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AVOIDANCE BEHAVIOR OF GOLDFISH IN SHUTTLEBOXES: CONTINGENCY VARIATION AND A PSEUDO-LEARNING EFFECT

by

Terry Glover Malcolm

A dissertation submitted to the Graduate
Faculty in Psychology in partial fulfillment
of the requirements for the degree of
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1979

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

May 22, 1979 — date
Robert L. Thompson — Chairman of Examining Committee

May 22, 1979 — date
Martin L. Hoffman — Executive Officer

Professor Robert L. Thompson

Professor Sheila Chase

Professor Frank J. Mandriota
Supervisory Committee

The City University of New York

ABSTRACT

AVOIDANCE BEHAVIOR OF GOLDFISH IN SHUTTLEBOXES: CONTINGENCY VARIATION AND A PSEUDO-LEARNING EFFECT

Terry Glover Malcolm

Advisor: Robert L. Thompson

Three experiments were designed to investigate the role of response-reinforcer contingencies in controlling avoidance behavior of goldfish in shuttleboxes. Experiment 1 recorded operant level shuttling and obtained increased responding over days (a pseudo-learning effect). In Experiments 2 and 3 a new, individually-matched-shock-density (IMSD) extinction procedure, was introduced which removed the contingency between the response and reinforcer but did not alter shock densities from those received during avoidance. IMSD extinction, which was noncontingent, i.e., the probability of shock following no response equal to the probability of shock following a response, individually matched shock densities during extinction to those received during final avoidance for each fish.

Most theories of avoidance behavior are based on response-reinforcer contingencies (Herrnstein, 1969). In contrast, Woodard and Bitterman (1971,1973) suggested avoidance behavior by goldfish is the result of discriminated classical conditioning. On trials when no response is made, shock elicits activation which is paired with CS+. When a response is made, the CS+ with response-produced feedback acts as a CS-. While this explanation challenges the role of instrumental contingencies the pseudo-learning effect questions the data. Steiner (1971) found that goldfish placed in a shuttlebox with neither CS nor US, increased responding over sessions. Most goldfish studies have not included operant level sessions and consequently, their data may reflect a pseudo-learning effect.

Experiment 1 was designed to replicate and investigate the variables affecting the pseudo-learning effect. Thirty-six goldfish were assigned to light or dark and and a 35-, 65-, or 95-cm shuttlebox. After eight days of adaptation to the illumination condition, free operant shuttling was recorded in six 50-min sessions. Fish were then changed to the other illumination condition, adapted for eight days, and tested for six sesions. The effect was replicated with higher response frequencies occurring in the light condition. No shuttlebox length effect was found. There were large individual differences.

Experiment 2 tested the effectiveness of the response-reinforcer contingency using a reversal design. Nine fish received the following sequence of contingencies: operant level, avoidance, IMSD extinction, avoidance, IMSD extinction, and traditional no-shock extinction. Experiment 3 was designed to determine the effect of noncontingent shock before and contingent shock following avoidance. Twenty-six fish were assigned to one of three preavoidance shock densities. Woodard and Bitterman's position predicts the highest response probabilities in the group receiving shock on every trial in preavoidance. The sequence of contingencies was: operant level, preavoidance, avoidance, IMSD extinction, traditional no-shock extinction and punishment. In both experiments each phase consisted of 12 sessions of 20 trials with light as a CS and shock as a US. The major results for both experiments were: 1) The pseudo-learning effect was replicated with trials and a CS. 2) Responding was highest during avoidance, lower during noncontingent procedures. 3) Latencies were shorter during avoidance, longer during noncontingent phases. 4) High response probabilities during IMSD extinction did not correlate with high shock densities. 5) Shock received on the previous trial did not have an activation effect on the next trial. 6) There were large individual differences. In addition, in Experiment 3, in accordance with instrumental conditioning principles and contrary to a shock activation explanation responding was lowest during punishment. There were no significant differences between groups due to shock density during preavoidance.

These results emphasize an instrumental interpretation over classically conditioned activation, and caution that unless operant level data are included, results from goldfish in shuttleboxes may be confounded by a pseudo-learning effect.

ACKNOWLEDGMENTS

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Particular gratitude is due the following people who provided support while I was completing my dissertation: Robert Leslie, Gerry and Henry Opad, and Julie Sage-Day.

Lastly, I would like to especially thank my husband and colleague, David, for his patience.

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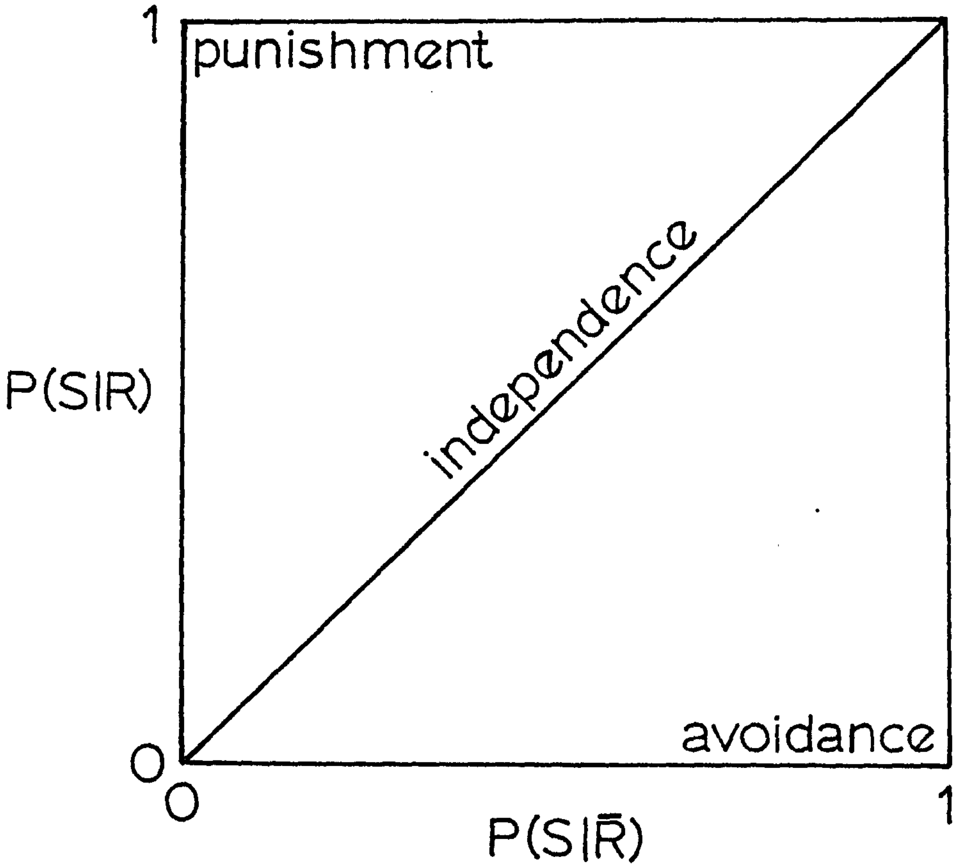
Acquisition and maintenance of avoidance learning has most frequently been associated with two-factor theory (Herrnstein, 1969; Mowrer, 1947 ; Rescorla & Solomon, 1967). This theory emphasizes specific roles for instrumental and classical conditioning. According to classical conditioning principles, the pairing of an initially neutral CS[1] and an aversive US results in the CS acquiring aversive (e.g., fear-inducing) properties. While the instrumental avoidance response prevents or postpones the US, it also reduces or terminates the CS and, presumedly, whatever aversive state the CS evoked. Two-factor theory stresses CS termination rather than avoidance of the US in maintaining responding. Two-factor theory was originally derived from procedures which used an explicit exteroceptive CS. Sidman (1953) and Anger (1963) extended two-factor theory to free-operant (Sidman) avoidance which lacked a specific-exteroceptive CS by proposing that dissipation of time between shocks and proprioceptive feedback from non-avoidance could act as CSs. One recent formulation (Seligman & Binick, 1977) did not emphasize the reduction of aversiveness of fear in maintaining avoidance but rather the production of a safety signal correlated with the absence of the US. One-factor theories have been based on the instrumental consequences of US reduction, prevention or postponement. When Herrnstein and Hineline (1966) used a negative reinforcement paradigm which de-emphasized the potential for classical conditioning by randomly presenting shock and omitting a CS they found that reduction in shock density alone was sufficient to condition and maintain responding. Herrnstein (1969)argued that a one-factor (instrumental) theory was the most parsimonious explanation for this data.

Another type of one-factor theory, based on classical conditioning and used to explain data from goldfish in shuttleboxes, has been presented by Woodard and Bitterman (1971, 1973). They found that responding when shock was unavoidable was almost as probable as when shock could be prevented by responding. Since they felt these results could not be easily explained as instrumental learning, Woodard and Bitterman presented an explanation based on the classical conditioning of activity by shock. Shock initially increased activity, including shuttling, which then came under control of the CS. Avoidance learning was explained as discriminated, classically conditioned activation: the CS light with feedback from responding was never paired with shock and became a CS- while light with no feedback from shuttling became a CS+.

The initial data which prompted Woodard and Bitterman (1971) to suggest classically conditioned activation was maintenance of a high level of responding when an unavoidable shock phase following avoidance training. Davenport, Olson, and Olson (1971) suggested that a procedure such as that used by Woodard and Bitterman should logically be considered an extinction procedure for avoidance. Using rats, Davenport et al. found unavoidable shock resulted in decreased responding. They reasoned that since the response no longer prevented shock, responding would decrease. However, it should be noted that this introduced a punishment effect since all behavior was followed by shock. A more appropriate procedure which removes the response-reinforcer relationship but does not alter shock densities now seems necessary. Shock densities in extinction can be individually matched to those received during avoidance so that the subject receives an identical response-independent noncontingent shock density. One such individually matched shock density (IMSD) extinction procedure was reported by Smith (1974). IMSD extinction procedures can be matched on the basis of frequency, pattern (replication of the order over trials of shocks received in avoidance), or noncontingent delivery. Smith matched total frequency and pattern received during the final avoidance session. Thus, the relationship between responding and shock was not noncontingent. Smith's procedure did not insure that the probability of shock following a response and following no response were equal so that shock delivery was noncontingent (truly random). Specifying shock trials in a way which permits quantitative control of contingency using traditional trial specification terminology is difficult. Gibbon, Berryman, and Thompson (1974) specified both response and no-response alternatives in a two-dimensional space, the contingency square (Figure 1). Within this square any combination of shock or no-shock and response or no-response relationships can be located. The probability of shock given no response

Figure 1. Contingency square representing the possible combinations of the probability of shock given a response, $P(S|R)$ and the probability of a shock given no response, $P(S|\bar{R})$. Adapted from Gibbon, Berryman and Thompson (1974).


1
punishment
independence
P(S|R)
avoidance
0
0
1
P(S|$\bar{R}$)

is given on the abscissa. The probability of shock given a response is on the ordinate. Contingencies can be specified as Cartesian (x,y) coordinates of the probability of shock given no response and the probability of shock given a response. The lower right corner with the probability of shock given no response equal to one, i.e., $P(S|\overline{R}) = 1$, and the probability of shock given a response equal to zero, $P(S|R) = 0$, with coordinates (1,0), is the point of maximal avoidance contingency. The upper left corner is the maximal punishment contingency with coordinates (0,1). The diagonal is the locus of all noncontingent procedures where the probability of shock is equal for responding and not responding. Point (0,0), the lower left corner, is the point in the contingency square at which shock is never delivered on any trial. The upper right corner, (1,1), represents shock delivery on every trial independent of responding. This is the same contingency as a 100% reinforced classical conditioning paradigm. If matched shock density procedures limited extinction to points on the diagonal shock would be noncontingent and response and no-response trials would be proportionately shocked.

Steiner (1971) presented other data challenging an instrumental view of avoidance learning by goldfish in the shuttlebox. She found that goldfish increase responding over sessions in the absence of any explicit stimulation. If this is typical of performance, then results of other studies may have reflected this pseudo-learningeffect rather than learning. This data from Steiner and from Woodard and Bitterman suggest that certain parameters and procedures affect goldfish and possibly other fish differently from mammals. If there is no difference in the way goldfish learn then their results have implications for general learning theory. Perhaps these phenomenon are not limited to shuttlebox studies with goldfish. For example, Bolles, Moot, and Nelson (1976) suggested that classical rather than instrumental conditioning may control shuttlebox learning with rats. As Estes (1975) and Hineline (1977) have suggested, further clarification of the procedure is important in understanding avoidance.

The present series of experiments was designed to replicate controversial findings and to gain a further understanding of the variables affecting the shuttling response in goldfish. Experiment 1 investigated the pseudo-learning effect under light and dark in shuttleboxes of different length. In Experiments 2 and 3 the role of the response-reinforcer relationship was studied by manipulating a variety of contingencies including an individually-matched-shock-density extinction procedure.

