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AVOIDANCE CONDITIONING IN GOLDFISH: EFFECTS OF FEAR CONDITIONING WITH AND WITHOUT AN ESCAPE CONTINGENCY ON SUBSEQUENT ACQUISITION

by

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GENERAL INTRODUCTION

Recent emphasis has been placed on the assessment of phyletic generality of learning phenomena. The aim has been to detail the similarities and differences between the learning processes in the commonly used mammalian species and those in submammalian vertebrate species. Toward this end investigators have used fish as subjects in experiments analogous to those used in studying learning in the rat and other mammals.

Positive reinforcement studies have shown that a target striking response can be maintained in goldfish on a variety of schedules of reinforcement (Gonzalez, Eskin, and Bitterman, 1962) and that secondary reinforcers can maintain a lever pressing response in goldfish (Salzinger, Freimark, Fairhurst, and Wolkoff, 1968). Differences in the way reinforcement parameters affect conditioning in the fish and in the rat have been demonstrated in several studies. Partial reinforcement increases initial resistance to extinction in fish when the number of reinforcements is equated to continuous reinforcement, but not when the number of trials is the same. Both procedures increase resistance to extinction in the rat (Gonzalez, Eskin, and Bitterman, 1962). Shifting amount of reinforcement from small to large reward decreases response latency in fish as it does in rats, but shifting from large to small reward does not correspondingly increase response latency (Lowes and Bitterman, 1967). Successive extinction periods each following reconditioning lead to a progressive decrease in resistance to extinction over extinction periods in both fish and rats. The two species differ in that rats develop an asymptotic resistance independent of the interpolated reinforcement period while fish respond at a higher rate at the beginning of each extinction period (Gonzalez, Holmes, and Bitterman, 1967). Fish do not show the progressive improvement in performance on successive reversals of a simple discrimination which is characteristic of the behavior of the rat (Behrend and Bitterman, 1967; Behrend, Domesick, and Bitterman, 1965). In probability learning experiments, fish match the reinforcement probabilities in situations where rats maximize the number of reinforcements (Behrend and Bitterman, 1962; Bitterman, Wodinsky, and Candland, 1958).

Shuttlebox avoidance training has been studied in fish both as a means of examining sensory capacities (Jacobs and Tavolga, 1967) and to compare the effects of manipulating avoidance conditioning parameters with the effects in mammalian species. The avoidance parameter experiments have produced results which are different from the results of analogous procedures in mammals and which may show important phylogenetic differences in learning. Bitterman and his associates have investigated the role of the CS-US[1] interval in avoidance conditioning procedures; number of trials avoided decreased to asymptote as CS-US interval increased for fish while for rats no significant relations between CS-US interval and performance has been obtained. For rats, increasing the intertrial interval increases performance up to a point, but then performance declines with longer intervals. Pinckney (1966) found no decline in performance for fish with intertrial intervals as long as 20 min. Jacobs and Popper (1968) found that pinfish reach criterion on an avoidance task faster with a visual stimulus than with an auditory stimulus, while rats perform better with an auditory stimulus.

Bitterman writes: "There is little reason, perhaps, to expect that avoidance learning in the fish will differ in any important respect from avoidance learning in higher animals, but an assumption of functional similarity and a demonstration of it are quite different things." (Behrend and Bitterman, 1963)

It is in this light that an investigation of the effect of fear conditioning on shuttlebox avoidance learning is undertaken. The usefulness of results bearing upon questions of basic conditioning processes depend in part on their generality. Most of the data has been obtained from

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[1]The classical conditioning terminology will be used to describe the avoidance contingency.

the rat. Experimentation with the phylogenetically simpler goldfish should either give broader scope or introduce qualifications of the interpretations of conditioning results.

Avoidance conditioning

One of the first shuttlebox avoidance conditioning studies and a model for this procedure was published by Mowrer and Lamoreaux (1942). A rat was placed in one compartment of a two compartment shuttlebox and a light signal came on. After five seconds the light was joined by shock across the grid floor on which the rat stood. If the rat crossed from one compartment to the other in response to the shock, the light and shock were terminated, and an escape response was said to have occurred. If, however, the rat crossed during the light, but before the shock came on, the light was terminated, delivery of the shock avoided, and an avoidance response was said to have occurred. These contingencies have come to be termed the discriminated escape-avoidance conditioning procedures.

After avoidance conditioning was isolated as a phenomenon separate from simple Pavlovian conditioning, difficulties in accounting for the behavior arose. Calling the response that forestalls shock an avoidance response describes the behavior as seen by an observer, but does not easily lead to an explanation of the behavior. As an explanatory term, it implies a response with foreknowledge of shock. In a theory of behavior, however, how can the threat of shock act to condition a response? The problem, as stated by Schoenfeld (1950), is "how the nonoccurrence of an unconditioned stimulus can act as a reinforcement."

The following account will show how a two-process learning theory deals with the formation of an avoidance response in the form described above. In addition, a line of research that evolved from two-factor theory and some recent questions about it are described which involve the effects of prior shock on avoidance conditioning.

Two-process learning theory

The basic postulate of two-process learning theory is that there are two fundamental paradigms of learning. One is the establishment of a conditioned response (CR) by the temporal contiguity of a neutral stimulus (CS) and an unconditioned stimulus (US). The other is the establishment of an instrumental response by its consequences. It stresses that the two processes interact so that Pavlovian conditioning affects the establishment of instrumental behavior.

A general theoretical statement of two-process theory in regard to aversive control procedures was offered by Rescorla and Solomon (1967).

> (a) Pavlovian association processes precede the acquisitions of emotional reactions to previously neutral stimuli; and (b) these emotional reactions have motivational properties that can influence instrumental responding. It follows that any empirical or theoretical law of Pavlovian conditioning has profound implications for the control of instrumental responding when the two processes are interactively combined by *E*'s procedures.

In accord with two-process theory, discriminated avoidance conditioning may be analyzed into two separate and distinct operations (Dinsmoor, 1954). The first is the pairing of a stimulus, neutral with respect to a selected response, with an aversive stimulus. The second is reinforcement of a response by the termination of an aversive stimulus. These Pavlovian and instrumental contingencies are combined in the avoidance conditioning procedure.

The two-process explanation can thus be outlined as follows. The contiguity between the signal and the aversive stimulus establishes the signal as a conditioned aversive stimulus. The reinforcement for the avoidance response is the termination of the conditioned aversive stimulus.

The mediation of classical conditioning in the formation of the contitioned aversive stimulus is stressed by two-process theory. A constellation of responses which may be defined as fear is elicited by the aversive stimulus. The contiguity between the CS and US establishes fear as a CR. The internal stimuli produced by the fear response are aversive and thus mediate the establishment of conditioned aversive stimulus.[2]

The critical proposition in the analysis of avoidance conditioning is that the pairing of the CS and the US establishes the CS as an aversive stimulus whose termination is reinforcing. It follows that if a CS and US are paired (a procedure termed fear conditioning) the reinforcement value

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[2]It may be noted that, strictly speaking, in this explanation the stimuli produced by fear and not the CS are aversive. However, since it does not damage the account, the CS will be considered a conditioned aversive stimulus for the sake of simplicity.

of termination of the CS should be demonstrable. Several studies have shown this (Brown and Jacobs, 1948; May, 1948; and Miller, 1948).

The experiment by Brown and Jacobs (1948) is illustrative of the procedure and effect of fear conditioning. In phase I rats were confined in one compartment of a two compartment shuttlebox. While in the compartment the animals received 22 trials with a combination light and tone stimulus (on for nine sec) which was overlapped by a pulsating shock for the last six sec of each trial. The pairing of CS and US without means of escape was defined as fear conditioning. To test the effect of this operation, 40 additional trials were presented in phase II to each animal with the shock eliminated and a door separating the two compartments opened with the onset of the CS. A response of crossing into the other compartment terminated the CS. Latencies for animals crossing from one compartment to the other were recorded and found to decrease over trials. Control animals which had not been shocked in phase I showed originally longer and increasing latencies with increasing trials. Results like those of Brown and Jacobs confirm the two-process theory prediction that a conditioned aversive stimulus can be established whose termination itself is reinforcing.

To demonstrate, however, that escape from a conditioned aversive stimulus does in fact mediate avoidance responding it is necessary to separate the classical and instrumental contingencies and demonstrate the effect of the one on the other.[3] A straightforward way of separating the two is to isolate the Pavlovian contingency and then demonstrate a facilitative effect on avoidance conditioning. Thus, after fear conditioning, the establishment of the avoidance response should be facilitated. Unfortunately, the results of studies of this type have been equivocal and will be discussed in detail later.

An alternate strategy for confirmation of the fear mediation hypothesis is to demonstrate the effect of Pavlovian conditioning on an already established instrumental avoidance response. The problem with this strategy is that it is susceptible to confounding by adventitious instrumental contingencies. For example, if the instrumental response has already been established, it is a highly probable response to shock. If fear conditioning is now given it is quite likely, although the contingency has not been explicitly arranged, that the occurrence of the instrumental escape/avoidance response will coincide with the offset of shock. In this manner the response may receive instrumental reinforcement which confounds the classical contingency.

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[3]It may be noted here that I wish to limit my discussion here to what has been called the "weak" form of the fear mediation hypothesis (Maier, Seligman, and Solomon, 1969). That is, that fear mediates the acquisition of the discriminated avoidance response. It is not necessary in this view to extend the hypothesis to the acquisition of the response in all avoidance situations nor to the maintenance of a well-established avoidance response.

An experiment by Solomon and Turner (1962) attempted to overcome this difficulty. They first trained dogs to press a panel in a discriminated avoidance situation with a visual CS. The dogs were then curarized and subjected to a discriminated Pavlovian conditioning procedure in the same apparatus, in which one tone (CS+) was paired with shock and another tone (CS-) was never paired with shock. When later tested, the animals made short-latency panel press responses which terminated CS+ although they had never made that response in the presence of a tone. Further, they did not respond to CS-.

Since the dogs were paralyzed by curare no movement response which could be similar to panel pressing was being adventitiously reinforced by shock termination. The remote possibility remains, however, that since the Pavlovian conditioning was administered in the same apparatus as the avoidance conditioning, some central "pressing" response was being made and reinforced by shock termination. An experiment by Leaf (1964) controlled for this possibility.

In Leaf's study dogs were immobilized with curare and secured in a harness. They were subjected to fear conditioning trials with a CS+ tone followed by shock and a CS- tone never followed by shock. The animals were then transferred to a shuttlebox where they acquired a barrier jumping avoidance response to a visual CS. In extinction, the dogs produced short latency responses to CS+, but either long latency or no response to CS-.

Further evidence that the events mediating avoidance conditioning are classically conditioned comes from studies which show that fear conditioning follows the same rules as other Pavlovian conditioning procedures such as salivary conditioning. Studies showing Pavlovian laws operating in the control of avoidance responding have been published by Solomon and his associates (LoLordo, 1966; Moscovitch and LoLordo, 1967; Rescorla, 1967; and Rescorla and LoLordo, 1965). The evidence is reviewed by Maier, Seligman, and Solomon (1969).

One-factor avoidance theory

Recently, Herrnstein (1969) has argued that a Pavlovian contingency is not necessary for the acquisition of an avoidance response and is indeed insignificant even in cases where a CS is explicitly supplied. He proposes that avoidance conditioning is adequately explained by the single factor of instrumental reinforcement. The only necessary condition is that "a response producing a particular state of affairs is increased in frequency, the state of affairs being here the reduction in shock rate."

Herrnstein contends that two-factor avoidance theory becomes irrefutable when called upon to explain avoidance conditioning without an explicit CS. The crucial experiment to determine the necessity of a Pavlovian contingency is what Herrnstein (1969) calls the "minimum avoidance procedure --one containing no conditioned stimulus, either explicit or plausibly postulated." Herrnstein suggests a random-shock procedure (Herrnstein and Hineline, 1960). This procedure entails two random-shock schedules, one with a higher frequency than the other. The shock schedule shifts from high to low frequency following a response and back to the high frequency schedule following a shock. A response simply decreases the probability of a shock during time t following the response, but does not avoid a shock in any meaningful sense. A shock may still occur at any instant following a response.

Such a procedure has neither an explicit signal nor a fixed temporal relation between response and shock to provide a CS for classical conditioning. Herrnstein (1969) contends that if a Pavlovian contingency were necessary for the establishment of an avoidance response, the random-shock procedure should produce no conditioning. Yet this procedure is as effective as other avoidance conditioning procedures. From this result Herrnstein argues that reduction of shock frequency is a sufficient condition for the establishment of a response.

To explain this result, two-factor theory must postulate hypothetical stimuli differentially associated with the two random-shock schedules. At this point two-factor theory is driven to irrefutability because the stimuli are neither observable nor can they be plausibly inferred. Herrnstein concludes "that CS termination is either an unnecessary or an untestable feature of avoidance procedures."

The issue of irrefutability, however, hinges on whether an appropriate experiment has been selected to test two-factor theory. The random-shock experiment is not crucial to the form of two-factor theory which states that fear conditioning mediates the acquisition of the discriminated avoidance response. The issue, then, as Herrnstein recognizes, is whether the classical contingency has a significant role in avoidance acquisition for which a CS has been explicitly provided. The "weak" form of two-factor theory holds that even if an avoidance response can be acquired solely by the consequence of a reduction in shock frequency, this does not in itself explain discriminated avoidance. An explicit Pavlovian contingency establishes a response as an escape response to a conditioned aversive stimulus presumably before it can be established as a result of the reduction in shock frequency.

At issue is the role of the CS. Herrnstein contends that the CS merely acts as a discriminative stimulus which sets the occasion for an avoidance response. Two-process theory asserts that the CS becomes an aversive stimulus, the termination of which is reinforcing. The crucial experimental procedure, then, is not to test whether an avoidance response can be maintained without a demonstrable CS, but to test whether a CS can be classically conditioned as a conditioned aversive stimulus which can support an escape response and affect future conditioning.

Kamin (1956) designed an experiment to test the potency of CS termination as a reinforcer of the discriminated avoidance procedure. A CR was defined as change of side in a shuttlebox between CS onset and US onset for four experimental groups with hooded rats as subjects. The groups and the percentage of CRs attained in 100 trials by each were: 1) a "normal" group which could both terminate the CS and avoid the US produced 78% CRs; 2) a group which could terminate the only CS produced 43% CRs; 3) a group which could avoid the US, but could not terminate the CS produced 47%; and 4) a "classical" group which could neither avoid the US nor terminate the CS produced 22% CRs. All groups could escape the US by the running response.

The impressive result of this experiment is that termination of the CS alone produced twice the number of CRs that the classical control did. The high probability of a CR was attained in spite of the fact that each response was punished by the presentations of shock within a maximum of five seconds. The significant effect of an avoidance contingency without CS termination may be explained by the hypothesis that the explicit CS is not the only available conditioned aversive stimulus. Proprioceptive and temporal stimuli produced during the CS-US interval are also available. By the fear mediation hypothesis, fear and its concomitant stimuli are conditioned to these stimuli as well. Even without termination of an explicit CS, then, conditioned aversive stimuli are reduced. The similarity between the CS termination only and the avoidance only groups, in fact, argues for the reinforcement potency of CS termination, because CS termination alone supports responding as well as an avoidance contingency with an ill-defined CS.

