	45
	2	15	20	20	50	25
	3	20	35	25	15	15
	4	10	5	10	0	10
	\bar{X}	23.7	27.5	21.2	25.0	23.7

APPENDIX B

Percentages of CRs in extinction for blocks of 5 trials.
Only 4 trials are included in the first block of extinction.
The first extinction trial was not scored because it could
not have reflected the effects of nonreinforcement.

DAY 2 - EXTINCTION

Group	<u>S</u>	Trial block						
		1	2	3	4	5	6	7
100%	1	100	100	20	80	40	20	20
	2	25	100	60	20	0	0	20
	3	100	80	60	60	20	0	0
	4	100	100	100	100	80	80	40
	5	25	60	40	20	0	50	20
	6	75	100	40	20	40	40	20
	7	100	80	60	60	80	20	40
	8	100	20	40	40	40	20	0
	\bar{X}	78.1	80.0	52.5	50.0	37.5	28.7	20.0
R-50%	1	100	100	100	60	40	60	20
	2	50	40	0	0	40	0	0
	3	75	60	100	60	100	0	20
	4	100	0	40	0	0	20	20
	5	100	80	20	40	40	20	40
	6	0	0	0	0	0	20	20
	7	50	20	20	20	80	60	60
	8	0	0	0	0	20	40	20
	\bar{X}	59.4	37.5	35.0	22.5	40.0	27.5	25.0
A-50%	1	0	60	60	100	40	60	80
	2	75	100	60	80	40	20	20
	3	100	80	100	100	100	40	40
	4	75	100	60	60	0	0	0
	5	50	60	40	40	20	60	20
	6	100	60	60	40	60	0	40
	7	60	40	20	40	0	20	0
	8	100	40	40	0	0	20	0
	\bar{X}	70.0	67.5	55.0	57.5	32.5	27.5	25.0
C	1	25	20	80	20	40	20	40
	2	0	20	20	0	20	20	0
	3	25	20	20	20	20	20	60
	4	25	0	20	0	0	20	0
	\bar{X}	18.7	15.0	35.0	10.0	20.0	20.0	25.0