EXPERIMENT 1

An Analysis of the Pseudo-learning Effect: The Role of Shuttlebox Length and Illumination Conditions

Steiner (1971) studied the performance of goldfish in a shuttlebox under contingencies of fixed cycle avoidance, unavoidable shock, and in the absence of shock (operant level). Among the findings was that shuttling increased over sessions in the operant level group in a manner resembling avoidance acquisition. The potential generality of this result questions the nature of avoidance learning in all of those experiments not measuring baseline performance prior to conditioning or in independent control groups. Operant level per se is rarely studied in the context of avoidance conditioning. As operant conditioning techniques became widely accepted and operant research emphasized steady states, researchers usually did not include an operant level baseline. Today, operant level data are most often found in research with novel organisms and novel reinforcers. Data collection methods used during operant level are sometimes procedurally similar to those used during adaptation. The term adaptation is often used in the context of studies of general activity and exploratory behavior.

Although there are many studies of operant level using rodents, there have been very few using fish. Thus, when Steiner (1971) included an operant level control group, the pseudo-learning effect was not anticipated. Since other operant level studies with fish have not been as extensive the question arises as to the generality of the phenomenon. Is it specific to Steiner's fish, apparatus, and procedure? These are important questions which should be answered before determining the role of operant vs. respondent contingencies in avoidance conditioning of goldfish.

Steiner tested 72 goldfish over eight 25-min sessions. Half the fish were assigned to a 60-sec shock-shock interval while the other half were assigned to a 30-sec shock-shock interval. Within each of the two conditions fish were assigned to one of three shock procedures: One-third received no shock, one-third received unavoidable shock and one-third were on fixed cycle avoidance (FCA). For the FAC fish, shock was programmed by a recycling timer and was delivered at the end of the fixed interval if no response was made during the interval. There was no exteroceptive signal. During the experiment, groups of four fish were kept in community tanks but tested individually in shuttleboxes. Shuttleboxes were constructed of white plexiglas with inside dimensions of 4 x 12 in. (10.2 x 30.5 cm). A 2-inch (5.1 cm) hurdle was placed in the tank and covered with water to a depth of 3/4 in. (1.9 cm). Shocks of 100 msec duration and 5VAC were delivered by stainless steel electrodes which lined the length of the shuttlebox. Steiner did not indicate whether voltage measurements were peak to peak or root mean square (rms). Responses were detected using a photocell system. Illumination conditions were unspecified

Steiner found that response rates tended to increase over days. Fish assigned to the 60-sec shock-shock groups responded more frequently than those assigned to the 30-sec groups. Even the 60-sec no-shock group responded more frequently than the 30-sec no-shock group despite the procedures being identical. In all groups there was a trend toward increased responding over the first 4 to 6 sessions. During the last few sessions responding remained at the same level or decreased in all but the unavoidable group. Until the last two sessions responding was highest in the no-shock and lowest in the unavoidable groups. These results led Steiner to conclude that avoidance measures specified in percentage are meaningless without adequate baseline data.

Woodward and Bitterman (1971) measured operant level for 17 days, 10 trials per day for one group, and 4 days, 10 trials per day for two groups. Goldfish averaging 6 cm in length were tested in a shuttlebox measuring 25.4 x 11.4 x 10.8 cm. Water depth over the 5 cm high hurdle was 2 cm. Each trial was 10 sec long with an unspecified intertrial interval (ITI). A photocell system detected shuttling responses. Background illumination conditions were unspecified. Fish were divided into three groups of 11. During operant level two of the groups increased slightly from the first to the second day and then decreased on the following. Another group decreased monotonically over four days to a mean of two responses. The activity control group was monitored for an additional 13 days. Responding in this group stayed at approximately the same level with between 1 and 3 mean responses. In the second experiment of the study operant level was recorded for three days for 18 fish. Mean responses ranged from approximately 3 to 4. In a later study Woodard and Bitterman (1973) again monitored shuttlebox crossings for 10 trials per day for three days. As in their previous experiments responding was low and there were slight increases from the first to the second day with little change thereafter. The difference in operant level responding found by Steiner and Woodard and Bitterman requires further clarification of variables affecting activity.

Patterns of general locomotor activity of goldfish over days have also been studied. Peeke and Peeke (1972) recorded number of midline crossings in an aquarium 30 x 29 x 59 cm for seven days. Thirty goldfish, measuring 5 to 8 cm, were adapted for 12 days to the aquarium prior to testing. Activity was recorded during a 10-min test period on seven consecutive days. During the test period a plastic tube filled with brine shrimp was placed in the aquarium. Peeke and Peeke found increases in responding over all sessions except the fourth and fifth. Although the increases were much smaller than Steiner's the initial trend was similar.

Other locomotor activity studies have been done using other species of fish in a variety of apparatus. Turnbough and Lloyd (1973) recorded locomotor responses of adult <u>Betta splendens</u> (siamese fighting fish). Using an E-shaped structure placed in home tanks, responses were measured when a subject entered the upper or lower leg of the E. Turnbough and Lloyd presented data for one subject over five adaptation sessions. Entrance into the E increased over the first four sessions. Despite increases in responding during operant level "adaptation", responding was higher during subsequent conditioning.

A different shape activity curve was found by Varnelli and Cleave (1974) for Atlantic salmon Salmo salar. Fifty-one salmon were tested in either a 61 x 31 x 31 cm rectangular tank or in a circular alley, 10 cm wide, with an outside diameter of 46 cm. Activity was recorded using an electromechanical system which transduced swimming movements. Fish were placed in the apparatus 48 hours prior to 15 days of continuous recording. In terms of overall activity most fish showed decreases toward the end of the experiment. Since fish were not fed during the course of the experiment, the authors felt lack of feeding may have decreased activity.

Rhoad, Kalaf, and Klopfer (1975) studied swimming from one area of a tank to the other by using four adult Betta splendens. Although they were primarily interested in studying approaches to various stimuli such as conspecifics and models the experiment was preceded by an operant level phase. Fish were housed and tested in a 22.8 x 17.6 x 17.6 cm portion of a 2 gal (7.61) tank. The length of the chamber was divided into thirds and crossing into a different third was defined as a response. Fish were tested during the light portion of a 14 hr/10 hr light/dark cycle between October and March. The number of days of adaptation prior to operant level, if any, were not specified. Fish made about 25 responsesper hour during operant level. Three of the four showed an increase from day 1 to day 2. Operant level was redetermined following tests with various stimuli. It was at the same level as during the first two sessions.

Data from all of these studies showed an increase in responding from the first to the second day. Generally responding continued to increase over a few more sessions and then decreased or remained the same. The magnitude of increase appeared to be more sensitive to species and response requirement differences than the general shape of the curve did. The major exception is the study by Varnelli and Cleave (1974) where lack of feeding may have had a debilitating effect which reduced responding. Relative changes in response frequency in all studies where lower than those found by Steiner (1971).

Since the pseudo-learning curve phenomenon has implications for experimental design it should be ascertained to what extent this phenomenon has been found with other investigtors and with which species and what kinds of apparatus. Classic studies of operant level (Schoenfeld, Antonitis & Bersh, 1948; Kish & Antonitis, 1956) used rats as subjects. Schoenfeld et al. tested 40 rats in an operant chamber. A lever was inserted into the chamber for one hour on six consecutive days. The subjects were adapted to the cage without the lever for two days prior to testing. At the start of each session the rats were water-deprived for 23 hr, 15 min. The group mean decreased monotonically over the six sessions from 58.6 to 12.8 level responses. Decreases were larger during early sessions than during later sessions. The authors noted spontaneous recovery at the beginning of each session with periods of bursting alternating with periods without responding. They referred to the curve of daily means as "extinction-like".

Kish and Antonitis (1956) recorded the operant level rate of stepping onto an activated platform. Two strains of 85-95 days old male mice were tested during 25-min sessions on six consecutive days. Although there were differences in the shapes of the curves, both strains decreased over days.

Russell and Williams (1973) reviewed some of the literature of open-field data and found two patterns. One of the patterns, decreased responding over sessions, is similar to that found by Schoenfeld et al. (1948) and Kish and Antonitis (1956).

The other pattern frequently found in open-field studies was an initial decrease followed by an increase. An example of this is provided by Russell and Williams

(1973) own research. Twelve rats were exposed to the open field for 5 min daily on 10-consecutive days. Results indicated a decrease in locomotion on the first three days followed by an increase thereafter.

These studies using rats and mice did not result in a increased responding over successive days. Since the effect does not occur with all species and apparatus it is of interest to determine which parameters contribute to the pseudo-learning curve effect.

An important variable affecting fish physiology and behavior is illumination. Fish appear to be sensitive to seasonal, daily, and brief changes in illumination. For example, controlled experiments have shown that light alone can cause changes leading to spawning in the American brook trout, Salvelinus fontinalis (Marshall, 1966). Some fish such as minnows are more active during the light (Jones, 1956) while others such as mormyrids are more active in the dark (Malcolm, 1977). Certain aspects of goldfish responsiveness to light have been studied. The physiology and psychophysics of the goldfish eye are fairly well known. Both electrophysiological and psychophysical studies have found that goldfish are responsive to wavelengths between 360 and 800 nm. Their eyes are composed of rods and cones and both scotopic and photopic curves have been behaviorially determined (Jacobsen, 1968; Yaeger, 1968). Sutherland (1968) has shown that goldfish can discriminate a variety of shapes although they do not identify rotations as the same shape.

Background illumination, which is the visual stimulus most manipulated in shuttleboxes, has been studied by Tavolga (1977). Prior to threshold determination, fish were trained to avoid shock in the presence of a light CS. When overhead illumination was above threshold it served as a CS and an avoidance response followed. When illumination was below threshold fish failed to respond. The light source was a cathod-ray tube whose luminance was controlled by the brightness adjustment, by blanking scan lines and by adding neutral density filters. Some shuttleboxes were painted dull white (reflectance 2%) while others were painted matte black (reflectance .2%). Tavolga found the mean threshold to be 2.91 pW/cm^2. He notes that this value when converted to irradiance is similar to Bartley's 1951 threshold for humans. There was no difference between thresholds in black vs. white shuttleboxes. This led Tavolga to suspect that his subjects were not only using vision to swim across the hurdle. He felt that the tactile and lateral line senses might have been used.

Timms (1976) studied the effect of light vs. dark on swimming by comparing totally blinded, unilaterally blinded, and normal goldfish. He tested 25-30 cm goldfish in a tank 5.0 x 5.0x .05 meters using a matrix of 1936 photocells. General patterns of movement such as number of consecutive turns were similar in bilaterally blinded and normal fish. Unilaterally blinded fish showed circus movement toward the blinded side. The major difference between the blinded fish and the other fish was in the velocity of movements, the blinded fish being slower. Kapoor (1971) has shown that fish have different activity levels under light and dark conditions. He tested pumkinseed fish (*Lepomis gibbosios*) in a circular tank. Partitions, which extended inward from the parimeter of the tank divided the tank into 16 wedge-shaped compartments. The compartments were open at the center of the tank so that fish could swim from one compartment to another by swimming into the center of the tank. Normal and blinded fish were exposed to three illumination levels. Prior to testing subjects were maintained on an unspecified daily light/dark cycle with the light conditions brighter than the brightest experimental condition. Recordings began 6-12 hrs after placement in the test tank. Fish were recorded under each condition for 24 hours on three consecutive days. Kapoor found a direct relationship between light intensity and number of compartment changes. For example, in the normally sighted group the number of total compartment changes for normal, dim and dark conditions were 1,821, 1,458, and 1,173, respectively. Responding increased as a function of light intensity in the other two groups, although means were lower in the blinded group. The results for the blinded group were attributed to pineal photoreception.

Another potentially important variable affecting the pseudo-learning curve is shuttlebox size. Steiner (1971) felt that the high operant level of shuttling might be "due to the general aversive properties of confined space" (p. 54). Greenway and Bitterman (1973) also suggested that there might be a relationship between shuttling and shuttlebox measurements. Since shuttlebox size might influence activity level and the probability of crossing, shuttlebox dimensions may be an important parameter in Woodard and Bitterman's conditioned activation explanation. Tavologa (1977) as previously noted felt that tactile and lateral line cues were important in his study using goldfish in a shuttlebox. This also indicates that shuttlebox size may be important. Despite these conclusions shuttlebox size has not been systematically studied.

A wide variety of shuttlebox sizes appear in the literature. Although there are a few commercial aquatic shuttleboxes, most investigators use custom-made shuttleboxes. Not only are dimensions not standardized but also shapes differ. Length to width ratios, hurdle heights, and water depth vary. In addition, there is no standardized relationship between body size and shuttlebox size. Most shuttleboxes are between 25 and 40 cm in length and range from 7.5 to 18 cm in width. Occasionally, shuttleboxes as large as 47 x 26 cm have been used (Warren, Bryant, Petty & Byrne, 1975).

The effect of seasonal differences has recently been a focus of attention with a few investigations using goldfish. Although seasonal effects in the natural habitat are well known and documented for many fish (Breder and Rosen, 1966; Marshall, 1966) they have been ignored until recently in laboratory studies of learning. Whether or not learning is inferior during the summer is still a matter of debate. Agranoff and Davis (1968) noted that lower mean scores for shuttlebox avoidance occurred between May and August. Their fish were trained and tested in shuttleboxes similar to Bitterman's (Horner, Longo & Bitterman, 1961) using a 20-sec CS-US interval with a light CS and intermittent shock as the US. During training fish received 20 trials in a single session and 72 hours later were tested for retention. Agranoff and Davis felt summer learning was inferior because goldfish were being transported during the breeding season and because more transportation problems occurred during the summer. Shashoua (1973) also noted seasonal differences. He sutured ball shaped-floats to the underside of goldfish which initially caused fish to swim upside down. The fish could learn to right themselves. Shashoua found that latencies to normal swimming were shorter during the winter months.