Bolles, Stokes, and Younger (1966) replicated the Kamin study with similar results. However, four additional groups were included which were identical to the first four except that the shock was very brief and inescapable. The percentage of CRs was significantly greater not only for the CS termination and avoidance factor which confirmed Kamin's results, but also for the escapable shock factor. Significant interactions suggested that CS termination had no effect unless coupled with either escape or avoidance contingencies. Herrnstein (1969) interprets these data as providing the explanation for the apparent reinforcement strength of CS termination. "It seems questionable to call this CS-terminating response an 'avoidance' response when it could so easily have been a generalized escape response."

This explanation may in fact hide a two-process explanation. Could a "generalized escape response" merely mean that the escape contingency makes the response more probable and that that response is "generalized" as an escape response to a newly aversive CS? This would mean that an animal learns to escape a conditioned aversive stimulus and that the more probable the requisite response, the faster the acquisition. Bolles, Stokes, and Younger (1966) provide additional evidence which indicates that the escape contingency simply makes the response more probable and has no effect on the reinforcement potency of CS termination. They selected a response (a running wheel response) with a higher _a priori_ probability of occurrence than the shuttle-box response. When this response was used in the same eight conditions as in the previous experiment, both the avoidance and CS termination variables remained significant, while neither the escape variable nor the interactions were significant. Their results indicate that with a high probability response, employing an escape contingency has no effect. Further evidence (Overmier and Seligman, 1967; Weiss, Krieckhaus, and Conte, 1968) reported in a later section of this paper indicates that inescapable shock fosters immobility in mammals and that this effect may be overcome by a higher probability response.

The CS termination results, however, do not prove the significance of a Pavlovian contingency for discriminated avoidance as the random-shock data do not prove its irrelevance. What is crucial to two-process theory is the efficacy of fear conditioning and its effects on avoidance acquisition. Results pertaining to these questions are reported above and will now be developed in more detail.

Effects of fear conditioning

It was previously suggested that a basic prediction of two-process theory was that preceding avoidance training by fear conditioning should facilitate acquisition if the CS was the same. The mixed results obtained when this prediction was tested have led to an important new area of study in the aversive control of behavior. Questions arose about special consequences of aversive stimuli both in their effect on avoidance conditioning and on behavior in general. These issues will be considered next: first in terms of fear conditioning and then in terms of general theoretical implications.

Fear conditioning has been shown to facilitate subsequent avoidance acquisition (Baum, 1969; Brookshire and Frumkin, 1969; de Toledo and Black, 1967; and Frumkin and Brockshire, 1969), but also to interfere (Behrend and Bitterman, 1963; Mullin and Morgenson, 1963; Pinckney, 1967; and Weiss, Krieckhaus, and Conte, 1968). Prior CS-US pairings appear to facilitate in cases where the response is easily acquired such as in the one-way avoidance situation both in rats (de Toledo and Black, 1967) and in fish (Frumkin and Brookshire, 1969) or for rats in a ledge jump avoidance (Baum, 1969). In the two-way shuttlebox, facilitation has been demonstrated only for fish given a long CS-US interval during acquisition (Brookshire and Frumkin, 1969) and for rats when fear conditioning was administered after the avoidance response was already established (Weiss, Krieckhaus, and Conte, 1968).

Interference effects of fear conditioning have arisen in the more difficult avoidance task (cf. Theios and Dunaway, 1964 and Theios, Lynch, and Lowe, 1966) of the two-way shuttlebox for rats (Mullin and Morgenson, 1963; and Weiss, Kreickhaus, and Conte, 1968) and fish (Pinckney, 1967; Behrend and Bitterman, 1963). Unsignalled shock has also been shown to interfere with the subsequent acquisition of a shuttlebox avoidance response (Overmier and Seligman, 1967).

Several parameters of the disruption effect of shock on shuttlebox avoidance have received recent attention. In rats, Weiss, et al. (1968) showed that the interference effects of fear conditioning did not disappear with the passage of time. Overmier and Seligman (1967) found that the interference effect of unsignalled shock did not depend on the duration, number, density, or intensity of the shocks nor upon whether it was given to a curarized animal or not, nor upon the fact that shocks were administered outside the avoidance chamber. In fish interference increased as the number of fear conditioning trials increased. Fear conditioning interfered with acquisition in poor (below median) performers, but not in good (above median) performers (Pinckney, 1967). Avoidance acquisition was better after fear conditioning than after unsignalled shock for good performers, but that variable made no difference for poor performers. In poor performers acquisition was better if it followed either fear conditioning or unsignalled shock by 24 hours than if it followed immediately, but this effect was not significant for good performers (Frumkin and Brookshire, 1969). The time lapse between unsignalled shock and avoidance acquisition was important in dogs also (Overmier and Seligman, 1967). In this species, however, the interference effect was demonstrated with a 24 hour time lapse, but not with 48 or more hours.

Learned helplessness

Overmier and Seligman (1967) propose that the source of the interference effect of fear conditioning is "learned helplessness." Learned helplessness, they suggest, is acquired in situations in which an aversive stimulus such as shock is inescapable. In this situation the animal learns that no response is effective in terminating the shock because all responses or attempts to respond are punished.

The randomness of shock termination with respect to the behavior of the subject is crucial to their argument (Maier, Seligman, and Solomon, 1969). They argue that for any shock of fixed duration there is a fixed probability that the shock will terminate at time *t*. If the shock is five seconds, then the probability that it will end at time *t* is 0 for all times except the fifth second when the probability is 1. There is also a conditional probability which is greater than 0 of shock terminating given a response *r*. Since for inescapable shock, shock terminations and responding are independent, for any time *t*, the conditional probability given any response of shock termination is equal to the unconditioned probability of shock terminating. That is to say that given any response the probability of shock termination remains the same. It follows then that the probability of shock terminating with response *r* is the same as the probability of shock terminating in the absence of response _r_.

Maier, _et al_. propose that an _S_ is sensitive to the contingency where the probability of shock termination is equal given the presence or absence of any response. In other words, _S_ learns that reinforcement is independent of responding or "Nothing I do matters." They explain how this kind of learning produces the interference effect for dogs first shocked in a harness and then given shuttlebox avoidance acquisition.

> a) At first the dog makes active responses during shock in the harness. b) Because shock is inescapable, he learns that shock termination is independent of his behavior. c) The incentive for initiation of active responding in the presence of electric shock is partly produced by the expectation that responding will increase the probability of shock termination. When the expectation is absent, the incentive for response initiation is low. d) The electric shock in the shuttlebox arouses the same expectation that was learned in the harness (i.e. that shock termination is independent of responding). Therefore, incentive for initiation of response in the presence of shock in the shuttlebox is low. So the probability of jumping the barrier is low, as is the probability of doing anything active (Maier, _et al_., 1969).

Helplessness, by this hypothesis, is not due to the shock _per se_ nor to its manner of presentation, but to the independence of responding and shock termination. Several predictions relating fear conditioning and avoidance acquisition can be generated from this theory.

a) Since helplessness does not depend on the relationship between CS and US, unsignalled as well as signalled shock should interfere with subsequent avoidance acquisition. Overmier and Seligman (1967) delivered inescapable unsignalled shocks to dogs secured in a harness. The dogs were tested 24 hours later with ten trials of shuttlebox avoidance acquisition. They found that, compared to a control group which was not shocked, the shocked groups had significantly greater mean latencies, number of failures to escape shock and percentage of Ss never escaping shock.

b) Since the helplessness is not an active response, but the absence of responding, Ss incapable of responding during inescapable shock should also show an avoidance deficit. Overmier and Seligman (1967) first immobilized dogs with curare and then subjected them to the same procedure outlined above. On the avoidance test (not under curare) shocked dogs did significantly worse than curarized dogs, but not shocked controls and similar to dogs that had received shock but not curare.

c) Since helplessness is due to S's lack of control over shock, preshock with an escape contingency should not interfere with avoidance acquisition. Seligman and Maier (1967) gave different groups of dogs escape training, inescapable shock yoked to the escape group, and no shock in a harness. When tested on the shuttlebox avoidance task the inescapable shock group was significantly inferior to both the escape group and the no shock control in mean latency and mean number of failures to escape shock. The escape group and the no shock group did not differ from each other.

Freezing as a UR

An alternative hypothesis to learned helplessness to explain the interference effect of fear conditioning on shuttlebox avoidance learning has been proposed by Weiss, Krieckhaus, and Conte (1968). They suggest that fear may play a dual role in aversive conditioning. On the one hand the reduction of fear is a reinforcer. On the other, fear is a US which elicits a strong freezing UR. During the pairing of CS and US in the fear conditioning procedure, freezing is conditioned to the CS. Since freezing is incompatible with the movement required to acquire a shuttlebox avoidance response, prior fear conditioning interferes with it.

They also suggest that if the avoidance situation is structured so that the freezing response is overridden by the instrumental response then the interference effect does not appear and fear has a facilitory effect. This occurs if the avoidance response is originally made more potent by a conditioning procedure or presumably if the avoidance task is simple. This would help account for the fact that fear conditioning does potentiate the one-way avoidance response. It also predicts (as does the learned helplessness hypothesis) that making the prior shock escapable or delivering it after some acquisition will nullify the interference effect.

Evidence for their hypothesis comes from a study on the effects of fear conditioning on avoidance acquisition and movement (Weiss, *et al.*, 1968). Rats were divided into four groups of *S*s and placed in one compartment of a shuttlebox for four trials on each of two days. Group I received eight CS-US pairings (the US was inescapable and the CS was a tone); group II received eight CS alone trials, group III received eight US alone trials and group IV received eight CS-US trials, but with a different CS (light). (It should be noted that E attempted to minimize similarities in environmental stimuli; e.g. handling, lighting, odor, between preacquisitions and subsequent avoidance for groups III and IV.) Shuttlebox avoidance acquisition followed for all groups in eight daily sessions for a total of 150 trials.

Data were taken not only on the number of avoidance responses, but on movement throughout the experiment. Movement ratings were taken for three consecutive 10 sec intervals (before, during and after CS) for each trial in both preacquisition and acquisition.

The results for acquisitions showed that group I gave significantly fewer avoidance responses both overall and in the last ten trials than the other three groups. Groups II, III, and IV did not differ significantly among themselves. The results of their analysis of movement was as follows: group I showed less movement than II during preacquisition; I showed less movement than II, III and IV during the first CS in acquisition and over the entire acquisition; there was no difference, however, between groups in movement before the first CS in acquisition. They further found that for group I the movement rating during fear conditioning was highly correlated (.83) with the total number of avoidance responses in acquisition. Movement during preacquisition for group II correlated only .20 with avoidance responding.

Weiss, et al. conclude that not only does prior fear conditioning interfere with avoidance acquisition, but that the interference was specific to the CS. During fear conditioning, movement reduction was specifically conditioned to a CS. If that CS was used in avoidance acquisition, then freezing interfered with responding. If a different CS or no explicit CS (and minimal similarity) was used during fear conditioning, there was no effect on acquisition.

These data are at variance with the Maier, Seligman, and Solomon learned helplessness hypothesis at at least two points. The fact that shock alone did not affect acquisition if similarities were minimized and that fear conditioning with a different CS had no effect are contrary to the learned helplessness hypothesis.

Results verifying the prediction of the freezing hypothesis that if the instrumental response is already established then fear conditioning will facilitate avoidance responding have been obtained by Weiss, et al. (1968) and by Hyson and Brookshire (1968). Weiss, et al. found that with a well-established avoidance response, fear conditioning reduced avoidance latencies as compared to groups which received either CS alone or shock alone. Hyson and Brookshire found that after an alleyway avoidance response was established, shock in the start box elevated the number of responses in extinction. A further result supporting the hypothesis that high levels of fear produce freezing was obtained by Weiss *et al*. (1968). They found that if poor avoiders in the shuttlebox were given the therapy of fear extinctions, their subsequent avoidance responding was significantly better than matched *S*s without such therapy.

Another study supporting the hypothesis that a freezing response is generated by fear was reported by Blanchard and Blanchard (1969). They examined the incidence of a crouching response in rats after subjecting them to a single one second shock. The behavior of each *S* was sampled for one second in each minute and assigned to the categories 1) crouch, 2) stand, 3) groom, 4) activity, and 5) lie. It was found that *S*s subjected to shock and then remaining in the shock box crouched significantly more than nonshock control *S*s while shocked *S*s shifted to non-shock boxes, crouched even less than crontrol *S*s. When the shifted *S*s were returned to the shock boxes, the incidence of crouching increased markedly and was now significantly greater than the crouching of control *S*s.

The significance of these data is that the crouching is assumed to be in response to the situational stimuli associated with prior shock and not simply to the shock itself. Since the crouching response appears to be the same as the freezing response of Weiss, *et al*. (1969) it may be concluded from this experiment that fear elicits freezing after a single fear conditioning trial.

Purpose of present experiments

Although the mechanism is disputed, it appears reasonably conclusive that situations which produce fear in mammals, elicit freezing responses (Blanchard and Blanchard, 1969; Overmier and Seligman, 1967; and Weiss, et al., 1968). Since freezing is inconsistent with the behavior required in an active avoidance task, any situation which maximizes freezing minimizes avoidance behavior. The standard fear conditioning contingency presumably produces freezing behavior. It follows that fear conditioning has not shown a facilitory effect on shuttlebox avoidance conditioning because it maximizes a freezing response to fear.

By the same logic, more fear conditioning trials will have either no effect by balancing freezing and fear facilitation or an interfering effect by maximizing freezing. Mullin and Morgenson (1963) have found that in rate increasing the number of fear conditioning trials from 0 to 100 has neither a facilitory nor inhibitory effect on shuttlebox avoidance acquisition.

The few studies of prior exposure to shock on fear conditioning in goldfish seem to show results similar to those obtained in mammals. Previous exposure to noncontingent shock had an inhibitory effect on Sidman avoidance acquisition in the results reported by Behrend and Bitterman (1963). Pinckney (1967) found that increasing the number of fear conditioning trials had an inhibitory effect on poor performers and no significant overall effect on subsequent shuttlebox avoidance.

These results may not, however, adequately demonstrate the effect of fear conditioning on shuttlebox avoidance in goldfish. Brookshire and Frumkin (1969) found that while fear conditioning did not facilitate avoidance conditioning with a 10 sec CS-US interval, when that interval was extended to 30 sec, acquisition was facilitated. The CS-US interval in fear conditioning made no significant difference in subsequent avoidance conditioning. Further data reported by Frumkin and Brookshire (1969) showed that fear conditioning does facilitate avoidance for good performers as compared to a US only group even when a 10 sec CS-US interval is used in acquisition. These results indicate that the effects of fear conditioning on shuttlebox avoidance may be demonstrable in goldfish under appropriate conditions. One such circumstance suggested by the Brookshire and Frumkin data is a longer CS-US interval than the 10 sec typically used in avoidance acquisition. This result may be explained by the freezing hypothesis presented above. Lengthening the CS-US interval tips the balance in favor of conditioned aversiveness because the fear component is given a longer time to manifest itself.

Other factors determining the relative weights of fear and freezing may be experiment specific. Such factors as the configuration of the avoidance chamber and the topography of the required response may be included. In these cases facilitation may be shown if procedural details are changed.

EXPERIMENT I--SHOCK INTENSITY

Before investigating the effects of fear conditioning, normative data on the acquisition and extinction of an avoidance response in goldfish were desirable. An important parameter of avoidance conditioning is shock intensity. The relationship between shock intensity and avoidance acquisition has been determined for several mammalian species in a variety of aversive conditioning situations. This function has not been reported for goldfish.

The effect on performance of varying shock intensity has been studied in a variety of aversive control techniques including escape and avoidance conditioning, classical conditioning, conditioned suppression, punishment and approach-avoidance conflict. In general, the results have shown that performance increases to an asymptote as a function of increasing shock intensity (Passey, 1948; Campbell and Kraeling, 1953; Trapold and Fowler, 1960; Bell, Noal and Davis, 1965; Annau and Kamin, 1961; Denenberg, 1959).

The evidence for avoidance conditioning employing a manipulandum also suggests that acquisition performance increases to an asymptote with increasing shock intensities. Boren, Sidman, and Herrnstein (1959) used eight shock levels in free operant nondiscriminated avoidance training and found that rate of bar pressing increased to an asymptote at 1.0 mA. A 1.0 mA asymptote was also found by Kimble (1955) for the latency of a wheel-turning avoidance response.

Shuttlebox avoidance, however, does not show a monotonic relationship between shock intensity and avoidance acquisition. Brush (1957), using dogs, obtained results which indicated that an inverted U-shaped function related shock intensity to shuttlebox avoidance learning. Brush evaluated avoidance performance at five shock levels with seven indices and found increasing performance through the fourth level of 4.8 mA and a decrease at the highest level. The indices of latency of the last shock and average speed of response in 200 extinction trials were significantly nonlinear. The indices showing curvilinear trends (although nonsignificant) were percentage of animals learning, total number of shocks received, number of alternations between escape and avoidance responses, and trial number of the last shock.

The Brush study indicated the possibility that shock intensities that were high, yet not high enough to physically impair movement, lead to decreased shuttlebox avoidance performance, The disruption of avoidance responding was confirmed by Moyer and Korn (1964). Above 1.0 mA, the percentage of avoidance responses decreased significantly, while latency increased.

Similar results were found for shock levels above 0.5 mA by Levine (1966) and Kurtz and Shafer (1967) and in nondiscriminated avoidance by Johnson and Church (1965). Ragusa (1967) also found that avoidance responding was inversely related to shock intensities of 150, 300, and 450 V and that there was no interaction between the effect of intensity and intertrial intervals at 30-120 sec.

In a study of shuttlebox avoidance in cats, Wolfe, Kavanagh and Lunbar (1966) used three shock levels (1.0, 2.0, 4.0 mA) and found a clear optimum at 2.0 mA. Avoidance responding of the 4.0 mA group was inferior to the 2.0 mA group on measures of trials to criterion and speed of responding in both acquisition and extinction. Responses classified as "emotional" were also rated and "emotionality" increased with shock intensity. The authors noted that the optimum shock level for the cat, as would be predicted by the relative weights of the animals, lay between the optima of 1.0 mA for the rat (Moyer and Korn, 1964) and 4.8 mA for the dog (Brush, 1957).

The present study investigated the effects of four shock intensity levels on the acquisition and extinction of a shuttlebox avoidance response in goldfish.

Method

Subjects

Forty experimentally naive goldfish, *Carassius auratus*, were obtained locally. The fish weighed 2.5-3.5 gm and were housed communally in a 20 gallon tank until used.

Test apparatus

The avoidance apparatus used was patterned after that described by Horner, Longo, and Bitterman (1961). Each shuttlebox was a 16x5x6 in plexiglass tank divided by a barrier 4 in wide at its base, 1 3/4 in wide at top and 1 3/4 in high. There were 77 fluid oz of water in each tank with the water level 1/2 in above the top of the barrier. GE 306 14W lamps, used for the CS, were positioned behind both ends of the tanks in their own plexiglass boxes. All surfaces of the tank except the ends (but including the lamp housings) were covered with black tape to eliminate visual cues from outside the tank.

Barrier crossing responses were recorded by two sets of infrared photocell assemblies placed slightly higher and along the edges of the top of the barrier outside the long side of each tank. A response was recorded if the fish swam across the barrier, breaking the second photocell beam. Breaking the photocell beam also changed the state of a flip-flop which programs which CS light was to come on. With the start of a trial, the CS light behind the compartment containing the fish was lit. The tank walls fronting the lamp housings were faced with diffusing paper to reduce interior reflectance.

Responses were recorded on Lehigh Valley event recorder with a paper speed of .14 in per sec. Trial onset and shock duration were recorded on one channel while all responses were recorded on the other. Response latencies were obtained by direct measurement of the recording paper with an estimated accuracy of .1 sec.

Shock source

An interrupted shock source was used because continuous shock tends to produce tetanization (Wodinsky, Behrend, and Bitterman, 1962). A hysteresis motor pulsing a timer gated 150 msec of 60 Hz a.c. at the rate of two per sec. The current was delivered across stainless steel wire mesh grids covering both long sides of the tank. Shock voltage was developed from wall current stepped down by a transformer and controlled by a Variac to produce a voltage range of 0-32 V rms.

Since it is impossible to specify what proportion of the total current in the circuit flows through the fish, the shock can only be rated in terms of current through the water. The current density through the fish is directly proportional to the current flowing through the shock circuit, if the resistance of the fish and of the water remains constant. The model of equal resistances was approximated by keeping water conductivity constant at 400 μ mho and the weight of the fish within narrow limits. The conductivity was adjusted by the addition of deimized water before each run.

Procedure

The 40 fish were randomly assigned to four shock intensity groups of 3, 5, 7, and 9 V rms with 10 fish per group. After a 15 min adaptation period, each fish received 10 pretest trials. Pretest trials were identical to acquisition trials except that no shock was delivered. One hundred acquisition and 100 extinction trials were administered immediately following the pretest. Each fish received the entire test sequence in one day. Shock intensities were randomly chosen among the four alternatives such that no intensity was repeated until all four were used.

The avoidance conditioning procedure was similar to that used by Behrend and Bitterman (1962). An acquisition trial consisted of a 10 sec period of CS alone followed by a 15 sec period of CS plus the pulsed shock US. A response terminated a trial, shutting off the CS light and, if it was on, the US. All barrier crossings, whether terminating a trial or in an intertrial interval, were recorded. Intertrial intervals were programmed by a tape timer and were, in order, 50, 70 and 60 sec.

Extinction trials were similar to pretest trials. A trial was terminated either after a response or after 25 sec in the CS interval.

Two disqualification criteria were used. The first, as used by Pinckney (1967), was that fish which respond during CS presentation on five out of ten or two of the last five pretest trials were disqualified. The second criterion disqualified fish which allowed ten consecutive acquisition trials to pass without responding in the presence of either the CS or the CS-US combination. The first criterion eliminated fish which responded too often to measure the acquisition of an avoidance response or for which the CS itself was aversive. The second criterion eliminated fish which were either incapacitated or unmotivated by the shock and thus would confound avoidance acquisition results. Disqualified fish were replaced from the population pool.

Measures

There were five acquisition measures and two extinction measures used throughout the experiments reported here. The acquisition measures were: 1) percentage of avoidance responses in acquisition, 2) percentage of avoidance responses in the first 25 trials, 3) number of trials to the first two consecutive avoidance responses, 4) number of trials to the start of eight out of ten avoidance responses, and 5) percentage of avoidance responses in the last 25 trials. The extinction measures were: 1) percentage of responses of avoidance response latency (less than 10 sec), and 2) percentage of trials responded to. Fish that did not reach criterion on either trial to first two consecutive avoidance responses or trial to the start of eight out of ten avoidance responses were given an arbitrary score of 100. One additional acquisition score of percentage of trials with no response was recorded.

Results

The results for the acquisition measures percentage of avoidance responses, percentage of avoidance responses in the first 25 trials, and percentage of avoidance responses in the last 25 trials are presented in Figures 1-3. The total acquisition results represented in Figure 1 showed a monotonically increasing relationship between the percentage of avoidance responses and shock intensity for 3 V to 7 V and then a slight decrease at 9 V. An analysis of variance showed the differences among the groups to be highly significant ($F=23.05$, $df=3/36$, $p<.001$). Duncan's new multiple range test showed that the percentage of avoidance responses for the 5V, 7V and 9V groups was significantly greater than for 3V ($S_{\bar{x}}=4.39$, $p<.01$) and that the 7V group did significantly better than the 5V group as well ($p.<.05$).

The data for early avoidance as shown in Figure 2 shows the inverted U ordering of the groups even more clearly than the total percentage avoidance responses. The differences among groups was again highly significant ($F=20.47$, $df=3/36$, $p<.001$). Duncan's test showed acquisition at 7V to be significantly better than acquisition at the other voltage levels ($S_{\bar{x}}=.95$; 7V > 3V, $p<.01$; 7V > 5V, $p<.01$; 7V > 9V, $p<.05$). Performance at 9V was also significantly better than performance at either 3V ($p<.01$) or 5V ($p<.01$).

The differences among groups became smaller in later acquisition as shown in Figure 3. The differences among groups was still highly significant (F-12.82, df=3/36, $p < .01$), but performance at the three highest voltages was nearly equivalent. This was indicated by a Duncan's test which showed that in late acquisition the 5V, 7V and 9V groups did significantly better than the 3V group ($S_{\bar{x}}=1.62$, $p < .01$), but there were no significant differences among the performances of the upper three voltage groups. The other acquisition and extinction measures showed inverted U-shaped functions similar to the percentage of avoidance responses function. The complete data for all measures are tabled in Appendix I.

Responses during the intertrial intervals showed an inverted U-shaped function similar to that obtained for avoidance responses in acquisition as shown in Figure 4. The mean number of responses per subject increased as shock intensity increased from 3V to 7V and then decreased with a shock intensity of 9V.

Figure 5 shows the course of avoidance acquisition in blocks of 10 trials for the four groups. Response acquisition was almost equal for the 7V and 9V groups in early trials. In the middle trials, the two groups diverged with the 7V groups avoiding a greater percentage of shocks. Response acquisition for the 5V group was slower in the early trials than for either the 7V or 9V groups, but by the middle of acquisition the 5V group was avoiding as often as the 9V group. All three groups showed decreased avoidance percentage in the last 20 trials with the 7V group decreasing to the same level as the 5V and 9V groups. The 3V group acquired the avoidance response more slowly and remained at a lower avoidance percentage throughout acquisition as compared to the other three groups.

The number of trials with no response in acquisition for the four groups is shown in Figure 6. A U-shaped function was obtained with no response trials accounting for 10% and 5% of the acquisition trials of the 3V and 9V groups respectively. Fish which met the disqualification criterion of 10 consecutive no response trials in acquisition and were discarded were distributed about equally through the groups with two at 3V, one at 5V, three at 7V and two at 9V. Twelve fish were discarded in the pretest disqualification procedure.

Figure I. Experiment I.

Percentage of avoidance responses during 100 acquisition trials as a function of shock intensity for 10 Ss per group.