Fjerdingstad (1974) suggested that the differences were due to shipping conditions. During the summer months fish were exposed to higher temperatures and greater stress. Fjerdingstad, using a shuttlebox and schedule similar to Agranoff and Davis did not find any seasonal variation in learning. He noted that other studies used fish 1 to 2 days after they arrived in the laboratory and with the greater stress of summer shipments an adaptation period may be necessary.

Shashoua (1974) countered that he still obtained seasonal effects with animals from local suppliers. He compared the final level of performance of all Fjerdingstad's fish with data from his fish tested in the summer and found his own higher. Shashoua believed that Fjerdingstad's fish would have had higher scores if the test tanks were continuously aerated and the fish were fed less. Agranoff (1974) summarized the results by suggesting that the shuttlebox task is easier than self-righting with a sutured-float and therefore not as sensitive to seasonal changes. He feels that summer fish may be slower growers and may be retarded in many respects. The validity of this suggestion is weakened by the data showing lower asymptotic responding for the shuttlebox compared with the float Although the controversy surrounding seasonal effects has not been settled it is important for experimenters to be aware of potential effects.

Steiner (1971) presented the strongest evidence for the pseudo-learning effect with goldfish in shuttleboxes. The other cited studies were suggestive but not conclusive.

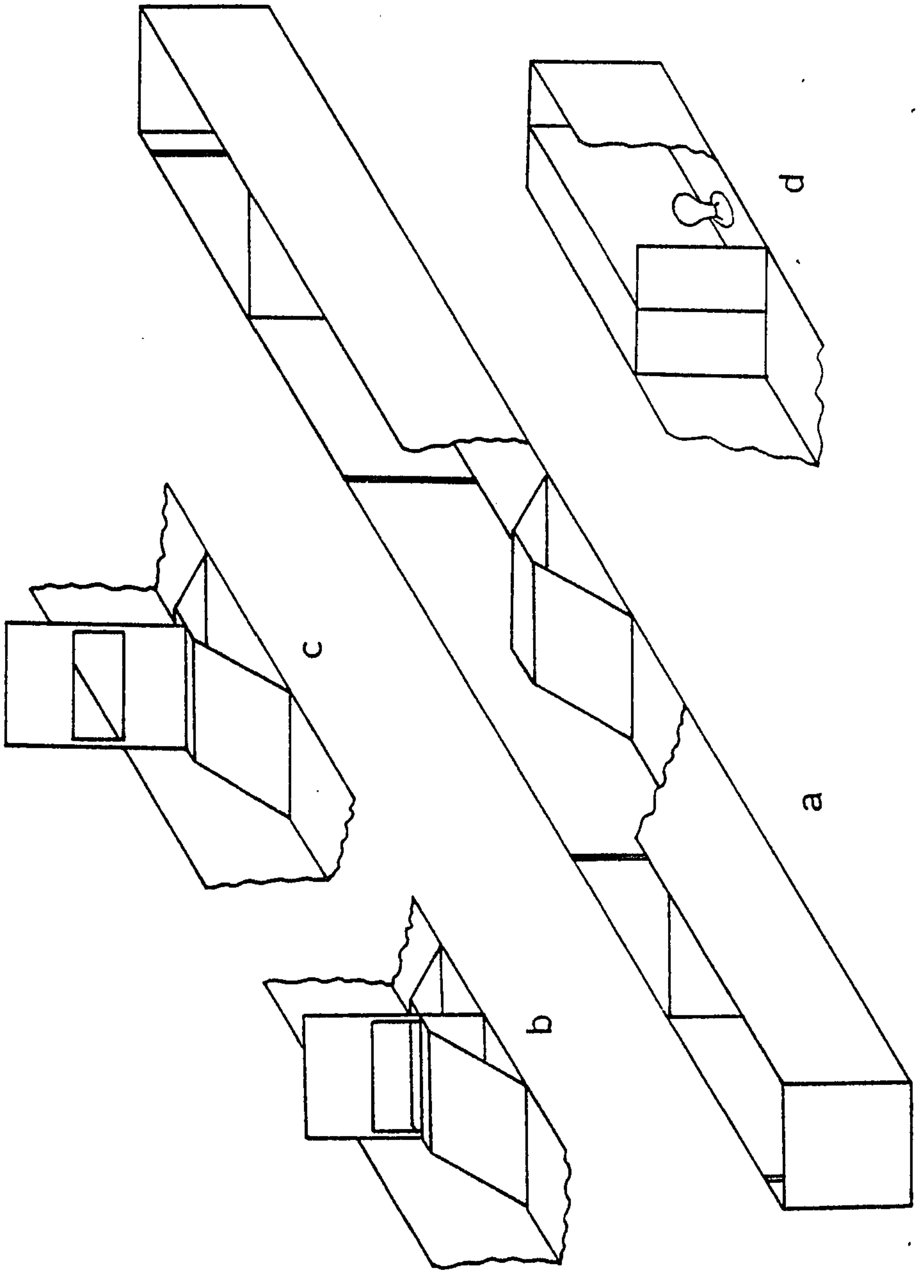
This could mean that the phenomenon is not robust and is sensitive to parametric manipulation. For this reason some aspects of Steiner's study were replicated (hurdle, height, etc.) in an attempt to establish that the phenomenon could be replicated. This study also parametrically varied certain variables in an attempt to identify conditions which might account for the fragility of the phenomenon. The experiment was designed as a 3 x 2 factorial with repeated measures. The two variables thought to be most influential were shuttlebox length and illumination level. Each fish was assigned to one of three shuttlebox lengths for the entire experiment. Fish were assigned to either light or dark initially and later reversed. Other relevant variables such as water temperature, and feeding schedules were held constant over the experiment. Seasonal records were kept to ascertain whether such an effect was evident.

Method

Subjects

Common goldfish (*Carassius auratus*) of similar size and unknown sex and age were obtained via a local supplier (Madison Avenue Pet Shop, New York, New York, 10028). Goldfish were maintained in aerated 6.8 l community tanks in a room with natural and 12 hours of artificial light for one week prior to the experiment. Fish were fed Tetramin goldfish flake food once a day. Seventy-two fish were initially assigned to the experiment. Twenty-four were

Figure 2. Schematic view of the shuttlebox. (a) The shuttlebox as used in Experiment 1 without the door or CS lights. The moveable end partitions are set at 65 cm in this view. The door in the (b) open, down position and (c) in the closed, up position. (d) View of the lamps behind the end partitions used in Experiments 2 and 3.


a
b
c
d

eliminated due to apparatus malfunction, illness, or experimenter error. From the remaining subjects, six were randomly selected from each of the six experimental groups to facilitate statistical analysis. The numbers eliminated from any one of the six groups ranged from 0 to 4. The mean length from nose to caudal peduncle of the fish used in the experiment was 5.9 cm with a standard deviation of .6. Their mean dorsal to ventral extent across the widest part of the body was 1.9 cm with a standard deviation of .5.

Apparatus

Experiments were conducted using two identical acrylic plastic shuttleboxes, shown in Figure 2, which had overall interior dimensions of 100 x 10 x 10 cm. End partitions could be moved between pairs of ABS plastic "H" channels which were fixed to the inside walls permitting shuttlebox length to be set at 35, 65, or 95 cm. The end partitions were covered with General Electric electroluminescent panels distributed by Grimes Mfg., Garden City, New York. The panels, which were not functional in this experiment, measured 7.2 x 9.8 cm and resembled flat sheets of pale yellow plastic when unlit. Centered in the shuttlebox was a formed Plexiglas hurdle measuring 13.0 cm at the base, 3.1 cm at the top, 5.0 cm in height and 9.5 cm in width. The hurdles and shuttlebox interiors, with the exception of photocell windows, were sprayed with Rustoleum flat black paint which is non-toxic to fish. Regardless of the placement of the pair of end partitions, the shuttleboxes were filled to a depth of 7.5 cm and held 7.5 l of water.

A pair of Lehigh Valley model 1533 photocells were mounted outside a pair of clear, unpainted 1.5 x 2.0 cm windows on either side of the top of the hurdle. An infrared filter was placed between the lens and lamp to reduce visable light emitted from the photocell arrangement. Fish were required to swim completely through both photocells without retreating before a response was recorded. Equipment was programmed using Scientific Prototype, Grason-Stadler, and Lehigh Valley modules. Timing equipment was calibrated with a Tektronix 502A oscilloscope.

The shuttleboxes were situated in two nearly identical windowless cubicles. The cubicle designated as the light condition was lit from 0630 to 1830 hours Eastern Daylight Time (EDT). The other cubicle, designated as the dark condition, was on a reversed cycle being lit from 1830 to 0630 hours. A 75-watt incandescent bulb, hung 52 cm above the tables housing the fish, illuminated each cubicle. The amount of light in each cubicle was measured at table height using a Gossen light meter. Readings were taken at the start of the experiment during the light portion of the cycles in each cubicle. In the dark cubicle readings ranged from 105 lx in the areas where the shuttlebox and some home tanks were placed to 60 lx in the table corners where additional tanks were placed. Similar readings in the light cubicle ranged from 104 lx in the area of the shuttlebox to 60 lx in the corners. Bulbs were changed monthly to prevent failure. There was no illumination in either cubicle during the dark period of each cycle. Minimal stray daylight briefly illuminated the dark cubicle when the experimenter entered to remove fish from the shuttlebox. A penlight was used to identify the home tank of fish after their removal from the apparatus in the dark cubicle. Tanks were arranged in order so that it was not necessary to use the penlight to identify tanks just prior to the transfer to the shuttlebox.

During the experiment fish were individually housed in clear molded plastic boxes from motorized filters. These filter box aquaria measured 31.0 x 9.5 cm at the base, 33.0 x 10.2 cm at the top and 18.0 cm in height and held 4.0 l of water. At the start of the experiment tanks and shuttleboxes were filled with two-thirds conditioned and one-third aged water. At the end of each day 1.5 liters of water were drained and discarded from each shuttlebox. This was replaced with 250 ml from each of the six experimental tanks in each cubicle which in turn was replenished with aged water. Shuttlebox water was discarded at the end of each series of six sessions. Individual aquaria were continuously filtered and aerated with outside, glass wool and activated charcoal filters. Filters were changed every other week. Shuttleboxes were filtered and aerated overnight with inside, glass wool and activated charcoal filters. Mean water temperature over the entire experiment was 23.2° C. Water temperature variation on successive days and among all tanks and shuttleboxes on a given day never exceeded 0.5° C.

Procedure

The general procedure was to assign fish to either 35, 65, or 95 cm long shuttleboxes. Fish were run for six consecutive operant level sessions following an eight-day adaptation period in either the light or dark cubicle. They were then transferred, in their tanks, to the other cubicle and adapted for eight additional days and run for a second series of six operant level sessions. Thus, with each subject assigned to one shuttlebox length, an operant level rate of shuttling was collected over six 50-min sessions in the light and six 50-min sessions in the dark.