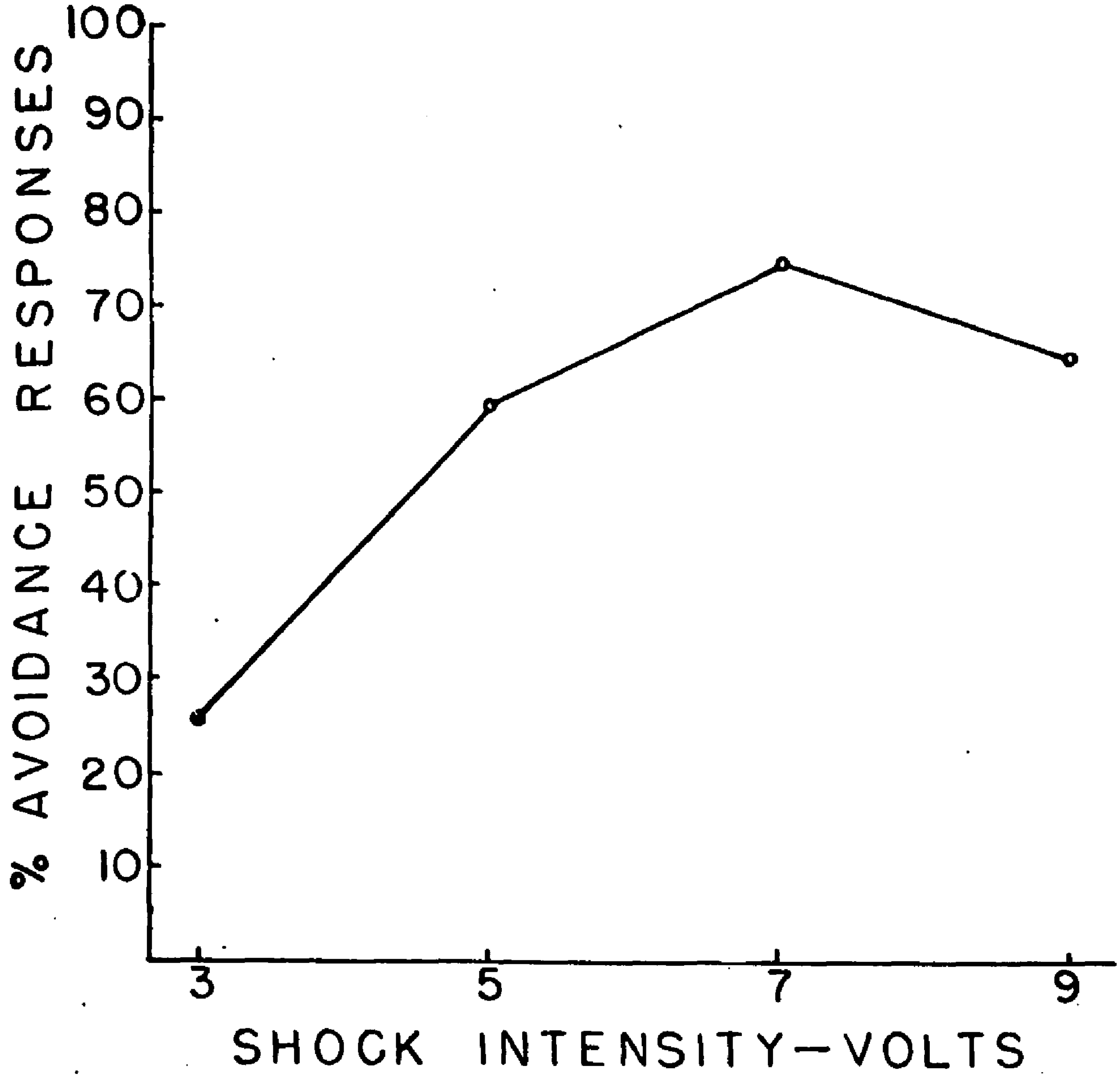
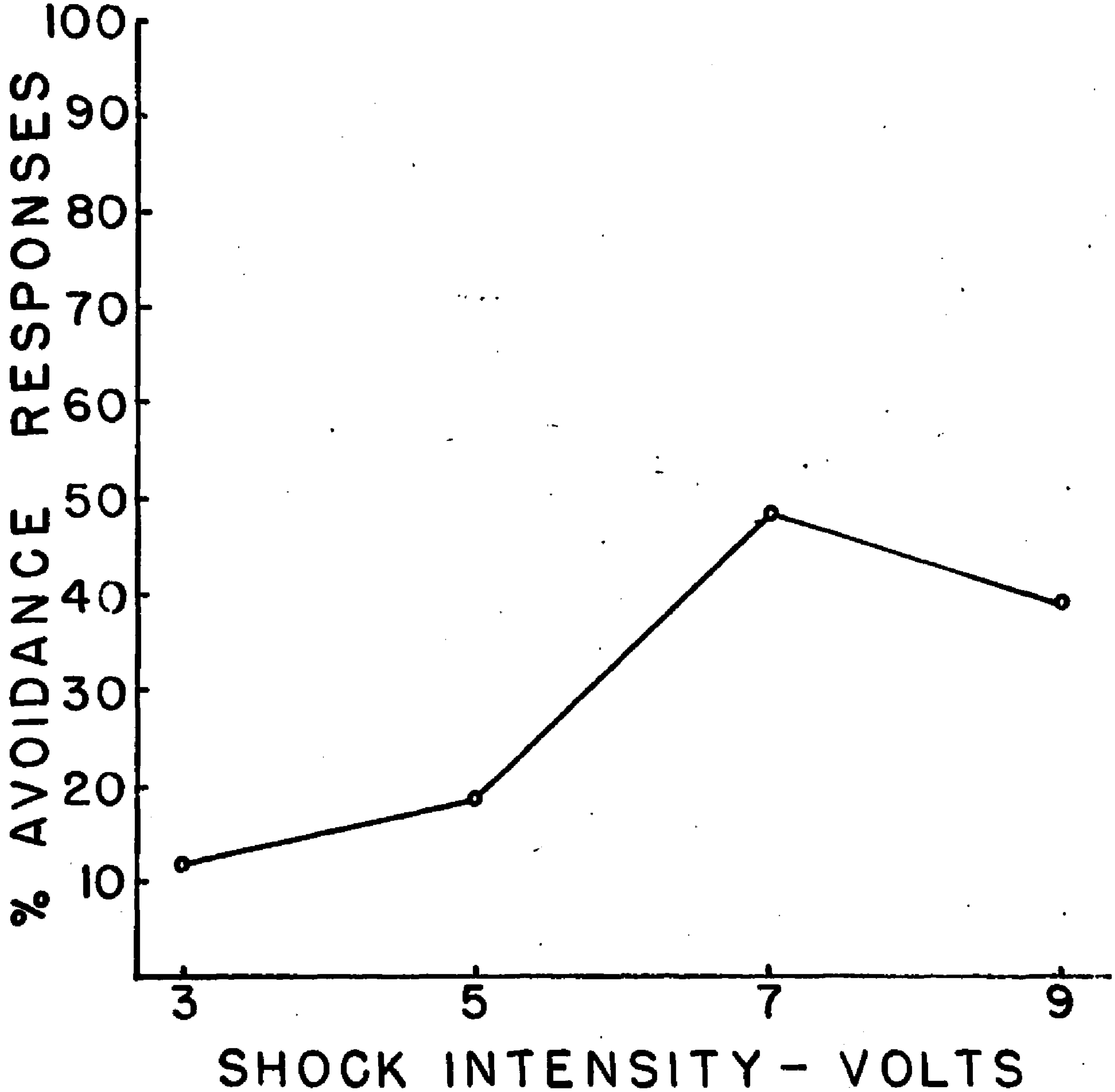
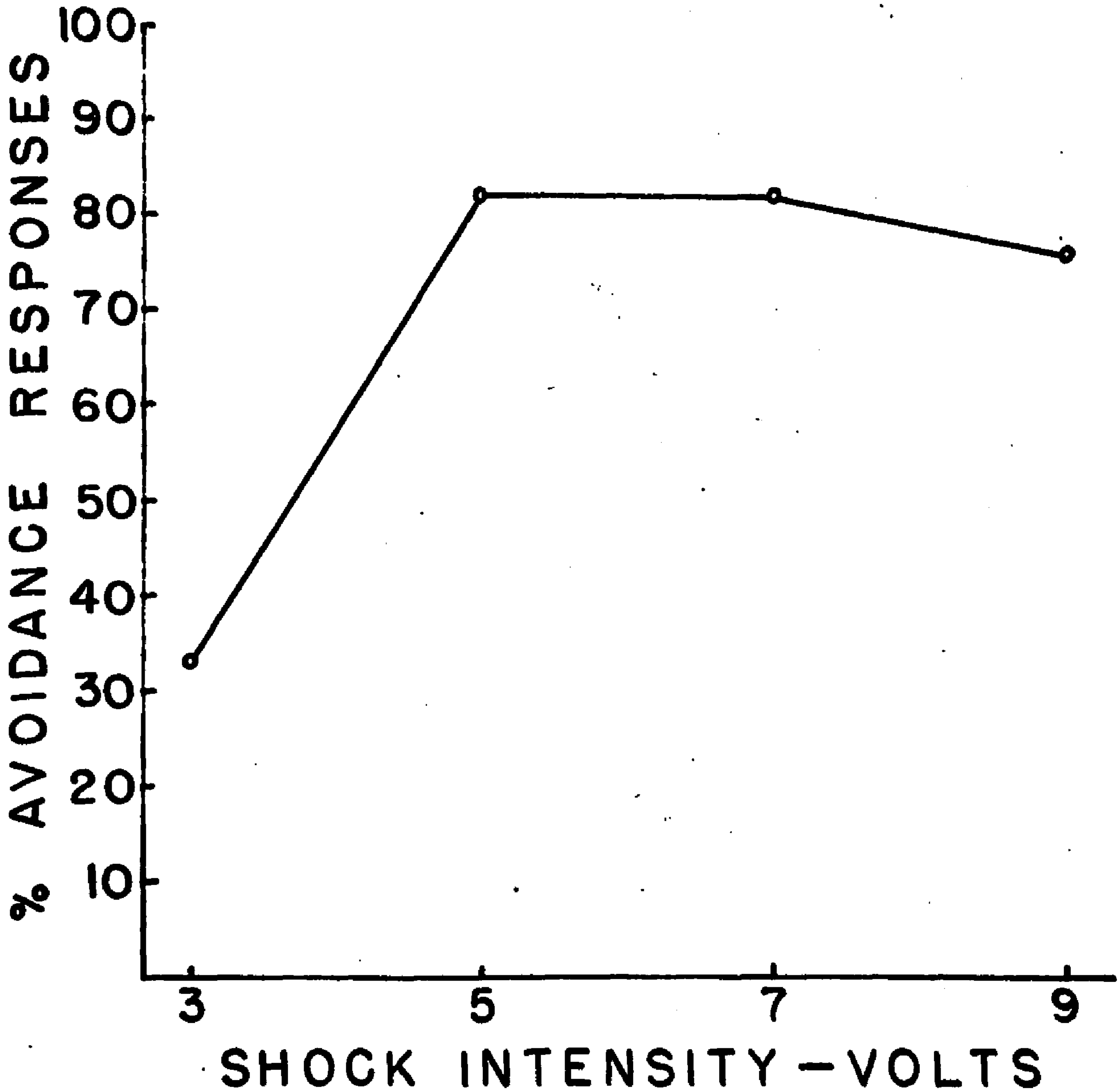

100
90
80
70
60
50
40
30
20
10
% AVOIDANCE RESPONSES
3
5
7
9
SHOCK INTENSITY—VOLTS

Figure 2. Experiment I.
Percentage of avoidance responses in the first 25 trials of acquisition as a function of shock intensity for 10 Ss per group.



% AVOIDANCE RESPONSES
100
90
80
70
60
50
40
30
20
10
3
5
7
9
SHOCK INTENSITY - VOLTS

Figure 3. Experiment I.
Percentage of avoidance responses in the
last 25 trials of acquisition as a
function of shock intensity
for 10 Ss per group.



100
90
80
70
60
50
40
30
20
10
% AVOIDANCE RESPONSES
3
5
7
9
SHOCK INTENSITY-VOLTS

Figure 4. Experiment I.

Number of intertrial responses per subject in 100 acquisition trials as a function of shock intensity for 10 Ss per group.

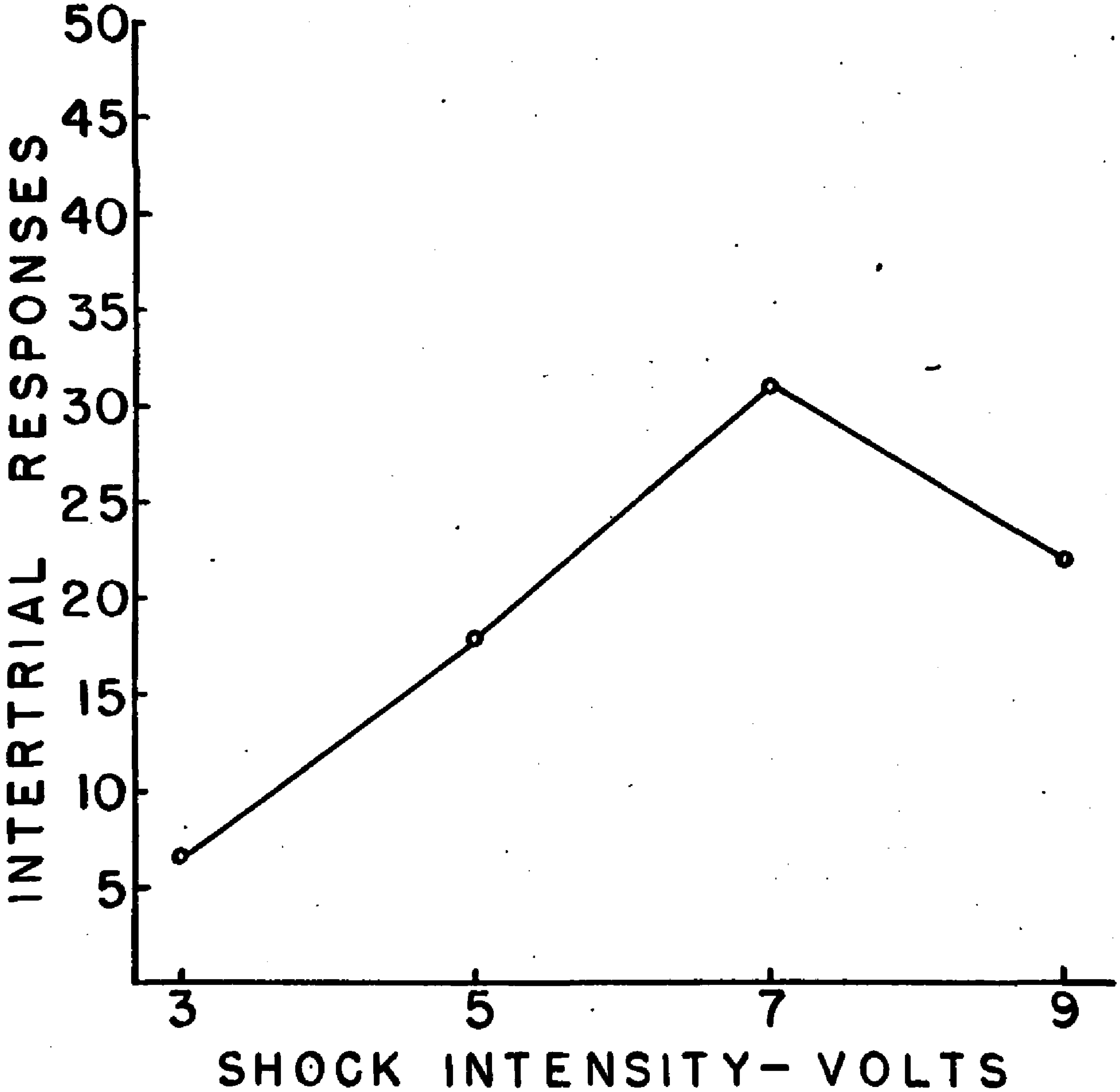

50
45
40
35
30
25
20
15
10
5
INTERTRIAL RESPONSES
3
5
7
9
SHOCK INTENSITY- VOLTS

Figure 5. Experiment I.

Percentage of avoidance responses in blocks of 10 trials for the four shock intensity groups for 10 _S_s per group.

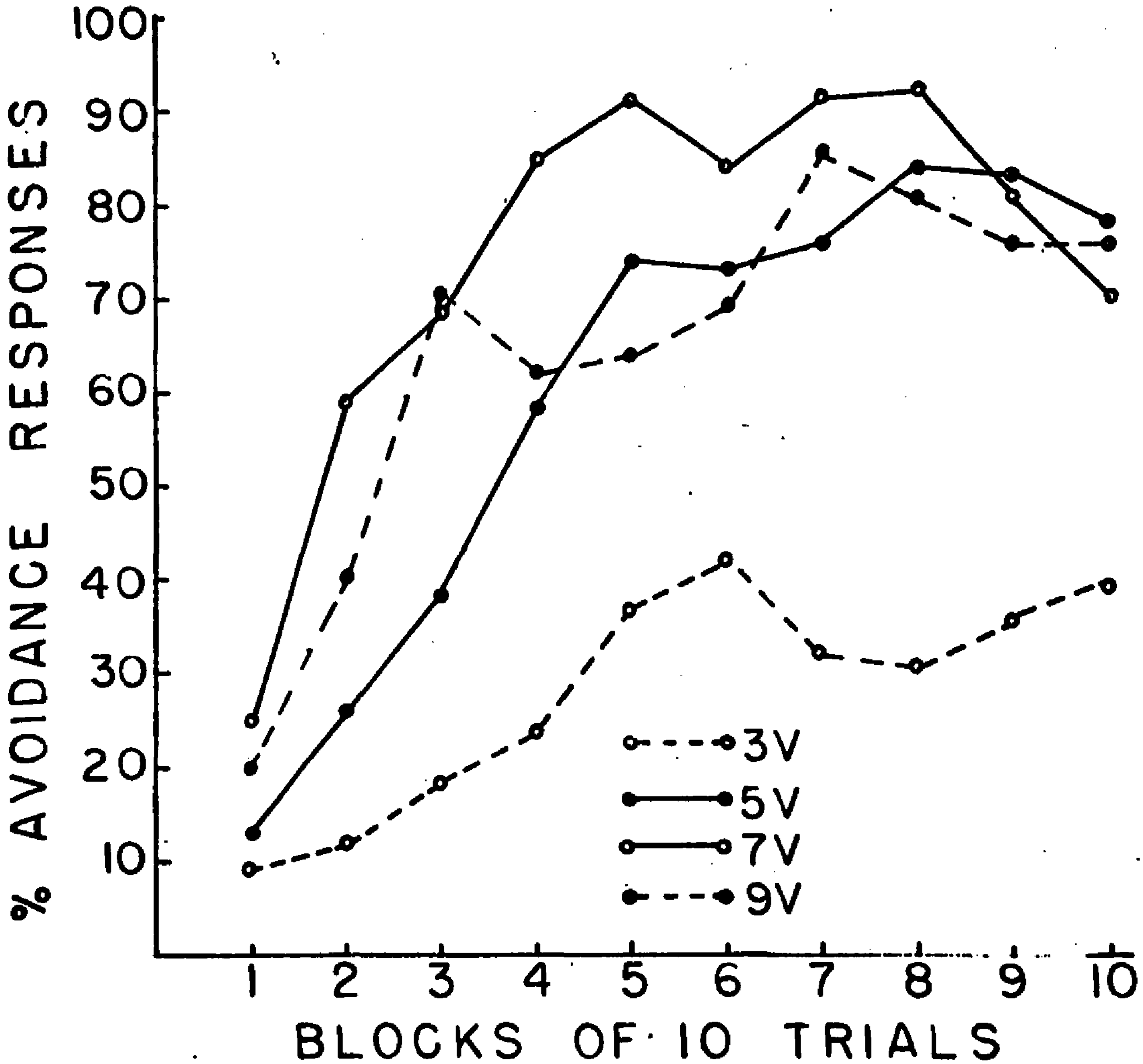
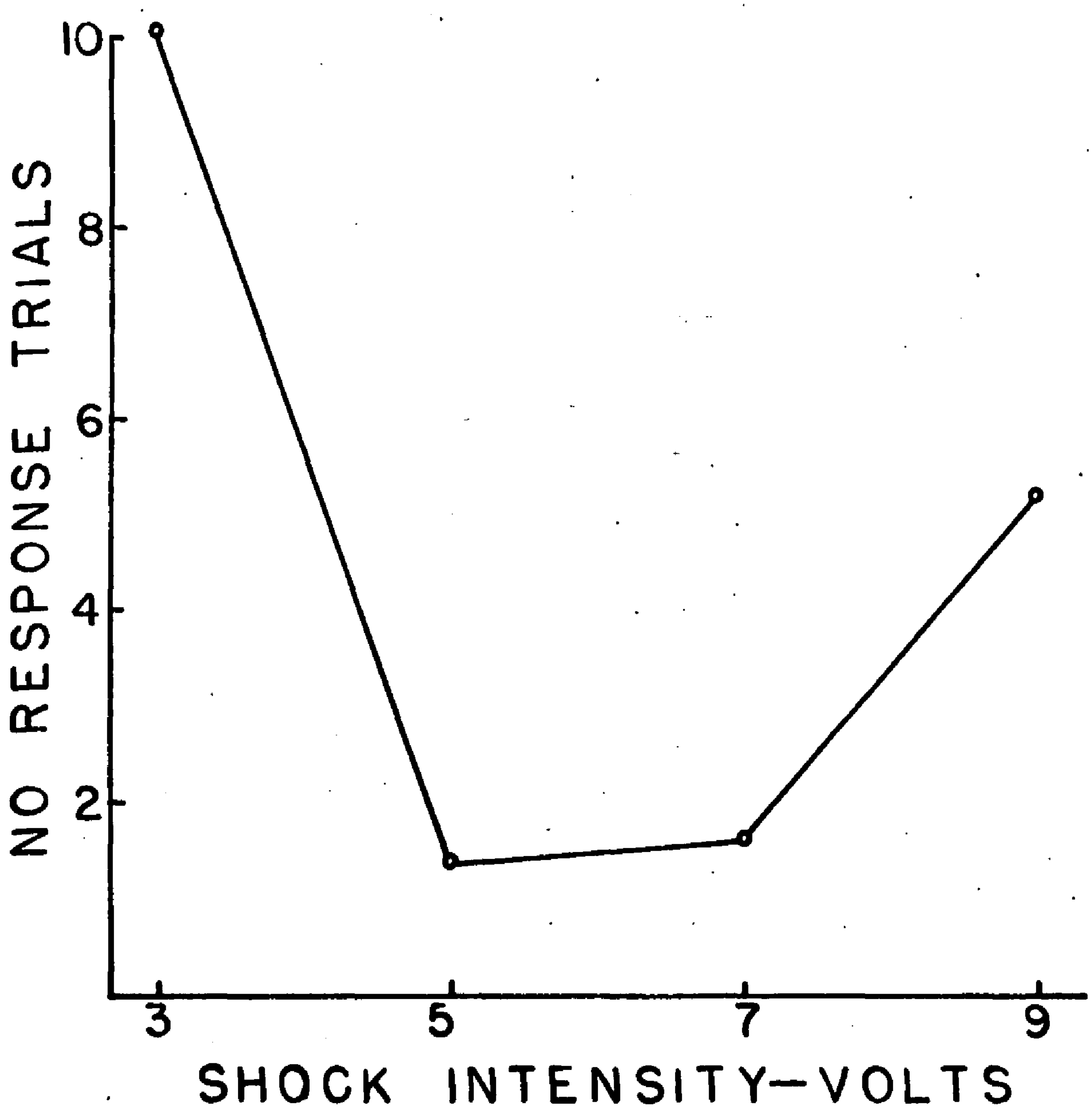

100
90
80
70
60
50
40
30
20
10
% AVOIDANCE RESPONSES
3V
5V
7V
9V
1
2
3
4
5
6
7
8
9
10
BLOCKS OF 10 TRIALS

Figure 6. Experiment I.
Number of acquisition trials terminated
after 25 sec with no response as a
function of shock intensity
for 10 Ss per group.


10
8
6
4
2
NO RESPONSE TRIALS
3
5
7
9
SHOCK INTENSITY—VOLTS

Discussion

The function relating total avoidance acquisition to US intensity obtained in the present experiment is similar in form to the functions obtained for dogs (Brush, 1957), cats (Wolfe, Kavanagh, and Lubar, 1966) and rats (Moyer and Korn, 1964). The function was an inverted U with an optimum shock intensity of 7V among the intensities tested. The advantage of the 7V group was most pronounced in the early avoidance trials.

Shock intensities above 9V were tried unsuccessfully. A 10V shock interfered with the swimming movements necessary for an escape response. In general the first application of a 10V shock resulted in violent swimming movements which sometimes did and sometimes did not result in an escape response. If it did not, swimming became less and less vigorous on succeeding trials until the fish floated on its side near the surface of the water. Only fish which quickly acquired a short latency escape response were able to complete the experiment.

Intertrial responses were distributed in an inverted U-shaped function similar to acquisition, indicating that overall barrier crossing activity increased up to 7V and decreased again at 9V. Similarly, the number of no response trials was greatest at the two extreme voltages. These two measures suggest that above 7V activity decreases, leading to decreased avoidance performance. Increasing shock intensity thus improves avoidance acquisition up to a point. Further intensity increases lead to deteriorating performance.

The data on the course of acquisition at different intensities indicated that acquisition for the 9V group keeps pace with acquisition for the 7V group through early acquisition, but deteriorates in the middle trials. The 5V group acquires the avoidance response more slowly than either the 7V or 9V group, but reaches and maintains a level of performance similar to the 9V group. The 3V group acquires the avoidance response slowly and maintains a low avoidance percentage. Presumably, 3V is not aversive enough to maintain an efficient avoidance response. An interesting feature of the response curves of the three higher voltages was deterioration of performance toward the end of the 100 acquisition trials. In all three cases, peak performance was obtained before the end of acquisition. The deterioration was possibly due to fatigue at the end of the 100 minute acquisition session.

EXPERIMENT II--PRETRAINING WITH ESCAPE AND FEAR CONDITIONING

If the fear and freezing formulation is correct, the two alternative ways of showing a facilitory effect of fear conditioning on avoidance acquisition are to increase the conditioned aversiveness of the CS or to decrease the probability of a freezing response. The latter may be done by requiring movement during fear conditioning. This may be achieved by establishing an escape contingency during fear conditioning.

An escape contingency can have a dual effect on shuttlebox avoidance acquisition. Movement is established so that freezing is less likely, but also a response topographically similar to the avoidance response is conditioned. To control for any facilitory effects the escape contingency might have, however, the fear plus escape group need only be compared to a group receiving escape training, but no CS.

Experiment II compares the shuttlebox avoidance acquisition of goldfish receiving prior exposure to: 1) fear conditioning, 2) fear conditioning with an escape contingency, 3) escape training, 4) shock only, and 5) no training. The fear conditioning group assesses the effects of pretraining with the classical conditioning component of the discriminated avoidance contingency, while the escape conditioning group assesses the effect of its escape contingency component. The fear-escape group combines both the fear and escape components, but eliminates the avoidance contingency. According to a two-process formulation fear-escape pretraining should facilitate avoidance acquisition more than either fear or escape conditioning because both components are strengthened independently. The shock only group should show any facilitory effects due to sensitization or inhibitory effects due to learned helplessness. The no pretraining group is the control comparison for all experimental groups.

Method

Subjects and apparatus

Fifty goldfish, obtained locally and weighing between 2.5 and 3.5 gm, were used. The shuttlebox, recording system and shock source, were identical to those used in Experiment I. Another shuttlebox with its own control and recording equipment was added and the programming modified to allow yoked contingencies between the two tanks. The same shock source was used for both tanks. Two other modifications were made in the apparatus used for Experiment I. A Lehigh Valley interval timer provided the pulse that gated the shock instead of a hysteresis motor, and all programming equipment was removed from the vicinity of the experimental fish.

Shock intensity

The shock intensities selected for Experiments II and III were based on the results of Experiment I. The optimum shock intensity value as determined by performance measures of acquisition was 7V rms. This intensity was used in Experiments II and III.

Procedure

The Ss were divided into five pretraining groups of ten Ss each. Four of the groups were run in two sets of yoked groups with the two shuttleboxes used alternately as the control tank. The pretraining followed a 15 min adaptation period. The fear-escape group received 20 trials of a light

(CS) joined 10 seconds later by an escapable shock (US). The fear conditioning group was yoked to the fear-escape group and received the same CS and US but responding did not terminate either CS or US. An escape conditioning group received 20 trials of an escapable US, but no CS. A shock group was yoked to the escape group and also received no CS. The control received 20 min of adaptation with no CS and no US. The intertrial interval averaged one min and the maximum US was 15 sec throughout the experiment. The CS during pretraining consisted of light at both ends of the tank although for avoidance acquisition only one light was used at a time.

Avoidance acquisition followed one intertrial interval after pretraining for all Ss and continued for 100 trials. If a barrier crossing response was made within 10 seconds after CS onset, the light terminated and shock was avoided for that trial. A response during shock terminated the CS and US simultaneously.

One intertrial interval after acquisition, 100 more trials were run in extinction. Extinction consisted of CS presentations without shock. A response during the CS terminated it and the maximum CS duration was 25 seconds.

One or two pairs of Ss were run per day. Fear-escape and fear conditioning pairs and escape and shock only pairs alternated with control pairs run after each two alternations. Responding was never blocked throughout the experiment.

The disqualification criterion of 10 consecutive no response trials during acquisition was used in this experiment.

The pretest disqualification criterion was eliminated because of possible confounding with pretraining conditions.

Results

The results for the percentage of avoidance responses in acquisition, in early acquisition (the first 25 trials), and in late acquisition (the last 25 trials) are presented in Figures 7 and 8. For the entire acquisition period as shown in Figure 7, the fear-escape group displayed the highest level of performance, avoiding on 86% of the trials. Both fear and escape groups made fewer avoidance responses than the fear-escape group, avoiding shock on 73% and 70% of the trials respectively. The control and shock only groups made the fewest avoidance responses, avoiding on 62% and 61% of the trials, respectively.

The early and late acquisition data is presented in Figure 8. In early acquisition the fear-escape group avoided shock on 71% of the first 25 trials and the fear group avoided shock on 52% of the early trials. The other three groups each avoided shock on less than 40% of the first 25 trials. In late adquisition avoidance responding was similar for all the groups. The fear-escape group still performed best, avoiding shock on 90% of the last 25 trials, but all groups avoided shock on more than 75% of these trials. The data for trials to first two consecutive avoidance responses and trials to the start of eight out of ten avoidance responses were similar to the overall acquisition data with the fear-escape group attaining both criteria on the earliest trial and the fear and escape groups responding approximately equally. For the first eight out of ten avoidance responses measure, the fear-escape group began the criterion run after an average of 8.6 trials, while the control group began after an average of 32.7 trials. The data for all acquisition and extinction measures are tabled in Appendix II.

Overall differences among groups during acquisition were significant for the percentage of avoidance responses for the entire acquisition ($F=2.66$, $df=4/45$, $p<.05$) and for the percentage of avoidance responses in the first 25 trials ($F=5.20$, $df=4/45$, $p<.01$). Orthogonal comparisons show that the variable fear had a significant facilitory effect by the same two measures ($F=5.28$ and 11.65, $df=1/45$, $p<.05$ and .01), but there were no significant effects due to the escape variable ($F=3.06$ and 2.20, $df=1/45$) or interaction ($F=.15$ and 1.03, $df=1/45$).

Duncan's new multiple range test for individual comparisons showed that the total percentage of avoidance responses for the fear-escape group was significantly greater than for either the control or shock group ($S_{\bar{X}}=6.19$, $p<.05$) and approached significance for the escape group ($p<.10$). In the early avoidance measure, the percentage of avoidance responses for the fear-escape group was significantly greater than for the control, shock only, and escape groups ($S_{\bar{X}}=1.91$, $p<.05$) and approached significance for the fear group ($p<.10$). For the same measure, the fear group had a significantly greater percentage of avoidance responses than the control group ($p<.05$). The fear-escape group was significantly better than the control group on trials to the first two consecutive avoidance responses ($S_{\bar{x}}$=6.43, p <.05) and better than the shock only group on trials to the start of eight out of ten avoidance responses ($S_{\bar{x}}$=8.16, p <.05).

Avoidance response ratios were computed for the fear-escape, fear and escape groups as compared to the control group by dividing the percentage of avoidance responses for each of the experimental groups by the control group percentage of avoidance responses. These ratios describe the facilitory effect of the three pretraining procedures on percentage of avoidance responses in early and late acquisition and over the entire acquisition period. In the first 25 trials, the avoidance response ratio for the fear-escape group was 2.58 and the ratios for the fear and escape groups were 1.88 and 1.35 respectively. In the last 25 trials, the ratios were 1.17 for the fear-escape group, 1.10 for the fear group, and 1.11 for the escape group. Over the entire acquisition period the ratios were 1.38 for the fear-escape group, 1.17 for the fear group, and 1.12 for the escape group.

The data for the two extinction measures showed small differences between groups. In the percentage of avoidance latency response, fear-escape was highest (75.6%) followed by fear (74.7%), control (73.6%), escape (64.0%), and shock only (61.5%). The percentage of responses of less than 25 sec latency ranged from 86.6% for escape to 94.5% for fear-escape.

Since one of the hypotheses explaining past fear conditioning results is that competing responses are established during fear conditioning, an attempt was made to assess their effect. The direct measurement of competing responses was not possible under the present procedure. Subjects were, however, free to make an explicitly noncompeting response; barrier crossing. Their responses were counted during fear conditioning and correlated with subsequent avoidance acquisition. The number of barrier crossings an S made during fear conditioning pretraining was positively correlated with the percentage of avoidance responses during the first 25 trials ($r=.72$), and this correlation was highly significant ($t_8=2.96$, $p<.01$). Similarly, barrier crossings in pretraining were positively correlated with the percentage of avoidance responses for the entire acquisition period ($r=.55$), and this correlation was significant ($t_8=1.86$, $p<.05$).

The effect of each condition on the total number of barrier crossings during pretraining was also determined as shown in Figure 9. The results show that while the two escape contingency groups made slightly more responses than the two noncontingent shock groups, the differences were small as compared with the differences between the shock groups and the control group. Statistical analysis shows that the differences among groups was highly significant ($F=4.84$, $df=4/45$, $p<.005$), but orthogonal comparisons show that the sole significant difference was between the combined shock groups and the control ($F=18.77$, $df=1/45$, $p<.001$).

The mean number of trials during acquisition on which no response was made is shown in Figure 10. The figure shows that subjects in the shock only group did poorest on this measure, with no response on approximately 5% of the acquisition trials. The control and escape groups did not respond on approximately 3% of the trials each. The number of no response trials for the fear and fear-escape groups was negligible at .7% and .1% respectively.

Shock durations were recorded during pretraining. Since the shock duration was contingent upon a response in the escape and fear-escape groups, it was a measure of escape latency for these groups. The mean shock duration for the escape and shock only groups was 4.95 sec and for the fear-escape and fear groups mean duration was 2.96 sec. Two fish failed to respond on ten consecutive acquisition trials and were discarded. Both fish received the shock only pretraining.

Figure 7. Experiment II.
Percentage of avoidance responses in
100 acquisition trials following
five pretraining conditions
with 10 Ss per group.
The pretraining conditions are:
fear-escape (FES), fear (FR),
escape (ES), shock only (SC),
and control (CON).