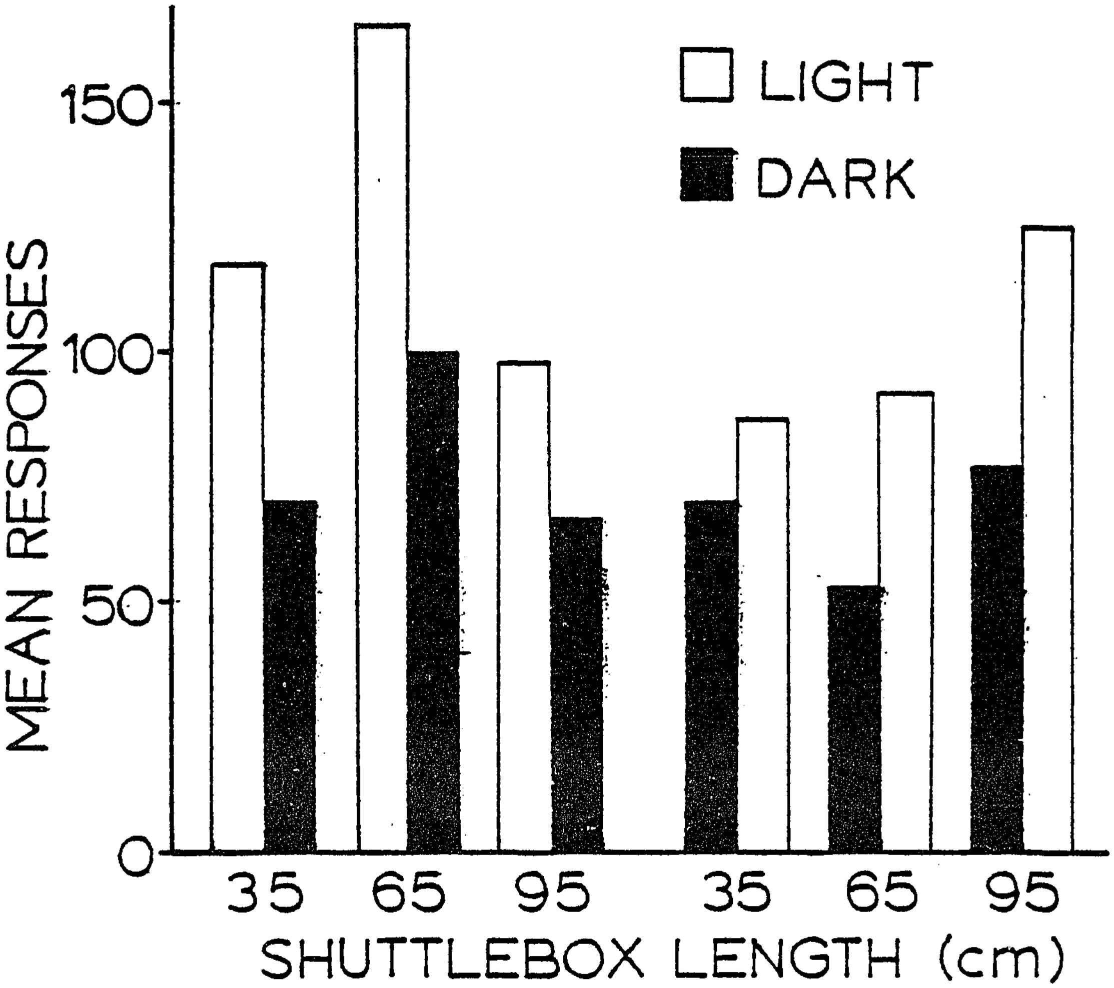
At the beginning of the adaptation period fish were individually measured and transferred to the light or dark cubicle. Fish were randomly selected from the community holding tanks and alternately assigned to the two illumination conditions. Initially seven fish were placed in each cubicle. At the end of the adaptation period two fish each were randomly assigned to the 35, 65, or 95 cm length groups in each cubicle. The seventh fish was discarded if all the fish survived the initial adaptation period. The day was divided into six one-hour time periods beginning at approximately 0930. Each fish was run once during each time period. Transfers between home tanks and shuttleboxes were made with nylon nets. The same length shuttleboxes were used simultaneously in each cubicle. The sequence of procedures and running schedule for the experiment are presented in Appendix A. Sessions were 50 min, twice the length of Steiner's, to ascertain whether the pseudo-learning phenonmenon was affected by session length. Groups initially assigned to light were designated LD while those initially assigned to the dark were designated DL. The numbers 35, 65, and 95 refer to the shuttlebox size assigned to a particular fish.

Results

Shuttlebox length

Initial conditions. Mean total responses over six sessions for each shuttlebox length under light and dark conditions are shown in Figure 3. Mean number of responses for each shuttlebox length during each session is shown in Figure 4. Although there appeared to be differences due to shuttlebox length, a repeated measures analysis of variance (Table 1) for initial illumination conditions revealed no significant differences due to shuttlebox length. As shown in Figure 3 overall total responding for the LD groups was highest under the light condition in the 65 cm shuttlebox (LD65). For the DL groups total respond-

Figure 3. Mean number of responses for each shuttlebox length under light and dark conditions.



MEAN RESPONSES
150
100
50
0
LIGHT
DARK
35
65
95
35
65
95
SHUTTLEBOX LENGTH (cm)

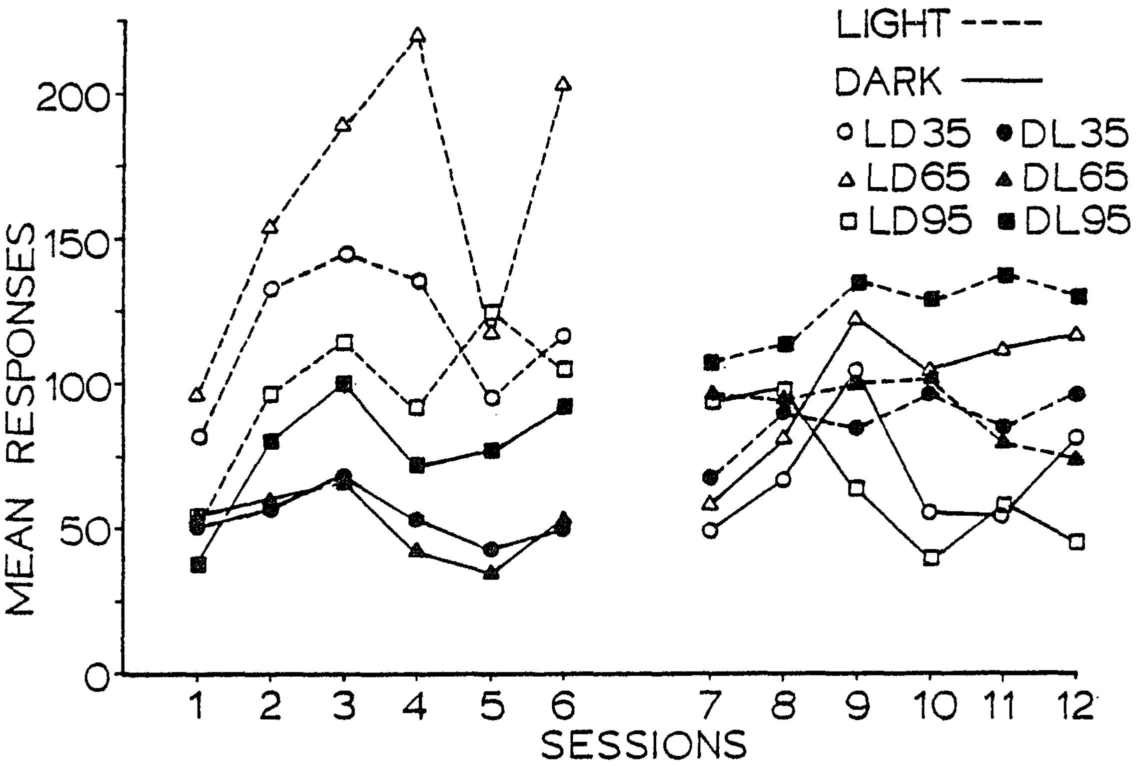
Table 1

Analysis of Variance for Mean Responses under Intial Illumination Conditions

Source	df	MS	F
Between subjects			
Light vs. dark (A)	1	232,591	7.83*
Size (B)	2	24,020	.40
A X B	2	73,192	1.23
Error	30	29,647	
Within subjects	5	12,220	5.75*
Sessions (C)	5	12,220	5.75*
A X C	5	3,776	1.77
B X C	10	2,686	1.26
A X B X C	10	2,320	1.09
Error	150	2,123	

$*p < .01$

Figure 4. Mean number of responses over sessions for each shuttlebox length under light and dark conditions.


LIGHT ----
DARK ——
○ LD35
● DL35
△ LD65
▲ DL65
□ LD95
■ DL95
MEAN RESPONSES
0
50
100
150
200
SESSIONS
1
2
3
4
5
6
7
8
9
10
11
12

ing in the dark condition was highest in the 95 cm shuttlebox. Figure 4 shows that these differences were not consistent for every session. Neither LD65 nor DL95 had the highest response frequencies during every session for their respective illumination conditions.

Reversed conditions. Figures 3 and 4 show total and daily means for all groups during the reversed illumination conditions. A repeated measures analysis of variance (Table 2) failed to reveal significant differences due to shuttlebox length during the reversal. Figure 3 shows that DL95 and LD65 again had the highest mean total response frequencies. For the DL groups these differences were larger under light conditions than under dark conditions. The differences were smaller in the LD groups after the reversal to the dark condition. As shown in Figure 4 the mean number of responses for DL95 was consistently higher than either of the other DL groups during the reversed condition. The LD65 group, however, did not have the highest mean during every session under the reversed, dark illuminated condition. Large individual variability, which will be discussed later, contributed to group variability in responding and may be responsible for the failure to find significance due to shuttlebox length.

Illumination Conditions

Initial conditions. Figure 5 shows the effect of illumination conditions on responding with shuttlebox

Figure 5. Mean number of responses over sessions under light and dark conditions with shuttlebox sizes combined.

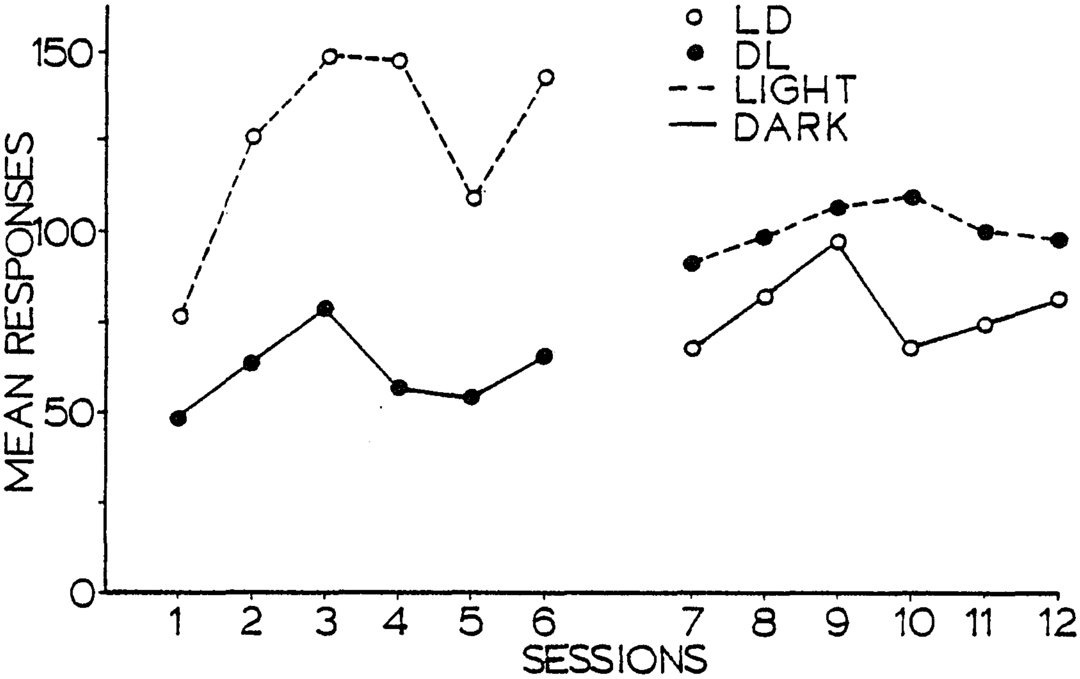

○ LD
● DL
-- LIGHT
— DARK
MEAN RESPONSES
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
SESSIONS

Table 2

Analysis of Variance for Mean Responses under Reversed Illunimation Conditions

Source	*df*	*MS*	*F*
Between subjects			
Light vs. dark (A)	1	26,666	1.11
Size (B)	2	7,438	.31
A X B	2	20,205	.84
Error	30	23,844	
Within subjects			
Sessions (C)	5	1,929	.90
A X C	5	982	.46
B X C	10	1,334	.62
A X B X C	10	3,287	1.54
Error	150	2,136	

sizes combined. Both LD and DL groups responded more frequently in the light. The mean number of daily responses during the first six sessions for the LD group in the light was 126.8 and for the DL groups in dark was 61.6. The repeated measures measures analysis of variance shown in Table 1 indicated a significant effect due to illumination conditions over the first six days. Although mean responses are higher during each of the first six sessions for the groups shown in Figure 5 this is not true for individual shuttlebox lengths as shown in Figure 4. During the first session one LD group had a slightly lower mean frequency than one DL group. However, beginning with the second session individual LD groups as well as the combined group had higher mean frequencies than the DL groups.

Reversed conditions. During the reversal, illumination conditions were found to have a significant effect (Table 2). A comparison of response frequencies from Session 6 before the reversal and Session 1 after the reversal, as shown in Figure 4, illustrates the effect of reversing light conditions. The LD groups decreased from 143.5 responses during the last light session to 68.1 during the first dark session. The DL groups increased from 66.6 responses during the last dark session to 91.3 during the first light session. Figure 3 shows that similar changes occurred in all shuttlebox lengths. After the initial reversal session the combined DL groups continued to respond more frequently than the combined LD groups although the differences were not as great as during the first six sessions. The lessened effect of illumination after the reversal is shown in Figure 3. During each session one or more of the LD groups responded more frequently than one of the DL groups.

Pseudo-learning effect

Initial conditions. Both Steiner's (1971) data and the data from the present experiment showed increases in responsing over initial sessions in the absence of reinforcement (Figure 6). Only data from the 35 cm shuttleboxes were included in this figure since this size is closest to the 30.5 cm length used by Steiner. When the data are compared in terms of sessions, the LD35 rate of responding increased more rapidly than Steiner's. During the fourth session the rate of increase was highest for Steiner's combined control group. Response rates decreased during the fourth session for both groups from the present experiment. Changes in responding over sessions were smallest in the DL groups.

Differences in the shape and asymtotic rate of responding between Steiner's data and this experiment might be due to differences in session length. Sessions in this experiment were 50 min which was twice the length of Steiner's. Figure 7 shows that rates during the first 25 and second

Figure 6. Mean response rate from Steiner's (1971) combined (0,0) groups and for initial light (LD35) and initial dark (DL35) conditions in the 35 cm shuttlebox.