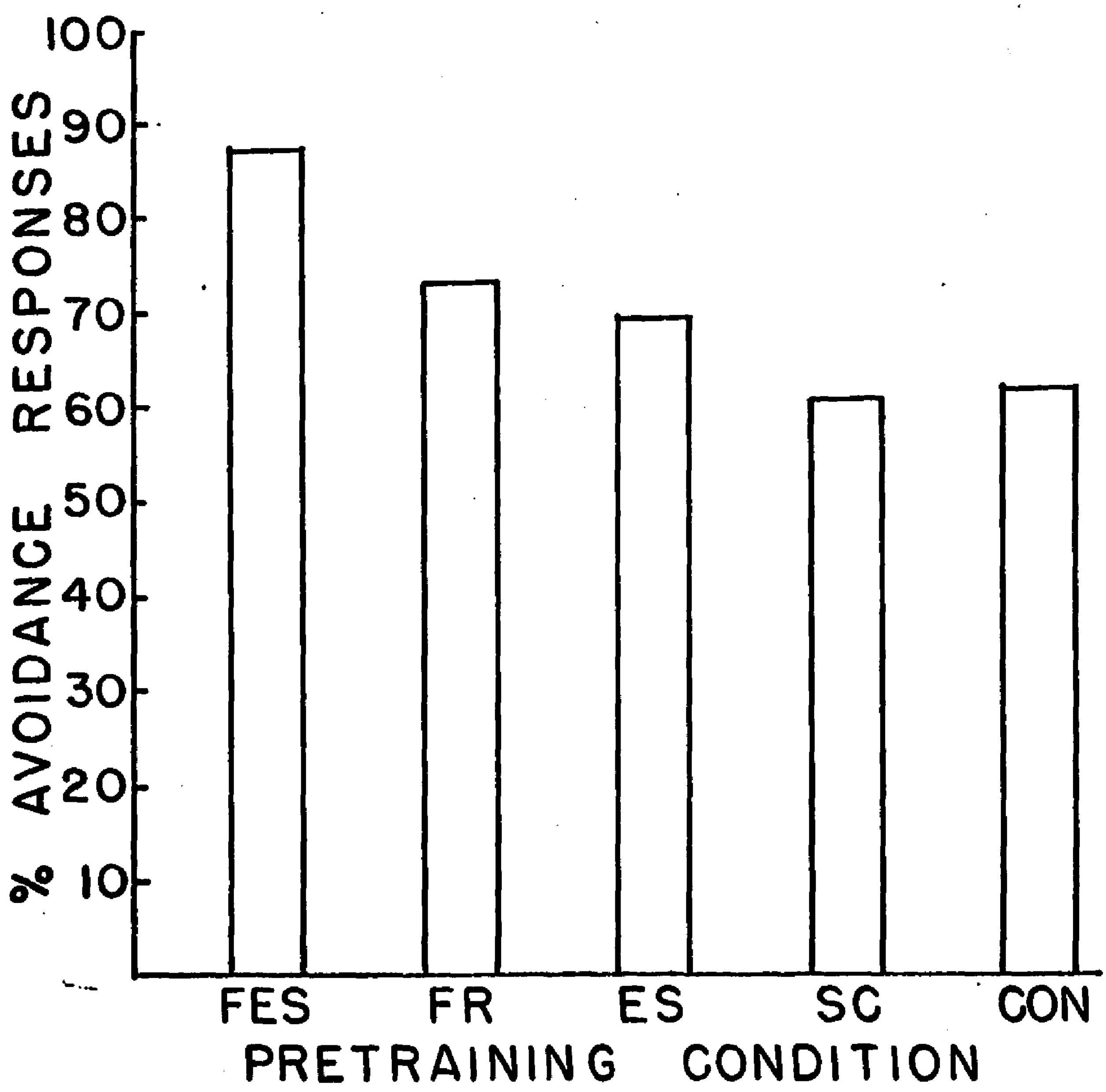

% AVOIDANCE RESPONSES
100
90
80
70
60
50
40
30
20
10
FES
FR
ES
SC
CON
PRETRAINING CONDITION

Figure 8. Experiment II.
Percentage of avoidance responses in the first and last 25 trials of acquisition following five pretraining conditions with 10 Ss per group.
The pretraining conditions are: fear-escape (FES), fear (FR), escape (ES), shock only (SC), and control (CON).

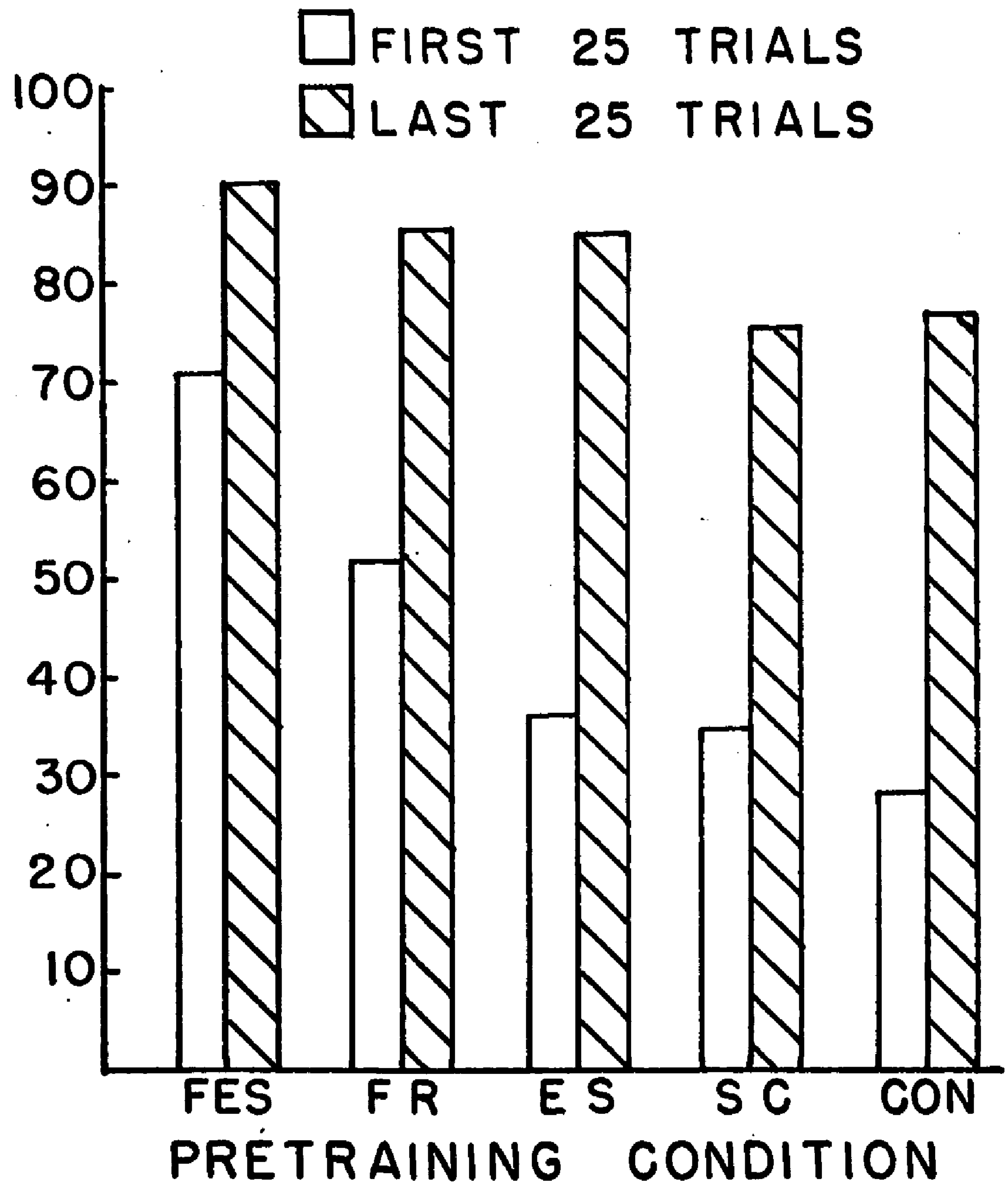

FIRST 25 TRIALS
LAST 25 TRIALS
100
90
80
70
60
50
40
30
20
10
FES
FR
ES
SC
CON
PRETRAINING CONDITION

Figure 9. Experiment II.

The total number of responses (including avoidance, escape and intertrial responses) in each of the five pretraining conditions with 10 Ss per group

The pretraining conditions are: fear-escape (FES), fear (FR), escape (ES), shock only (SC), and control (CON).

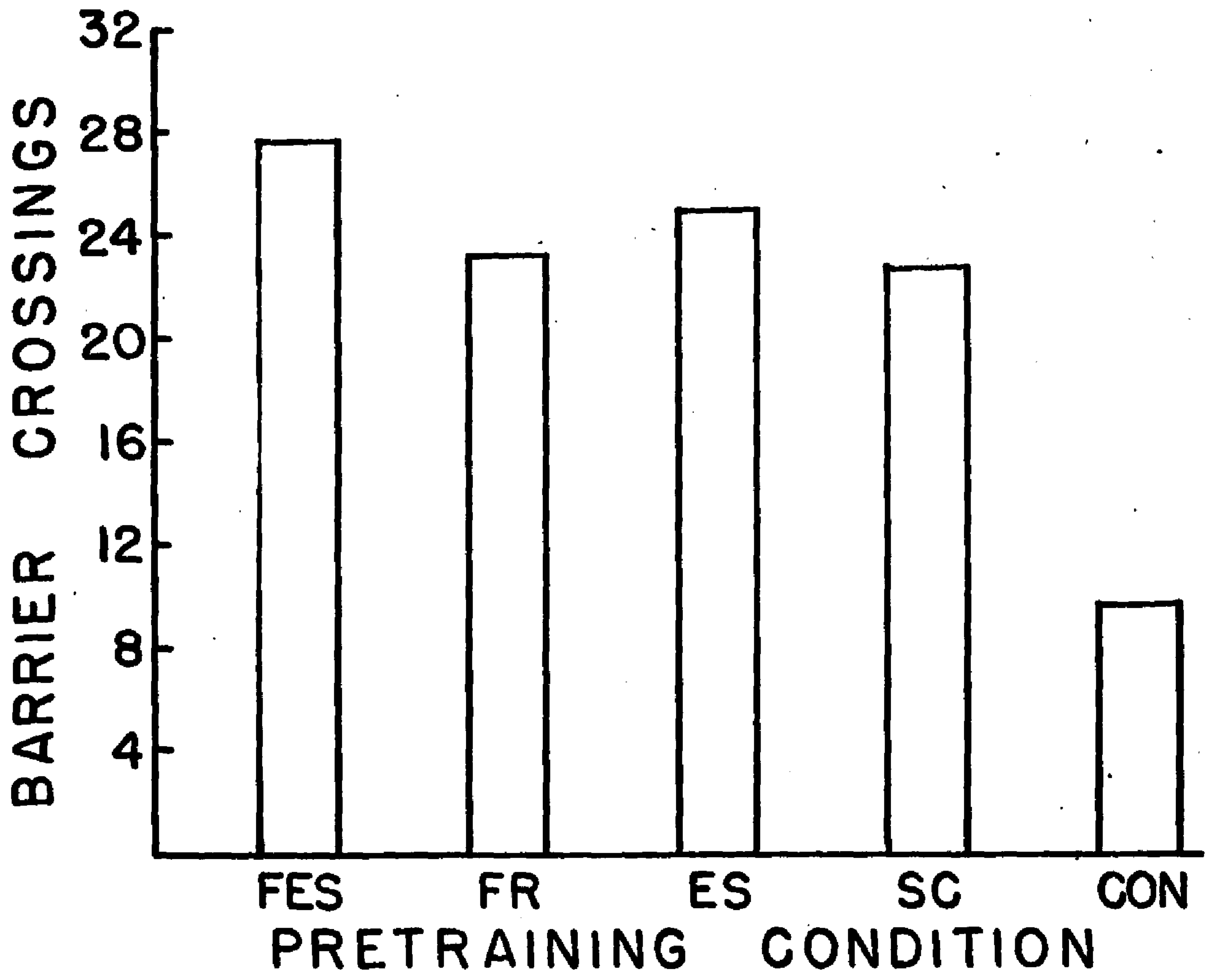
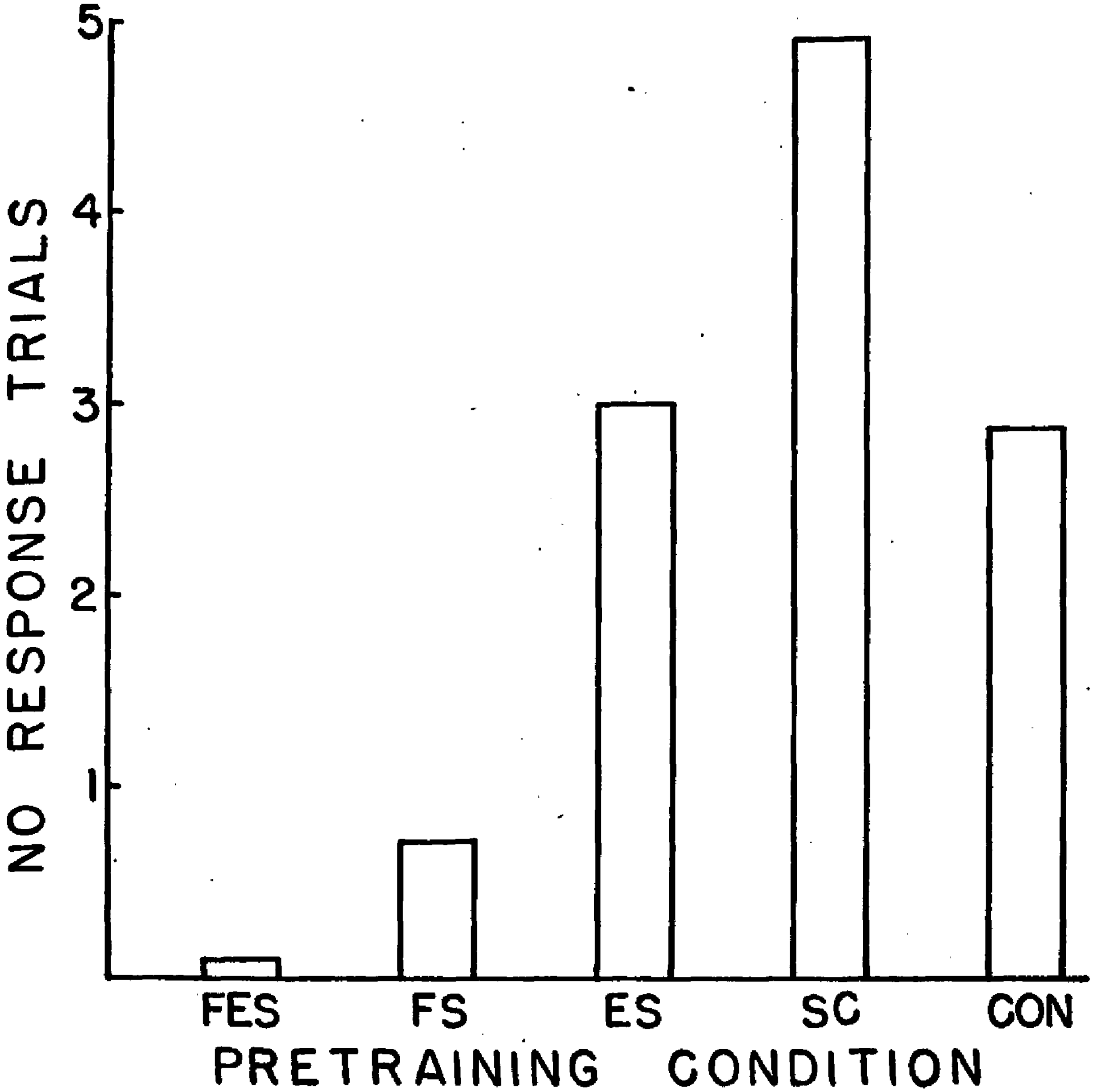

BARRIER CROSSINGS
32
28
24
20
16
12
8
4
FES
FR
ES
SC
CON
PRETRAINING CONDITION

Figure 10. Experiment II.
Number of acquisition trials terminated after 25 sec with no response for each of the five pretraining conditions with 10 Ss per group.
The pretraining conditions are: fear-escape (FES), fear (FR), escape (ES), shock only (SC), and control (CON).



5
4
3
2
1
NO RESPONSE TRIALS
FES
FS
ES
SC
CON
PRETRAINING CONDITION

Discussion

The results of Experiment II demonstrate an ordering of the effect of pretraining on subsequent avoidance conditioning. Fear-escape had the largest facilitory effect. The facilitory effects of fear conditioning and escape conditioning were of smaller magnitude than fear escape pretraining. Pretraining with shock alone had no effect when compared to the no pretraining control. The facilitory effect of pretraining was largely due to the variable fear.

These results are clearly compatible with two-process theory. This theory accounts for avoidance learning by the combination of classically conditioned fear and an instrumentally conditioned escape response which escapes the conditioned aversive stimulus. It is expected that if either response has been previously established, avoidance conditioning should be facilitated. In two of the conditions of the present study (fear and escape) the two processes, the classical and the instrumental, are independently developed and the effect on avoidance acquisition measured.

The fear and escape groups were similar on the acquisition measures. Both groups performed better on all measures than did either the shock only or control groups. These results indicate that satisfying the conditions of either process hypothesized by two-factor theory does facilitate acquisition. Statistical support for this conclusion was not obtained, however, except in the case of the fear group versus the control group on avoidance responses in the first 25 trials.

Greater support for the theory comes from combining the two processes in such a way that both are developed, but no avoidance response is conditioned. The fear conditioning with an escape contingency pretraining accomplishes this. The pairing of the signal and the shock sets the occasion for fear conditioning. The escape contingency conditions the instrumental response which becomes the avoidance response in acquisition. It can be logically predicted that the combination of the two contingencies should show a greater facilitory effect than either one individually. The fear-escape pretraining did, in fact, show a large facilitation effect in acquisition in spite of the fact that responses of avoidance latency were punished during pretraining.

As measured by avoidance responses ratios, the fear-escape group showed slightly more facilitation than the combined effects of the fear and escape groups for the early avoidance and total avoidance measures. It appears that if both a relatively efficient escape response and fear are conditioned in pretraining, the only step left for avoidance acquisition is a reduction in the latency of the escape response until it meets the requirement for an avoidance response. This interpretation of the facilitation effect is confirmed by the fact that fear-escape acquired a stable avoidance response very early in acquisition. A series of eight out of ten avoidance responses began on the average after 8.6

trials for the fear-escape group while it took an average of 32.7 trials for the control group. Since the difference is approximately the same as the number of pretraining trials it may be argued that the pretraining for the fear-escape group accomplished the same conditioning as did the first 20 trials of acquisition for the control group.

The data presented here do not show the equivocal or negative results for fear conditioning found by several investigators using mammals or by Pinckney (1967) using goldfish. Since the control and shock only groups were equivalent in avoidance performance, the learned helplessness hypothesis is inapplicable here. The learned helplessness hypothesis predicts that noncontingent shock should have a negative effect on subsequent avoidance acquisition and there was no evidence of that effect in the present study. There were significantly positive correlations between barrier crossings during fear conditioning and performance during acquisition, but this merely demonstrates that subjects with a higher *a priori* probability of making the selected response condition faster. The data on number of responses during pretraining per condition showed that all groups receiving shock made the response more frequently than the control group, regardless of an escape contingency. The conclusion that for goldfish fear conditioning has no inhibitory effect on responding is further substantiated by the fact that both fear groups failed to respond on only a small percentage of the trials, while the other three groups failed to respond more often.

In conclusion, fear conditioning facilitates avoidance acquisition in goldfish, particularly in early acquisition, at least under conditions where the subject is free to make the barrier crossing response at any time during pretraining. Escape conditioning tends to facilitate acquisition as evidenced by the position of the escape group on all acquisition measures. Pretraining with both fear and escape conditioning has the largest facilitory effect of all, as predicted since both components of the avoidance response are strengthened independently. Finally, pretraining with shock alone has neither a facilitory nor an inhibitory effect on avoidance acquisition as compared with the no pretraining control.

EXPERIMENT III--FEAR CONDITIONING WITH A RESPONSE BLOCK

The results of Experiment II established that either fear or escape conditioning or a combination of the two facilitates avoidance acquisition. The fear-escape condition, however, did not show a significantly greater facilitory effect than did the fear group, although the results were consistently in that direction. Experiment III attempted to determine whether fear-escape pretraining had a significantly greater effect than fear pretraining by replicating the two conditions.

In addition, two new pretraining procedures were instituted. The first was to investigate a possible source of the negative (Pinckney, 1967) and equivocal (Brookshire and Frumkin, 1969; Frumkin and Brookshire, 1969) results obtained in fear conditioning studies with goldfish. It may be argued that the probability of freezing is increased if the responses to be conditioned during acquisition is explicitly blocked during fear conditioning. The reasoning is that since the response which happens to occur at the instant of shock offset is reinforced and barrier crossing is blocked, the reinforced response is not barrier crossing. Conversely, if barrier crossing is allowed during fear conditioning there is a finite probability that barrier crossing will be adventitiously reinforced by shock offset. It may be assumed, then, that the probability that the barrier crossing response will be strengthened during fear conditioning is much higher if the response remains unblocked.

If this argument is correct, blocking the barrier crossing response should increase the probability of a competing response and decrease or cancel the fear conditioning facilitation. Thus a fear conditioning pretraining group with a response block (fear-block) was instituted for comparison with the fear, fear-escape and the control groups.

Three possible outcomes of the fear-block condition have different implications for the fear conditioning effect. If the fear-block group does no better than the control group in avoidance acquisition, the block may be the source of negative fear conditioning findings, but it also allows the possibility of a new interpretation of the results of Experiment II. That is that the facilitory effect of fear conditioning was due to adventitious reinforcement of barrier crossing rather than the fear conditioning. If acquisition by the Fbl group is better than acquisition by the control group, but worse than acquisition by the fear group, then the block did in fact strengthen competing responses, but fear maintained its facilitory effect. If in the final case the fear-block group was as good or better than the fear group, then blocking barrier crossing is not the source of competing response, nor can the facilitory effect of fear conditioning be attributed to adventitious reinforcement.

The fourth retraining procedure is a control condition. In Experiment II shock alone and no pretraining controls were used. In Experiment III a CS alone control is used to determine if the signal itself has a facilitory effect.

Method

Subjects and Apparatus

The Ss were 40 goldfish, obtained locally and weighing between 2.5 and 3.5 gm.

The avoidance conditioning apparatus was identical to that used in Experiment II, with the addition of a response block for one condition. The response block was a 1/4 in thick, 6 in x 4 in clear plexiglass rectangle, which could be placed in a tank at the edge of the barrier to prevent barrier crossing responses.

A recording system was also added to this experiment to allow a yoking condition in which a yoked S could be run at a different time than the controlling S. The CS and US duration for a controlling S were recorded by taping a gated 1000 H_z tone from a Hewlitt-Packard oscillator on a Tandberg tape recorder. The tones were played back into a Scientific Prototype tone detector to control the stimulus duration for a yoked S.

Procedure

The Ss were divided into four pretraining groups of ten Ss each. The adaptation period, avoidance acquisition, and extinction were the same as in Experiment II.

Two of the pretraining groups, fear-escape and fear, were identical to Experiment II, with fear yoked directly to fear-escape. The onset and durations of stimuli presented to the fear-escape subjects were recorded and used to control the stimuli presented to the other two groups. The remaining groups were a CS-control group and a fear conditioning with responding blocked group which were run simultaneously. An S in the CS-control group received 20 CS alone trials with CS durations identical to those received by its fear-escape yoke. An S in the fear block group received 20 trials identical to those an S in the fear group received with the addition of the block preventing barrier crossing. An S in the fear block group was trapped in one side of a tank throughout pretraining. The side an S was trapped in rotated from back to front and from tank to tank for different fish. The block was removed after pretraining.

The CS-US and intertrial intervals were the same as in Experiment II. Fear-escape and fear pairs were run alternately with CS-dontrol and fear-block pairs. The 10 consecutive no response disqualification criterion was used for this experiment.

Results

Figures 11 and 12 show the percentage of avoidance responses for the entire acquisition period, for the first 25 trials and for the last 25 trials for each of the four conditions. The fear-escape group, as shown in Figure 11, was highest on the overall acquisition measure, avoiding shock on 78% of the trials. The percentage of avoidance responses was lower for both the fear-block and fear groups, and there was little difference between them at 73% and 70% respectively. The avoidance acquisition of the CS-control group was poorest, with a score of 53%.

The performance during early acquisition period is shown in Figure 12. The fear-escape group was superior to the other groups, avoiding shock on 61% of the first 25 trials. The fear-block group avoided shock on 54% of the first 25 trials, while the fear group avoided shock on 38% of the trials. The CS-control group performed poorest on the early acquisition measure, avoiding shock on 21% of the trials. In the late acquisition measure also shown in Figure 12, fear-escape, fear-block and fear groups performed similarly with 88%, 86%, and 85% avoidance responses respectively while the CS-control group still avoided least with 68%. The data for the trial to first two consecutive avoidance responses and the trial to the start of eight out of ten avoidance responses were similar to the data for the entire acquisition period. The fear-escape group reached both criteria earliest, followed by the fear-block and fear groups with similar scores. The data for all acquisition and extinction measures are tabled in Appendix III.

Overall differences among groups for the percentage of avoidance responses during acquisition measure was significant ($F=3.51$, $df=3/36$, $p<.05$). Individual comparisons using Duncan's test showed that the difference between the fear-escape and the CS-control groups was highly significant ($S_{\bar{x}}=5.73$, $p<.01$) and that both the fear-block and fear groups avoided significantly more times than the CS-control group as well ($p<.05$). Overall differences among groups on percentage of avoidance responses for the first 25 trials also was significant ($F=4.06$, $df=3/36$, $p<.05$). Individual comparisons showed that both the fear-escape and fear-block groups were significantly better than the CS-control group on this measure ($S_{\bar{x}}=2.19$; $p<.01$ and $p<.05$, respectively). Significant differences among groups were also obtained for trial to the start of eight out of ten avoidance responses ($F=3.39$, $df=3/36$, $p<.05$). Individual comparisons showed that all three experimental groups, fear-escape, fear-block, and fear, attained the criterion significantly before the CS-control group ($S_{\bar{x}}=6.96$; $p<.01$, $p<.05$, and $p<.05$, respectively). Although an analysis of variance performed on the trial to the first two consecutive avoidance responses measure was not significant ($F=2.74$, $df=3/36$), individual comparisons showed that the fear-escape group was significantly better than the CS-control group ($S_{\bar{x}}=4.98$, $P<.05$) and that both the fear-block and fear groups approached significance when compared to the CS-control group ($p < .10$). No significant differences were obtained for percentage of avoidance responses in the last 25 trials ($F=2.34$, $df=3/36$).

Avoidance response ratios were computed for the fear-escape, fear-block, and fear groups as compared to the CS-control group for the early, late, and total acquisition measures. The avoidance response ratios for the first 25 trials were 2.87 for the fear-escape group, 2.55 for the fear-block group, and 1.79 for the fear group. For the last 25 trials the ratios were 1.29 for the fear-escape group, 1.25 for the fear-block group, and 1.24 for the fear group. The ratios for the total acquisition period were 1.46 for the fear-escape group, 1.36 for the fear-block group and 1.32 for the fear group.

The order of the groups on the two extinction measures was similar to the ordering on all acquisition measures. The fear-escape group produced the most responses and the CS-control group the least on both measures. The percentage of acquisition trials with no response was inversely distributed over groups as compared to the acquisition measures. As shown in Figure 13, the fear-escape group did not respond on a negligible .7% of the trials, while the CS-control group failed to respond on 3.9% of the trials. The fear-block and fear groups failed to respond on an intermediate 1.6% and 2.9% of the trials, respectively. Two fish met the disqualification criterion of ten successive no response trials in acquisition, one from the fear-escape condition and one from the fear-block condition, and were disqualified.

Since two of the pretraining conditions in Experiment III are a direct replication of two groups in Experiment II, an analysis was made of the differences between the fear-escape and fear groups across the two experiments. An analysis of variance shows that the combined fear-escape group made a significantly higher percentage of avoidance responses in acquisition than the combined fear group ($F=4.21$, $df=1/38$, $p < .05$). An analysis of variance was also performed on the two control groups, the no pretraining control group from Experiment II and the CS-control group from Experiment III. There were no significant differences either for avoidance responses in the first 25 trials ($F=.42$, $df=1/18$) or in total acquisition ($F=.75$, $df=1/18$).

Figure 11. Experiment III.

Percentage of AR in acquisition following four pretraining condition with 10 *S*s per group and the control (CON) condition from Experiment II. The pretraining conditions are: fear-escape (FES), fear-block (FBL), fear (FR), and CS-control (CS).