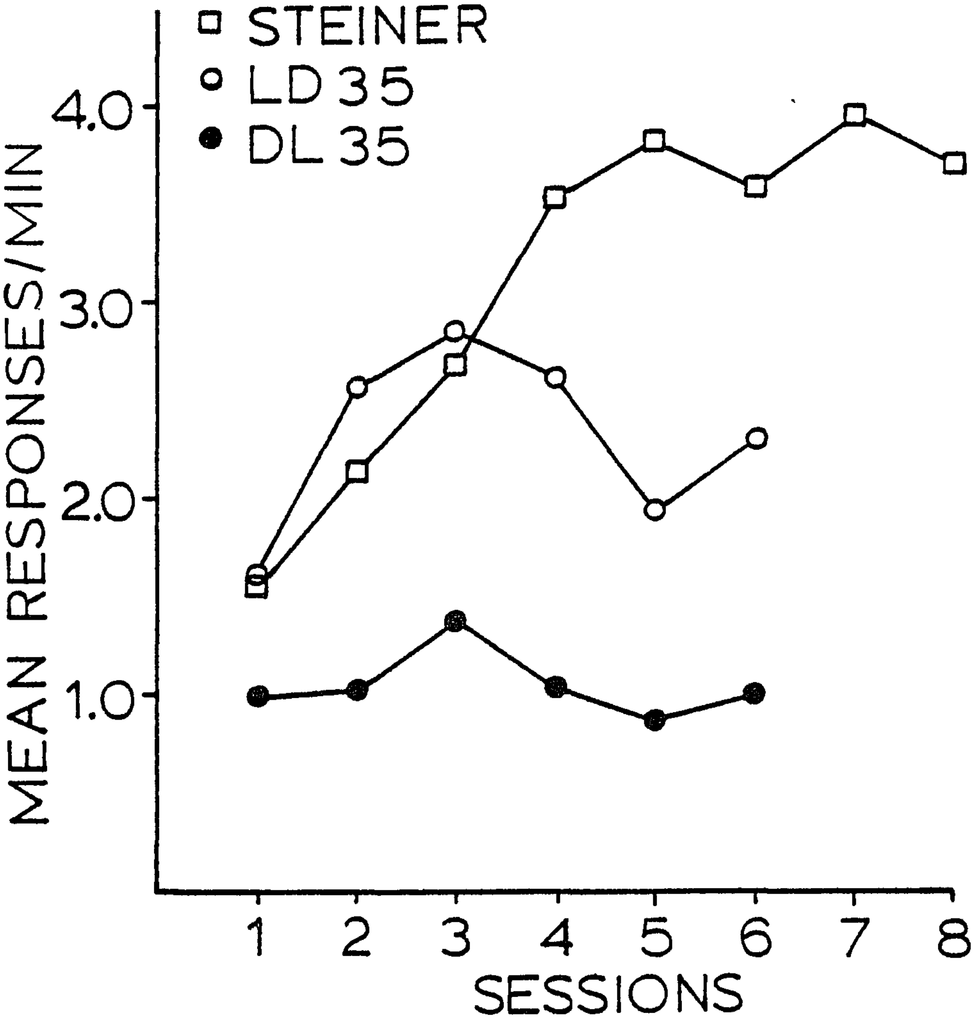
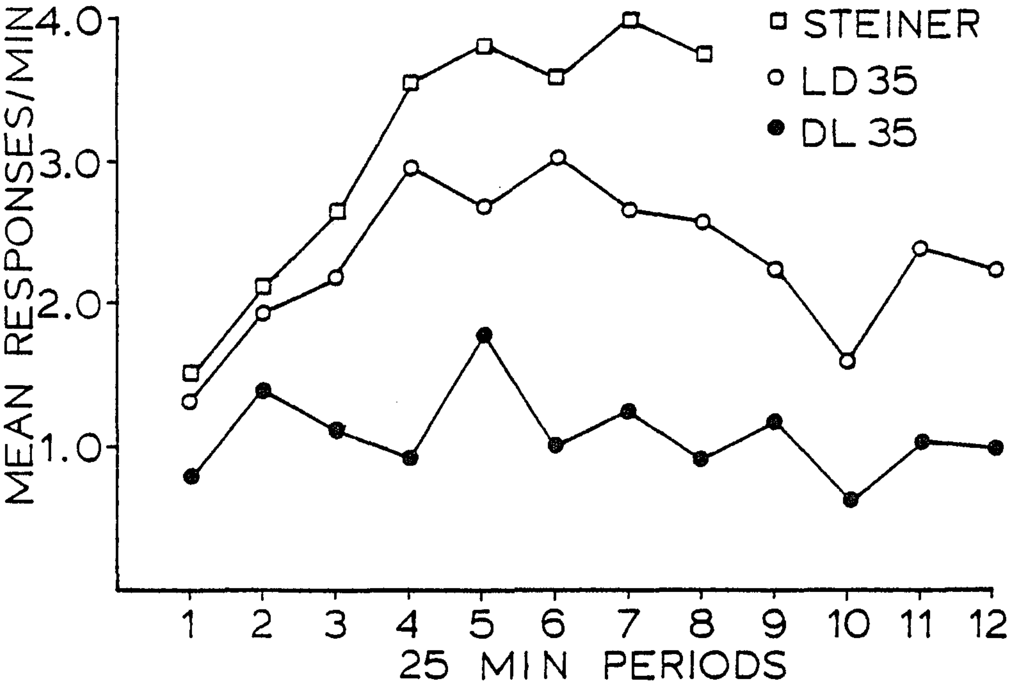

□ STEINER
○ LD 35
● DL 35
MEAN RESPONSES/MIN
4.0
3.0
2.0
1.0
1
2
3
4
5
6
7
8
SESSIONS

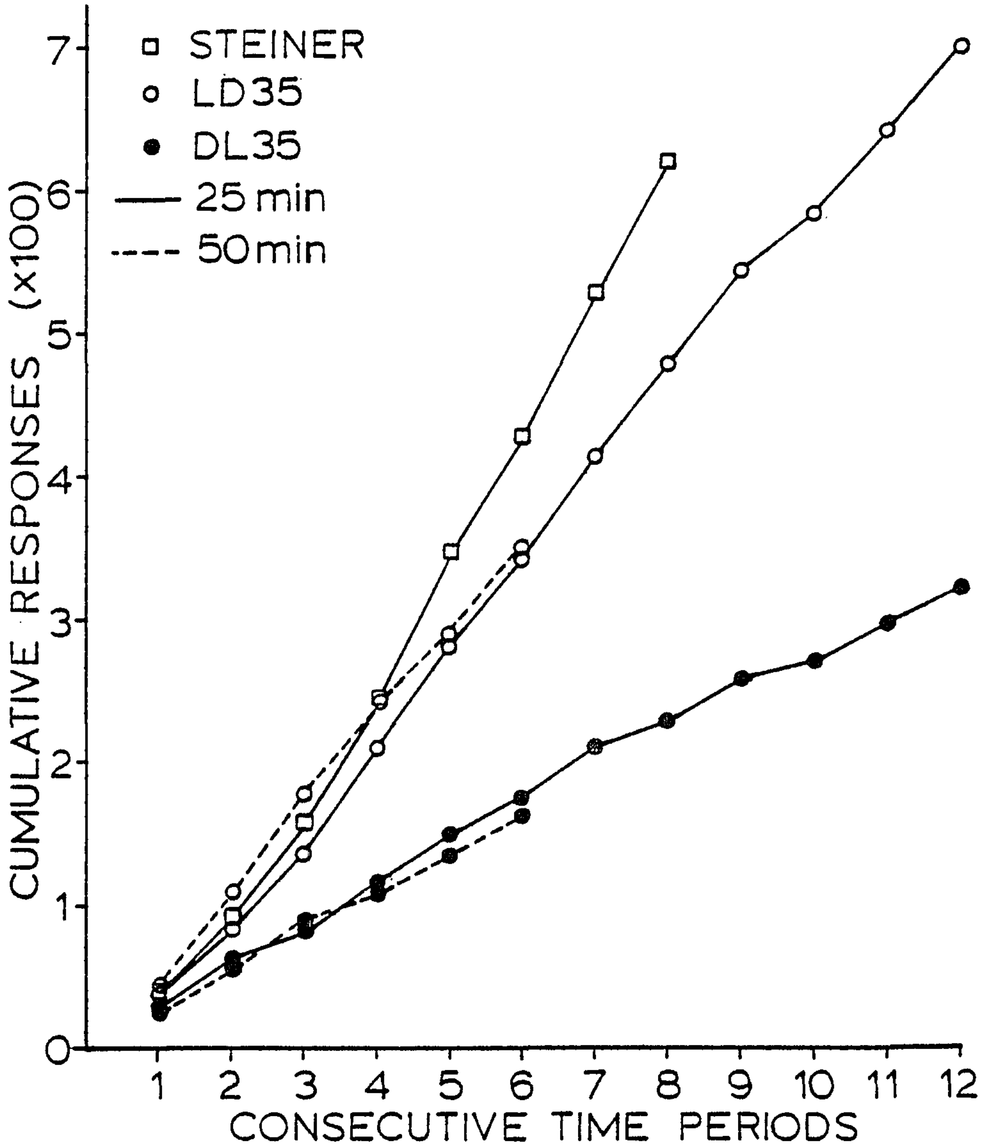
Figure 7. Mean response rate from Steiner's (1971) combined (0,0) groups and for initial light (LD35) and initial dark (DL35) conditions in the 35 cm shuttlebox. The 50-min sessions of the present experiment were divided into consecutive 25-min periods to match Steiner's session length.


MEAN RESPONSES/MIN
4.0
3.0
2.0
1.0
□ STEINER
○ LD 35
● DL 35
1
2
3
4
5
6
7
8
9
10
11
12
25 MIN PERIODS

25 minutes each session. An analysis of variance indicated no significant differences in responding between the first 25 minutes and the entire session, F (1,44) = 2.52, $p < .01$. Although no significant differences within sessions were found there could have been gradual changes over cumulated time in the experiment which affected responding level. Also in Figure 7 sessions from this experiment are divided into successive 25-min periods and compared to Steiner's 25-min sessions. This comparison based on equivalent time shows that Steiner's subjects responded at consistently higher rates. Cumulative responses for both sessions and time are presented in Figure 8. When sessions data from both experiments are compared, during the first session the highest frequencies occur in the LD35 group. However, when actual time in the experiment is compared Steiner's frequencies are higher. (Frequencies for 50-min sessions shown in Figure 7 were divided by two so that data from both session lengths had a common base of 25-min.)

Reversed conditions. As shown in Figure 5, after the reversal the LD group increased responding over the first three sessions and the DL group increased over the first four sessions. For both groups the increases are not as great as during the illumination conditions. No significant effect due to sessions was found (Table 2) under the reversed conditions. Individual curves for all subjects, presented in Appendix B, indicated that increased responding over

Figure 8. Cumulative responses from Steiner's (1971) combined (0,0) groups and for initial light (LD35) and initial dark (DL35) conditions in the 35 cm shuttlebox. Data from LD35 and DL35 are presented both in terms of 25-min consecutive periods and in consecutive sessions. Steiner used a 25-min session length.


□ STEINER
○ LD35
● DL35
—— 25 min
---- 50 min
CUMULATIVE RESPONSES (x100)
0
1
2
3
4
5
6
7
CONSECUTIVE TIME PERIODS
1
2
3
4
5
6
7
8
9
10
11
12

days occurs in many individuals as well as in the group data.

Individual variability

While only one fish responded more frequently in the dark than in the light there were large individual differences in responding between fish. Extreme rates of responding were produced by one fish L6E10 initially assigned to light and a 65 cm shuttlebox, and by fish L3E9 initially assigned to light and a 35 cm shuttlebox. Fish L6E10 made an average of 338.3 responses in light and 283.0 responses in dark. L3E9 made an average of 2.2 responses in light and no responses in the dark.

Even with this large variability among fish a pattern was evident. Generally fish tended to be high responders under both conditions or low responders under both conditions. A significant Spearman rank order correlation ($\underline{r}_s = .67$, $\underline{df} = 34$, $\underline{p} < .01$) confirmed that there was a positive correlation between ranks based on response frequency under both illumination conditions. In Appendix B graphs of individual fish show the tendency toward smaller variability within fish and greater variability between fish. Observations made during experimental sessions indicated that high responders tended to respond frequently under both conditions. They almost continuously crossed and recrossed the hurdle without utilizing the full length of the shuttlebox. Low responders often remained motionless near the hurdle or in a corner. The relationship between responding and time of year is presented in Figure 9. Each point represents the mean number of responses for an individual fish. The date of the first day of six sessions under a given light condition is indicated on the abscissa. There appears to be no relationship between when a fish was in the experiment and frequency of responding.