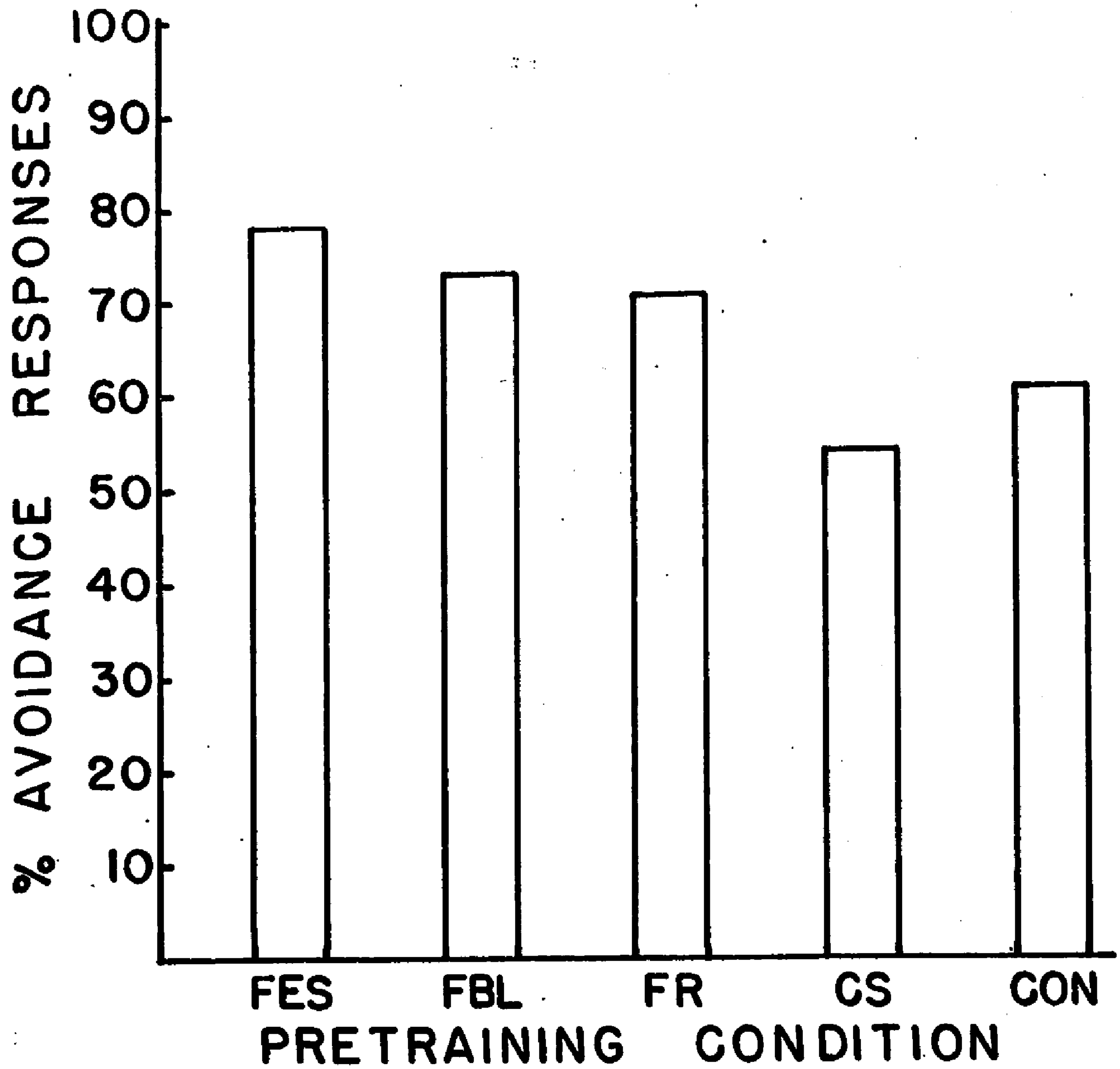

% AVOIDANCE RESPONSES
100
90
80
70
60
50
40
30
20
10
FES
FBL
FR
CS
CON
PRETRAINING CONDITION

Figure 12. Experiment III.
Percentage of AR in the first and last 25 trials
of acquisition following four pretraining
conditions with 10 Ss per group and
the control (CON) condition from
Experiment II. The pretraining
conditions are: fear-escape (FES),
fear-block (FBL), fear (FR),
and CS-control (CS).

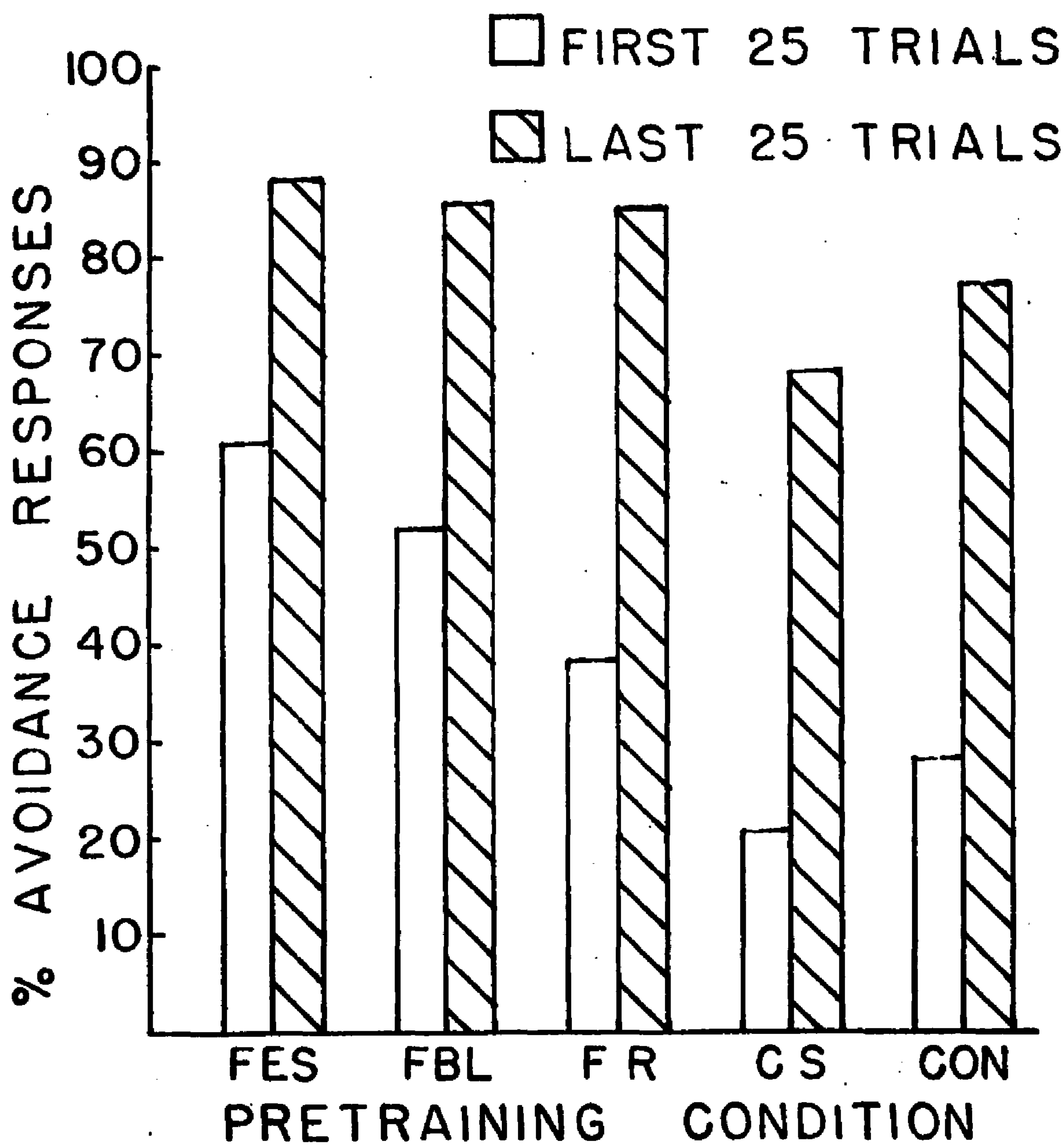
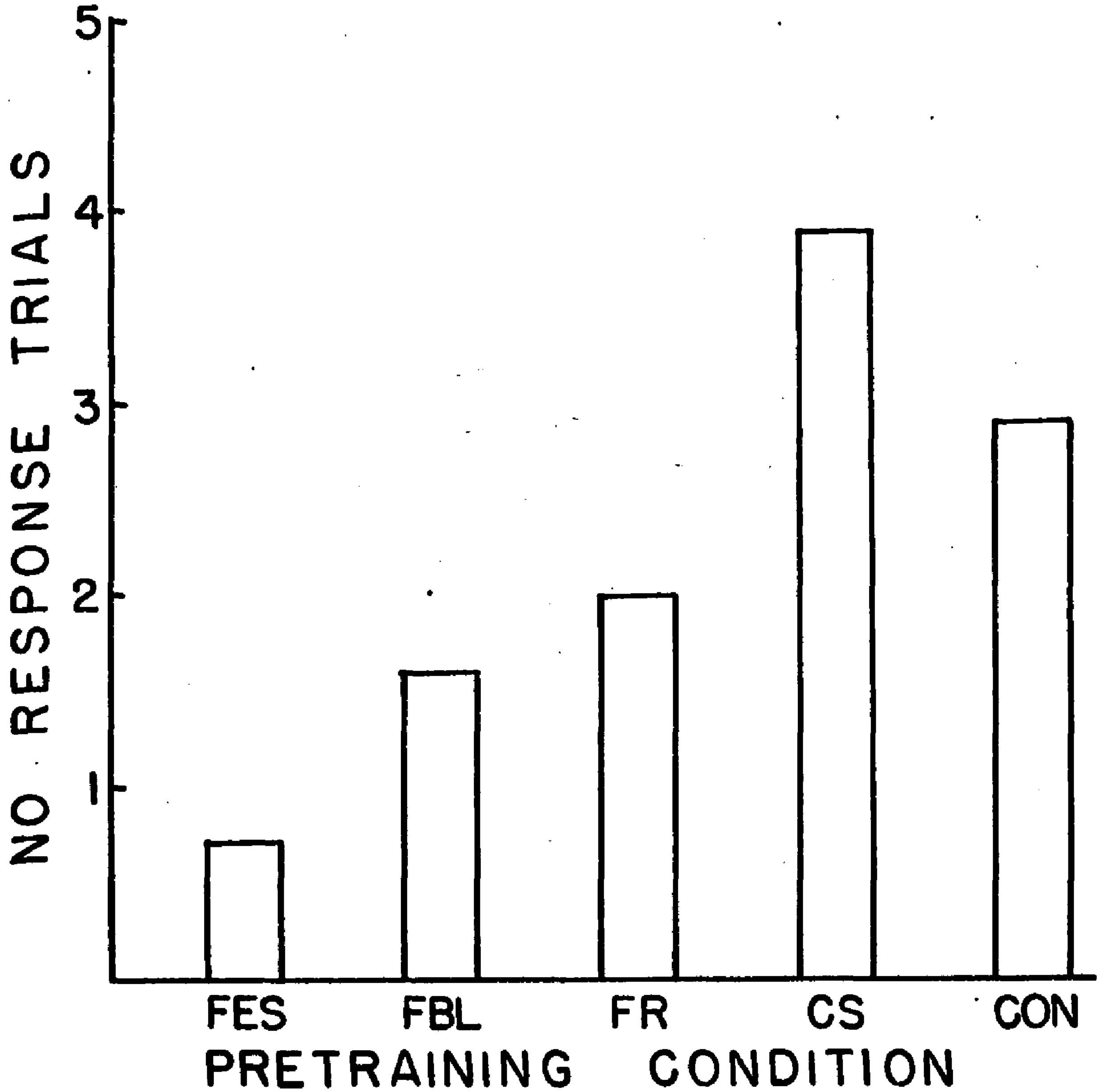

FIRST 25 TRIALS
LAST 25 TRIALS
% AVOIDANCE RESPONSES
100
90
80
70
60
50
40
30
20
10
FES
FBL
F R
C S
CON
PRETRAINING CONDITION

Figure 13. Experiment III.
Number of acquisition trials terminated after
25 sec with no response for each of the
four pretraining conditions with
10 _S_s per group and the
control (CON) from Experiment II.
The pretraining conditions are:
fear-escape (FES), fear-block (FBL),
fear (FR), and CS-control (CS).



NO RESPONSE TRIALS
5
4
3
2
1
FES
FBL
FR
CS
CON
PRETRAINING CONDITION

Discussion

The results of Experiment III extend the findings of Experiment II. The three groups that received fear conditioning during pretraining performed better than the control group on all acquisition and extinction measures. The facilitory effect of all three experimental procedures was demonstrated by the percentage of avoidance responses in acquisition measure. As in Experiment II, the facilitory effect is most pronounced in early acquisition. By late acquisition there are no significant differences among the groups.

The results further indicate that blocking the response does not decrease the fear conditioning effect in goldfish. The evidence, then, suggests that if either freezing or learned helplessness occurs, it does not interfere with the facilitory effect of fear conditioning in goldfish. The data for the fear-block group also counters the possible argument that the fear conditioning results in Experiment II may be explained by adventitious reinforcement. In the fear-block group the only response explicitly not reinforced is barrier crossing, because it can never occur.

The addition of a CS-control group in Experiment III and the comparison of that group with the control and shock only groups of Experiment II indicate that neither pretraining with the CS alone nor with the US alone has any effect on avoidance acquisition. The facilitory effect in these experiments can be accounted for only by the pretraining contingencies, either the Pavlovian fear conditioning, or the instrumental escape training, or the combination of both.

The combined results of Experiments II and III demonstrate that the combination of fear and escape pretraining has a greater facilitory effect than pretraining with fear conditioning alone. This result confirms the prediction that combining an excape contingency with fear conditioning strengthens the facilitory effect.

Experiments II and III provide strong evidence for a two-process theory of avoidance conditioning in the discriminated avoidance procedure. It is difficult to argue the irrelevance of a Pavlovian contingency, since fear conditioning provides a significant facilitory effect. The fear-block group cannot disguise an instrumental contingency in the form of adventitious reinforcement. Herrnstein's single factor theory does not predict the fear conditioning result, because no response changes the probability of the US. Further evidence for the two-process theory is the result that the combination of fear conditioning with escape has a greater facilitory effect than escape conditioning alone.

Fear conditioning has been shown to be a less complex phenomenon in goldfish than in mammals in that no freezing or learned helplessness interferes with its facilitory effect on avoidance acquisition. The literature suggests that both fear conditioning and unsignalled shock lead to immobility in rats and dogs. This immobility interferes with avoidance conditioning unless the task is simple or the freezing is overcome by other conditioning procedures. There appears to be no interference effect in goldfish, either with unsignalled shock or with fear conditioning under the conditions of the present experiments.

Appendix I

Table of Response Measures in Acquisition and Extinction for Experiment I: Means for 10 Ss per group

MEASURE

GROUP	ACQUISITION						EXTINCTION	
	% avoid in acquisition	% avoid first 25 trials	% avoid last 25 trials	trial to start; 2 avoids in a row	trial to start; 8 of 10 avoids	# of trials; no response	% avoid in extinction	% avoid or escape in extinction
3V	26.2	11.6	33.2	47.9	79.6	10.1	8.0	26.7
5V	59.9	18.8	81.2	27.8	42.5	1.4	53.7	76.3
7V	74.9	48.4	80.8	9.2	20.9	1.7	74.0	89.7
9V	64.7	38.8	76.4	13.0	22.8	5.2	62.7	79.0

Appendix II

Table of Response Measures in Acquisition and Extinction for Experiment II: Means for 10 Ss per group

MEASURE

GROUP	ACQUISITION						EXTINCTION	
	% avoid in acquisition	% avoid first 25 trials	% avoid last 25 trials	trial to start; 2 avoids in a row	trial to start; 8 of 10 avoids	# of trials; no response	% avoid in extinction	% avoid or escape in extinction
fear-escape	86.1	71.2	90.4	5.5	8.6	0.1	75.6	94.5
fear	72.9	52.0	86.0	14.7	26.0	0.7	74.7	90.6
escape	69.5	37.2	85.2	14.6	26.8	3.0	64.0	86.6
shock only	61.1	33.6	76.4	23.8	34.5	4.9	61.5	89.0
control	62.3	27.6	77.2	26.8	32.7	2.9	73.6	94.3

Appendix III

Table of Response Measures in Acquisition and Extinction for Experiment III: Means for 10 Ss per group

MEASURE

GROUP	ACQUISITION							
	% avoid in acquisition	% avoid first 25 trials	% avoid last 25 trials	trial to start; 2 avoids in a row	trial to start; 8 of 10 avoids	# of trials; no response	% avoid in extinction	% avoid or escape in extinction
fear-escape	78.4	60.8	88.4	8.9	14.6	0.7	85.6	96.9
fear-block	73.1	54.0	85.6	15.1	23.3	1.6	68.2	87.6
fear	70.8	38.0	84.8	13.9	24.3	2.0	65.6	93.1
CS-control	53.6	21.2	68.4	28.2	44.6	3.9	54.2	71.7

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