Latency

Initial conditions. Median log latencies for the LD and DL groups are shown in Figure 10. An analysis of variance (Table 3) indicated that only the sessions variable had a significant effect on latencies. Although latencies tended to be shorter in the light, no significant effect due to illumination conditions was found. The largest difference between the dark and light conditions occurred during the first session when the median latency for all groups in the light was 215 sec and for all groups in the dark was 316.5. There was no orderly relationship between shuttlebox length and median latency during the first three sessions. During the last three sessions the shorter median latencies occurred in the 35 cm length and the longest latencies occurred in the 95 cm length. These differences, however, were not significant. Group median latencies are presented in Table C . of Appendix C.

Reversed conditions. During the last six sessions both illumination conditions and sessions were found to be

Figure 9. Relationship between mean responding and date of initial and reversed conditions as represented by the first day of each condition showing no seasonal effects on responding.

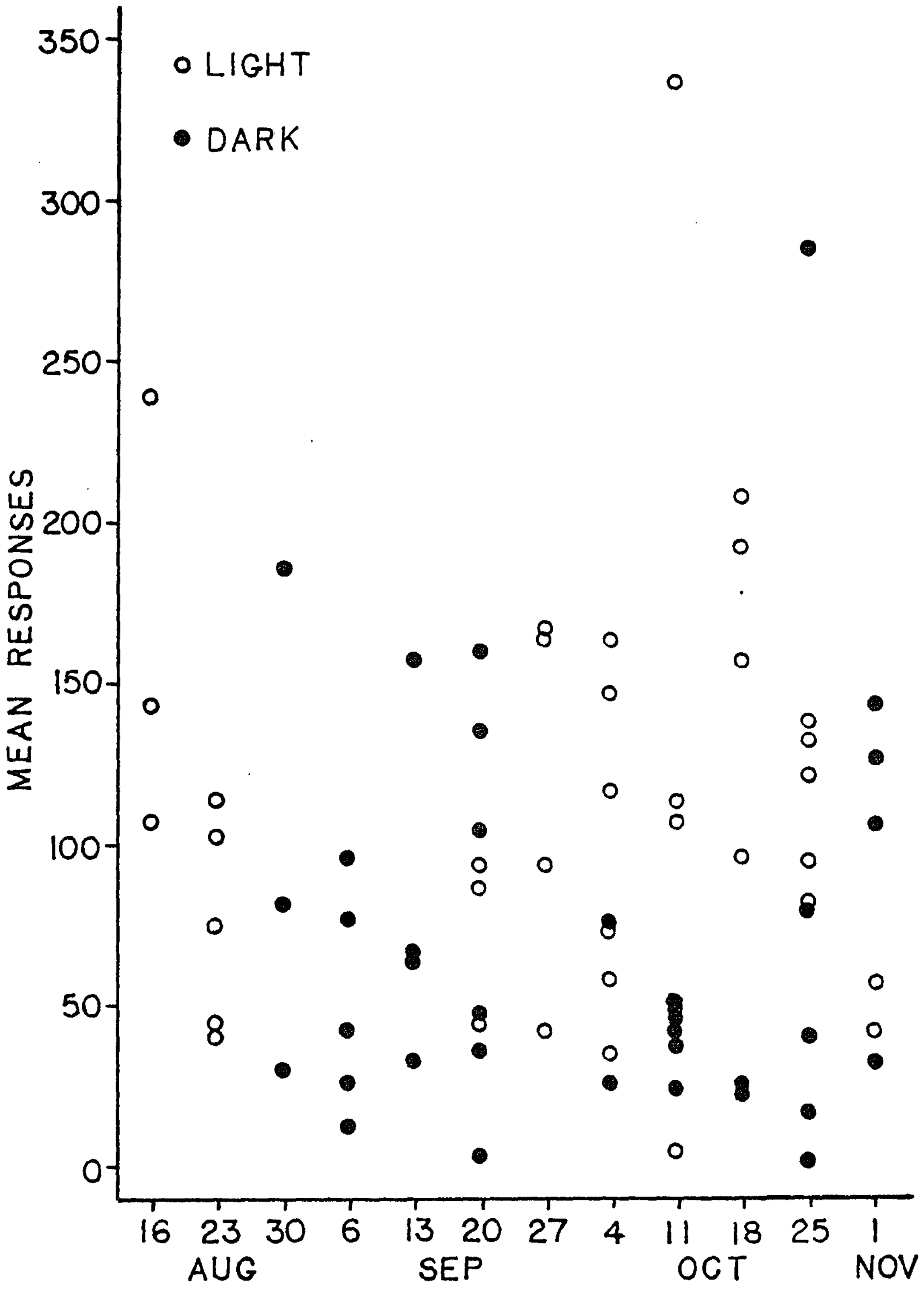

○ LIGHT
● DARK
MEAN RESPONSES
350
300
250
200
150
100
50
0
16
23
30
6
13
20
27
4
11
18
25
1
AUG
SEP
OCT
NOV

Figure 10. Log median latency to the first response in a session under light and dark conditions with shuttlebox lengths combined.

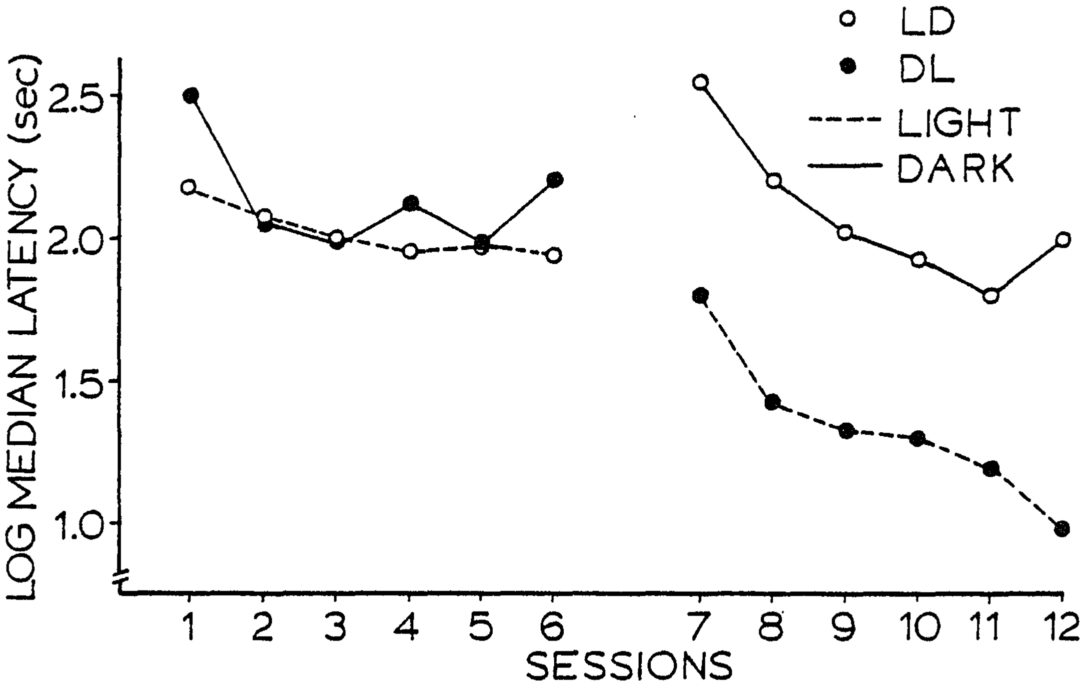

○ LD
● DL
LIGHT
DARK
LOG MEDIAN LATENCY (sec)
2.5
2.0
1.5
1.0
1
2
3
4
5
6
7
8
9
10
11
12
SESSIONS

Table 3

Analysis of Variance for Log Median Latencies under Intial Illumination Conditions

Source	_df_	_MS_	_F_
Between subjects			
Light vs. dark (A)	1	2.52	1.35
Size (B)	2	2.36	1.27
A X B	2	4.73	2.54
Error	30	1.86	
Within subjects			
Sessions (C)	5	1.34	5.15*
A X C	5	.15	.59
B X C	10	.23	.88
A X B X C	10	.17	.65
Error	150	.26	.65

*$p < .01$

significant as shown in Table 4. After the reversal, latencies decreased for fish changed from dark to light and increased for fish changed from light to dark. The differencies between latencies under the two illumination conditions are shown in Figure 6. Median latencies for the DL groups monotonically decreased from 63.0 sec on day 1 to 9.5 sec on day 6. Median latencies for the LD groups decreased from 404.5 on day 1 to 64.5 on day 5 and increased to 100.0 on the last day. During the reversal no significant relationship between median latencies and shuttlebox length was found.

There appeared to be no apparent pattern of latency scores within and between fish as there had been for response frequencies. Within subjects variability was large and individuals did not tend to have either short or long latencies. The only patterns revealed by the analysis of variance, were shorter latencies in light after the reversal and decreasing latencies over sessions.

Discussion

The major findings of this experiment were that goldfish in shuttleboxes: 1) increased responding over days when no contingency was present, 2) responded more frequently in the light phase than the dark, 3) did not respond differentially as a function of shuttlebox length. It was also found that latency to the first response of the session was more sensitive to illumination level than it

Table 4

Analysis of Variance for Log Median Latencies under Reversed Illumination Conditions

Source	df	MS	F
Between subjects			
Light vs. dark (A)	1	38.00	23.03*
Size (B)	2	.75	.45
A X B	2	.99	.60
Error	30	1.65	
Within subjects			
Sessions (C)	5	1.78	6.85*
8 A X C	5	.17	.65
B X C	10	.32	1.23
A X B X C	10	.31	1.19
Error	150	.26	

*$p < .01$

was to shuttlebox length and individual differences were large for both response and latency measures.

Pseudo-learning effect. Although this study replicated the pseudo-learning effect response rates were not as high as Steiner's. Steiner's fish reached levels of almost 4 resp/min during the seventh session. Fish in this study reached a level of slightly less than 3 resp/min during the sixth session under the light condition. Goldfish can respond at even higher rates as shown by Behrend and Bitterman (1963). Using a Sidman procedure rates of 6 resp/min were obtained. The differences in overall responding might be due to a number of variables which were similar but not identical in the two studies. Illumination level, which will be discussed later, may have contributed to the differences.

The difference in session length between the two studies is also a possible factor in the response level difference. The 35 cm shuttlebox, which most closely approximated Steiner's length of 30.5 cm had response rates approximately like Steiner's for the first two sessions. Steiner's sessions were 25 min and those of Experiment 1 were 50 min. It might be argued that total time rather than number of sessions is a critical variable in producing the pseudo-learning curve. This probably is not the case since asymtotic rates of responding for all light groups combined did not reach the level of Steiner's.

Data analysis of the first 25 vs. the second 25 minutes indicated that rates were constant during the entire session as shown in Figure 7. A direct comparison of responding as a function of time and number of sessions is shown in Figure 8. Over the first few days, responding as a function of the number of sessions rather than time more closely approached Steiner's data. There might however be an interaction effect between number of sessions and time. Perhaps the pseudo-learning curve effect can be maximized with a number of short sessions as opposed to fewer longer sessions.

Other experiments which measured goldfish operant levels used trial procedures which may or may not alter the effects of session length. Woodard and Bitterman (1971, 1973) used a variety of procedures when measuring operant level. In each of four experiments, they recorded shuttling during 10 blank trials of 10 sec each. In some experiments there were 10 additional blank trials during which shuttling was not measured. Session length, depending on the number of trials and mean ITI varied from approximately 33 min in some studies to 69 min in another. Despite the variation in procedure, activity levels ranged from 2 to 4 responses out of a possible maximum of 10 over the first three sessions. This suggests that at least for the first few sessions, length of session may be less influential than number of sessions.

Other differences may have contributed to the higher rate in Steiner's study. Although subjects in both studies had the same body length they may have been different ages. Age and sex cannot be readily determined in juvenile goldfish. Since these goldfish were obtained from a different supplier they may have been very different genetically. Data from other species has demonstrated that strain differences can have a large effect on activity level. This was demonstrated by Kish and Antonites (1956) using two strains of mice.

Steiner's housed four fish in each home tank during the experiment while fish in this study were housed as Woodard and Bitterman's (1971, 1973) in individual tanks.

Illumination. Illumination conditions were found to have a significant effect on responding. All but one fish responded more frequently in the light than in the dark. This effect was similar to that found by Kapoor (1971) in which activity of pumpkinseed fish was directly proportional to illumination level. Using goldfish, Zerbolio and Wickstra (1976a, 1976b) found that response rates during ITI's were higher when the ITI was illuminated. The increased responding in light may be related to the importance of visual stimuli for goldfish. This can be observed in feeding and reproductive behavior. Breder and Rosen (1966) note that goldfish restrict breeding to daylight hours in the natural habitat. Trevarthen (1968), in a comparative study of voluntary eye movements in fish, found that goldfish had a simple oculomotor scanning system. Since the system is not well developed it requires almost continuous locomotion for effective scanning. This suggests that there is a natural tendency for goldfish to be active in an illuminated environment.

Shuttlebox length. The failure to find differences due to shuttlebox length was not anticipated. Both Steiner (1971) and Greenway and Bitterman (1973) hypothesized that size might affect responding. Although there is data that acquisition rates may be affected by different types of apparatus (Bolles, 1970; Bolles, Stokes & Younger, 1966) there is less information on the effects of varying dimensions. These studies found that if the response required by the apparatus is compatible with a species specific defense reaction (SSDR) then acquisition is faster. One possible explanation for the failure to find a length effect may relate to the SSDR of the goldfish. The goldfish were observed to have a two-component SSDR in which freezing was followed by darting. Very low responders tended to remain inactive in corners of the tank. High responders tended to cross the hurdle repeatedly without using the full extent of the end compartments. Neither of these response topographies would be substantially affected by shuttlebox length. It should be noted that although no experimental stimulus, such as light or shock, was presented being transported in the net may have been a sufficient antecedent condition for a SSDR or similar response. The question still remains as to what mechanism would maintain the initial SSDR.

Individual Differences. The range of individual variation in responding was large. This may have been due in part to the free operant nature of the design where high frequencies of responding can occur without the time limitations of trials. Most studies including Steiner's (1971) do not include individual data. Kleerekoper, et al. (1974) in a study of goldfish exploratory behavior found large individual differences. Kleerekoper et al. stated that this variability might be due to differences in individual histories. As in this experiment fish were purchased from a supplier without information as to sex, age, or rearing conditions. Because individual differences can be large, researchers using goldfish should consider implications for experimental design.

Studies by Weiss, Krieckhaus and Conte (1968) and Harrison and Shaeffer (1975) found a relationship between operant level and later contingent responding in rats. Weiss et al. found that there was a correlation of .71 between spontaneous crossing and later avoidance. Harrison et al. found a positive relationship between operant level and a contingent running response. These data indicate that an operant level phase should precede contingent training when using various species including goldfish.

This is especially true with goldfish because of the pseudolearning curve effect. Additionally, responding should be measured in terms of changes from baseline rather than the usual assumption of an operant level of zero. A within-subjects statistical design would be appropriate. The usefullness of this type of design has recently been reaffirmed by Greenwald (1976).

EXPERIMENT 2

Repeated Acquisition and Extinction of Avoidance Behavior in Goldfish

As shown by the data from Experiment 1 an acquisition-like shuttling function can occur in the absence of a reinforcer or, at least, of an explicitly programmed contingency. This questions the role of reinforcement in shuttlebox studies using goldfish. Both Woodard and Bitterman (1971, 1973) and Scobie and Fallon (1974) have studied shuttling and aspects of the response-reinforcer and stimulus-reinforcer contingencies with goldfish. However, none of these gave adequate attention to the pseudo-learning effect, or the use of noncontingent shock as an extinction procedure.

Avoidance acquisition

Woodard and Bitterman (1971) investigated the role of the response-reinforcer relationship using a yoked control design. One group received an avoidance procedure with a CS-US interval of 10 sec and a .65 V/cm, .4 sec AC shock. If no response was made the single shock terminated simultaneously with the CS (a red or green light). If a response was made during the trial, the light was terminated and shock avoided. A second group was yoked to the avoidance group. A third control group was given blank trials. Following this all groups received an avoidance extinction procedure of shock on every trial (1,1) first and then received traditional extinction (0,0) with no US and a CS which was not response-contingent. The avoidance group responded most, the same as in Woodard and Bitterman (1971). In both experiments the acquisition phases were followed by seven extinction sessions in which subjects were unyoked. The authors do not specify whether a (0,0) or (1,1) extinction procedure was used: regardless of whether responding affected CS termination, activity was significantly higher in the avoidance groups than in the yoked groups. The 2-unit groups responded most frequently while the 18-unit groups responded least frequently. The 2-and 6-unit activity groups of the CS-termination experiment performed at a slightly lower level than those in the non-termination experiment. However, when the requirement was 18-units, the CS-termination group responded more frequently. During extinction all groups showed a significant decline.

The authors concluded that goldfish activity can be conditioned by avoidance as well as by classical procedures. They felt that even though the procedure was instrumental the process was one of discriminated classical conditioning: shock functioned as a US, the "CS-" was the CS with response feedback (FS) from activity and the "CS+" was the CS without feedback. In Greenway and Bitterman's view this interpretation was further supported by the better performance of the CS termination groups since termination increased the salience of feedback stimuli. It should be noted however that the two non-termination avoidance groups with the lowest activity requirements reached levels higher than those with CS termination.

In 1973 Woodard and Bitterman felt even more strongly that they could account for conditioning in shuttleboxes entirely in classical terms. In the first experiment in this series fish were assigned to one of six groups during conditioning: avoidance, with or without CS termination; classical, with or without CS termination, and a yoked group for each avoidance group. Three operant level sessions were followed with 14 conditioning sessions and 10 (0,0) extinction sessions. As in the previous studies the avoidance group with CS termination responded most frequently followed by the nontermination avoidance group. Both classical groups responded at a level below the avoidance groups. The yoked groups were significantly lower than all other groups. During (0,0) extinction all groups decreased responding with the yoked groups significantly lower than all other groups.

Woodard and Bitterman examined the role of a punishment contingency in a second experiment. Fish were assigned to either an instrumental (1,0) or classical procedure (1,1) neither of which included CS termination. After six conditioning sessions some of the avoidance fish were changed to a punishment (0,1) contingency. A comparison of the classical and avoidance groups revealed no significant differences when the number of trials on which one or more response occurred was the dependent variable. However an analysis of total responses indicated that classical subjects made significantly more multiple responses once an initial response was made. When the avoidance contingency was in effect extra responses were infrequent. Introducing the punishment contingency decreased initial responses immediately but did not reduce total responses until subsequent sessions. Once a punished fish made an initial response it was more likely than an avoidance fish to make multiple responses.

Woodward and Bitterman used discriminated classical conditioning to explain these results. Avoidance was effective because the CS alone was equivalent to a CS+ while the CS with response feedback was equivalent to a CS-. During punishment this was reversed. The CS alone was now a CS- and the CS with feedback was a CS+. This however did not explain why a CS+ in avoidance was not followed by a response while a CS+ in punishment was followed by a response. They postulated that increases in the avoidance group occurred because the CS alone was a CS+ which elicited activity. However, once the initial response was made the CS with feedback became a CS- and inhibited further responses. Conversely, during punishment each trial began with a CS- and once a response was made the stimulus complex changed to CS+ eliciting more responses. The yoked groups did not respond consistently because neither CS alone nor CS with feedback was reliably paired or not paired with shock.

The data from all of these experiments are consistent. Avoidance contingencies resulted in higher response frequencies than classical conditioning and both were significantly higher than the yoked groups. The punishment groups response frequencies were as low or lower than those of the yoked groups.

Scobie and his collegues have also compared the effects of classical and operant contingencies using goldfish in shuttleboxes (Pavlis, Scobie & Fallon, 1972; Scobie & Fallon, 1974). Fish were randomly assigned to either an avoidance or classical conditioning paradigm. Half the fish in each group terminated the CS when a response was made while the other half did not. Fish received fifty conditioning trials per day for 10 days in an 18 cm long shuttlebox. CS duration was 10 sec and was either an intensity change in overhead illumination or a hue change. As in Bitterman's studies the proportion of responding was highest in the avoidance group with a contingent US and a terminating CS. Responding was lowest in the classical group where neither CS nor US were response-contingent. Intermediate shuttling levels were found in the groups in which only the US or CS were response contingent. The authors felt that the shuttling avoidance response was primarily controlled by operant contingencies although there might be a classical component.

In a second experiment Scobie and Fallon further investigated the relationship between the CS and US. Four fish each were assigned to either: CS-only, US-only, CS/US unpaired or no CS/no US. There were five sessions of 50 trials each under these pretreatment control conditions. During a test session on the sixth day all fish received 25 CS-only trials followed by 25 avoidance trials. This was followed by four days of avoidance with 50 trials on each day. The CS was a 10 sec change from green to red (or red to green) in overhead illumination. The CS could only be response-terminated during avoidance sessions. At the end of five pretreatment sessions, responding was highest, approximately 35% of all trials, in the no CS/no US group. Responding was lowest in the CS/US unpaired group with intermediate levels in the US-only and CS-only groups. On the test day all groups responded less during the 25 CS-only trials. When the avoidance contingency was initially introduced the no CS/no US group and the CS-only group decreased responding while the unpaired group increased. By the end of four complete avoidance sessions all but the previous US-only group were responding at probabilities greater than .8. The previous US-only group had response probability of .7. The authors concluded that there was not a strong tendency for sensitization due to the CS, US or an unpaired CS/US and the CS-US contiguity was necessary for learning.

In an attempt to clarify the possible classical component Scobie and Fallon sought to identify a movement UR following US presentation. Fish were randomly assigned to either an avoidance or classical procedure and responses made during the 10 sec following US delivery were recorded during six sessions of 100 trials. In a subsequent experiment a comparision of post-US responses in a classical and a US-alone group was made during eight sessions of 50 trials. In the first experiment both the classical and avoidance groups had response probabilities of approximately .3 following US delivery on the first day. Thereafter, post-US responses decreased to .1 on the second and succeeding days. If shock elicited a shuttling UR, more post-US responses should have occurred in the classical group which received a US on every trial. In the second experiment the post-US response probability was .6 on the first day for both the US-alone and classical groups and decreased to .2 on succeeding days. The failure to find differences between these groups indicated that the CS does not modify a shuttling UR or cause the UR to move forward in time. Scobie and Fallon concluded that shuttling cannot be treated as a UR and that the relationship of the CS to a UR is difficult to define.

Steiner (1971) presented data relevant to the relationship between classical and instrumental condition-a response anywhere in the interval was effective. The LCA unsignalled group showed a more gradual gradient. The distribution for the FCA unsignalled group was flat. The highest percentage of effective responses was in the signalled FCA group and the lowest was in the unsignalled LCA group. Responses in the first interval following shock were low suggesting that unconditioned responding in response to shock did not occur. This agreed with the findings of Scobie and Fallon (1974). Steiner noted that Turner and Solomon (1962) found highly reflexive responses are difficult to condition with avoidance procedures. Although Steiner's results were not definitive they lent supporting evidence to her belief that shuttling is an operant. This supporting evidence was: 1) higher response rates occur with an avoidance paradigm than with noncontingent shock, 2) individual and group patterns of stimulus control developed with the LCA procedure, 3) highly reflexive responses rates during the interval following US delivery did not occur.

CS effects. Because of the complexity of the shuttling response of goldfish it is important to know the effect that light as a CS and shock as a US have on acquisition of a shuttling response. The importance of CS location in response-contingent shuttlebox studies has been investigated by Gallon (1974) and Zerbolio and Wickstra (1976a, 1976b). In Gallon's study the CS was presented in one of three locations relative to the fish: same side, opposite side, or both sides. Goldfish were trained using an avoidance-escape paradigm in a shuttlebox for 100 trials in a single session. The CS was a diffuse white light which lit the end panels of each compartment. The respective percentages of avoidance responses for CS onset conditions were: 63% for same side, 40% for both sides, 18% for opposite side. When CS offset was used responding was lower with smaller differences between groups: 28% for same side, 1% for both sides, 32% for opposite side. Gallon postulated that CS stimulus change activated the fish to cross the hurdle. When a CS-US pairing was introduced the CS would acquire aversive characteristics which would direct the fish away from the CS. The aversiveness of CS onset would then facilitate responding for the same group and retard responding for the opposite group. There would be intermediate, nondirectional activation in the both sides group.

Like Gallon, Zerbolio and Wickstra (1978a) found the predicted performance differences between groups with CS onset. However, there was no differences between groups with CS offset. Response levels for the offset groups were the same as for the both-CS onset group. In a systematic replication in which trials were distributed over four days the order of responding for CS location was both, same and opposite for the onset and the offset groups. The activation hypothesis would have predicted light onset. Overall responding was slightly less than in their first experiment. The largest decrease was in the traditional classical group. A comparison of fish receiving unavoidable and avoidable shock with and without CS termination showed more responding in the response termination group. Shuttling was higher in the CS-only and US-only groups than in the classical group. Zerbolio and Wickstra felt the abrupt CS in their earlier experiment produced a negative phototaxic effect which increased shuttling. When the CS was not abrupt instrumental avoidance performance was superior to classical performance. These studies suggest that a negative photoaxis may enhance or interfere with performance, especially when trials are massed and CS onset is abrupt.

Shock effects. Blintz (1971), Gallon (1972b) and Scobie and Herman (1972) found that probability of shuttling by goldfish is related to shock level. Blintz and Gallon both found an inverted U-shaped relationship between responding and shock level. These studies used 60 HZ AC. Blintz found that responding was generally highest under 9, 12 and 15 VAC. Comparable values in terms of V/cm were .59, .79 and .98. Gallon found responding was highest with 7 VAC and lower with 9, 5, 3 VAC (rms). Gallon's intensities converted to V/cm were respectively .56, .40, .72 and .24. Blintz did not identify whether shock was measured peak-to-peak, or rms. Scobie and Herman (1972) published a series of experiments determining thresholds for electric shock using goldfish. The first experiment was designed to determine whether voltage or current was appropriate for stimulus specification. Current density was varied independently of voltage by manipulating the salinity (and hence, conductivity) of the water. Reaction thresholds varied as a function of voltage change, not current change. Reaction thresholds for fish loosely restrained in a plastic perforated chamber were determined using a body twitch as the indicator response. Scobie and Herman found that 1) thresholds are higher when fish are perpendicular to the electrodes, 2) there was little difference due to duration over a range of 6 to 100 msec, 3) thresholds generally ranged from slightly less than .1 to .3 V/cm rms. Detection thresholds were obtained in free swimming goldfish in shuttleboxes. A strong 1.1V/cm rms shock was used as a US and weak shocks were used as CS. The indicator response was shuttling over the hurdle following CS onset. Scobie and Herman found very high rates both during CS presentation and during ITI's. Tavolga (1971) also found high ITI responding and adjusted water level over the hurdle to reduce false alarms. Scobie and Herman instituted a punishment contingency for responses made during the ITI. Thresholds were slightly higher than those obtained with restrained subjects. They also determined the shock threshold for escape behavior using a shuttlebox. These thresholds were more variable and higher than detection thresholds. Although .44 V/cm would initiate escape behavior it was not high enough to maintain shuttling over tirals. Escape behavior could be maintained at .65 V/cm. Repeated shock at .44 or .88 V/cm did not elevate reaction thresholds but suprathreshold shocks of 1.78 or 3.56 did.

Zerbolio and Wickstra (1975) compared a variety of shock durations and intensity combinations using an avoidance response by goldfish in shuttleboxes. The highest proportion of avoidances occurred with either 1.35 V/cm for 200 msec or .68 V/cm for 400 msec. Inverted U-shaped functions were again found for shock intensity.

Extinction Procedures

The role of the response-reinforcer contingencies can be evaluated not only by acquisition data but also by extinction data. The selection of the extinction process should be given careful consideration.

Maximal shock (1,1) extinction. The traditional extinction procedure following avoidance is removal of shock (0,0). However, extinction results can then be attributed to either the removal of shock or the disruption of the response-reinforcer or stimulus-reinforcer contingency. This procedure has been criticized because it is not analogous to the extinction procedure for reward conditioning (Davenport, Olson, & Olson, 1971). Both reward and avoidance training lead to an increase in responding over operant level. In reward conditioning, this is done by presenting a positive reinforcer. In avoidance this is done by preventing the delivery of an aversive stimulus. The usual extinction procedure following reward training is the removal of the rewarding stimulus making the response ineffecitve. The analogous extinction procedure, rendering the avoidance response ineffective, is presentation of shock. Coulson, Coulson, & Gardner (1970) used such an extinction procedure which presented unavoidable shock following Sidman avoidance. This extinction effectively reduced lever pressing by rats. Davenport et al. (1971) also found that rats decreased lever pressing when shock was delivered at end of every trial following conditioning with an avoidance/escape paradigm. Neffinger and Gibbon (1975) reported that (1,1) extinction reduced responding. Rats were avoidance-trained to lever press using discrete trials and no ITI. Trials were composed of a 19.5 sec response period followed by a .5 sec consequence period. The CS, a tone, was terminated either by a response or by the end of the response period. A .5-sec shock was presented during the consequence period. After extensive avoidance training three rats were changed to a (1,1) contingency for 15 session. Responding decreased to zero and remained at that level for two rats. One rat responded on almost every trial during the (1,1) phase. This rat and rats from other experiments that maintained responding during noncontingent extinction procedures were labeled Class II subjects. When these rats were further tested with a (1,1) procedure, response probability was close to 1.0. Thus a (1,1) procedure resulted in extinction with contingency-sensitive rats but led to high response probabilities with rats sensitive to shock-density.

Smith (1974) found that extinction using unavoidable shock tended to result in increased responding. He compared extinction procedures in a series of four experiments using Long-Evans hooded rats. Avoidance training consisted of an initial six-hour session followed by at least 10 sessions of 100 min each. Extinction did not begin until a criterion of 75 percent avoidance with less than 10 per cent variability was met. In three experiments rats were trained in a standard operant chamber with 1.5 mA, 400 msec shock. A Sidman schedule with a response-shock (R-S) interval of 20 sec and a shock-shock (S-S) interval of 5 sec was used. At least ten reconditioning sessions were interspersed between extinction phases.

Extinction procedures generally were in effect for 5 sessions except in Smith's second experiment where extinction was lengthened to 20 sessions. Smith found that in 9 of the 13 maximum shock phases responding increased rather than decreased. There were no systemic differences due to number of extinction session. During this procedure shocks were given irrespective of responding, with a rate of 12/min. Three rats received two unavoidable-shock extinction phases. A comparision between responding during the first extinction and second extinctions revealed no orderly relationship. Powell and Peck (1968) reported that rats previously trained on avoidance maintained high rates of responding when response independent shocks were presented. Pear, Moody, and Persinger (1972) found that lever pressing increased in two of three rats during unavoidable-shock extinction following eighteen sessions of Sidman avoidance. During extinction shocks were delivered every 20 sec. Two subjects responded at levels above final avoidance while one subject decreased from approximatley 600 responses per hour to less than 100 per hour. Two of the subjects showed gradual decreases during extinction while one showed an irregular pattern.

On aspect of the study by Pear et al. led Smith to include a replication with a shuttlebox. By using a lever made of two parallel bars Pear et al. were able to measure bite contacts as well as lever presses. They found that during extinction when unavoidable shocks were presented the number of bites exceeded the number of presses for the two rats with the high response levels. These rats had bitten infrequently during avoidance. This data indicated that responding during extinction with shock might be elevated in part because of the choice of apparatus Other research in which response-produced shock maintained responding has also shown a high incidence of shock-produced behavior such as biting and chain pulling (Azrin, Hutchinson, & Hake, 1967). Church and Getty (1972) noted that shock-induced responding must not be overlooked in analyzing Sidman avoidance data. Smith decided to test the generality of extinction procedure effects using rats in a shuttlebox. During initial maximum shock extinction one rat increased responding while the other two decreased. During the second maximum shock extinction the high responder shuttled more in initial extinction sessions than during avoidance but eventually decreased to the same level as during avoidance. In most cases there was a trend toward decreased responding over extinction sessions. The difference between performance in the operant chamber vs. the shuttlebox suggested that the effects of response-independent shock may depend in part on the apparatus and species.

Woodard and Bitterman (1971) and Wallace and Scobie (1977) have used a (1,1) extinction procedure with goldfish in shuttleboxes. When Woodard and Bitterman introduced shock on every trial responding did not decline. Fish had been avoidance trained during 12 sessions of 10 trials each using a both-side light onset CS. The CS was response contingent in avoidance but was not during the (1,1) phase. Wallace and Scobie, however, found that the (1,1) procedure reduced response probabilities from .89 to .60 during the first three extinction sessions. Responding did not decline further with additional extinction sessions. During avoidance, fish had been conditioned to an asymptotic level during four to five session of 100 trials each. The CS, onset of a 10 sec or 20 sec overhead light, was not response contingent.

Explanations can be provided for both increases and decreases in responding with response independent shock on every trial. Decreases in responding can be attributed to disruption of the response-reinforcer contingency (Davenport et al., 1971) or to suppressive effects of increased shock. Increased responding could be due to shock-induced effects (Pear et al., 1972; Smith, 1974) or because of the similarity of the procedure to classical conditioning (Woodard & Bitterman, 1971). Thus it appears that shock density is a variable which needs to be manipulated independently of the response-reinforcer contingency.

Matched shock density (MSD) extinction. Smith (1974), Wallace and Scobie (1977), and this study used procedures which match shock density during extinction to that of final avoidance. MSD procedures can be based on group or individual data and can be noncontingent or contingent. Smith using individual data replicated the pattern of shock received during the final avoidance session. For example, if shock occurred on the third trial in the last avoidance session it occurred on the third trial of every extinction session. This assured that shock density was matched but did not control the contingency between responses and shocks. To be truly non-contingent $P(S)$ following either a response or no response must be equal, $P(S|\bar{R})=P(S|R)$. If these are not equal an asymmetrical relationship results favoring either responding or not responding. When $P(S|\bar{R})$ $P(S|R)$ responding reduced shock density; when $P(S|\bar{R})$ $P(S|R)$ not responding reduced shock density.

Smith found that this matched pattern procedure led to decreases in lever pressing in eight of the nine extinction phases. In the shuttlebox each of the three rats decreased responding during matched extinction. In the shuttlebox there was a tendency toward reduced responding over extinction sessions. This trend was not observed with lever pressing.

Rather than matching shock density on the basis of individual data, Wallace and Scobie (1977) used a group mean. In their experiment they used two different matched shock density procedures. One of these, the random shock procedure was introduced at the end of the avoidance phase. Fish were randomly assigned to continued avoidance, CS with no shock (0,0), or random shock. For the random group, the percentage of shock was matched to the group mean percentage of shock received by the avoidance group on the previous day. During the five extinction sessions of 100 trials each the number of daily shocks ranged from 12 to 18. Two of these shocks each day were paired with the CS while the remaining were unpaired. Responding rapidly decreased during the first four extinction sessions. The decrease in responding for each day was almost identical for the random and (0,0) extinction conditions.

In a third phase of the experiment, another matched shock extinction procedure was introduced. The avoidance and random groups were changed to a partial classical extinction procedure. Shock density was matched to the percentage of shock received on the last day of avoidance (.13). CS's were presented on every trial while US's were presented on .13 trials. During this procedure response probability in the avoidance group decreased from .86 to approximately .4. The random group increased from .2 to .3. The decline with this procedure was not as great as the decline in the second phase using the random shock procedure. Two procedural explanations for the smaller decreases in the partial classical group are possible. The random group received four avoidance acquisition sessions prior to extinction while the partial classical received nine. The extra sessions may have made the partial classical group more resistant to extinction. A second factor may be the infrequency of CS-US pairing in the random procedure. Both the no shock-CS only and random shock groups decreased shuttling rapidly. In both cases one of the stimuli present during acquisition was absent or infrequently presented during extinction. Smith (1974) has suggested such changes make extinction more discriminable and therefore may reduce responding rapidly. The extinction curve for the partial classical group was still declining at the end of the experiment. Therefore it cannot be determined whether the MSD procedure resulted in a higher level of responding in extinction or a slower extinction rate.

Traditional (0,0) Extinction. Smith (1974), Neffinger and Gibbon (1975), Scobie and Fallon (1974) and Wallace and Scobie (1977) have compared the effectiveness of traditional (0,0) extinction with other extinction procedures. Smith using a within subjects design presented (0,0) extinction following avoidance acquisition. All rats decreased lever pressing to zero or near zero during five extinction sessions. When the avoidance contingency was reintroduced responding increased to levels of initial avoidance. Similar results were found by Neffinger and Gibbon (1975). Following avoidance conditioning (1,0) three rats were exposed to (0,0). Two rats stopped lever pressing by the third and fourth sessions while the third decreased to near zero after the eighth session. Two Class II, shock density-sensitive, subjects also stopped responding with a (0,0) contingency although they had maintained high levels of responding with either (.5,.5) or (1,1) contingencies. Smith also found that responding decreased when rats were given a (0,0) extinction procedure in shuttleboxes.

Using goldfish, Scobie and Fallon (1974) trained fish with either a classical or instrumental avoidance procedures. Data from both groups were pooled during the (0,0) extinction phase. Shuttling decreased from above .6

during the last acquisition session to below .4 during the first extinction session. Wallace and Scobie (1977) also found that (0,0) extinction led to a rapid decrease in responding during the first four extinction sessions. Responding during the last avoidance session was .83. By the fourth extinction session shuttling had declined to .2 and it stayed at that level for the remaining seven sessions. This response pattern was very similar to that of the random shock group in the same experiment. Wallace and Scobie in a second experiment again found (0,0) extinction was effective in a 2 X 2 factorial design comparing (1,1) and (0,1) contingencies. The (0,0) procedure resulted in a rapid decrease in shuttling. Only the contingent punishment group responded less frequently.

All the cited experiments using rats and fish found (0,0) extinction to be effective in reducing responding. The effect of (1,1) extinction was less clear. Coulson et al. (1970), Davenport et al. (1971), and Neffinger and Gibbon (1975) found that (1,1) usually resulted in a decrease in responding. Pear et al. (1972) and Smith (1974) generally found an increase in responding. Using goldfish Woodard and Bitterman (1971) found little or no decrease while Wallace and Scobie's found a decrease. Individually matched shock density extinction usually resulted in moderate decreases in response frequency (Coulson et al., 1970; Smith, 1979).

Design rationale

Experiment 2 was designed to assess the effect of the response reinforcer contingency within the context of a reversal paradigm with shock density during extinction unchanged. This type of design permits evaluation of the reinforcing contingency over time and is particularly suited to goldfish since both time-order effects (the pseudo-learning curve) and large between-subject variability were found in Experiment 1. Goldfish were successively exposed to: operant level testing (0,0), avoidance conditioning (1,0), noncontingent IMSD extinction, reconditioning (0,0), a second noncontingent IMSD extinction and traditional no-shock extinction (0,0).

Experiment 2 introduced a new procedure, noncontingent IMSD extinction. With this procedure noncontingent shocks, individually matched in frequency with shock frequency at the end of avoidance, were given. Noncontingency, represented by the diagnoal of independence on the contingency square (Gibbon, et al., 1974), is defined as $P(S|\overline{R})=P(S|R)$. Previous studies (Coulson et al., 1970; Smith, 1974) using IMSD extinction procedures did not attempt to maintain a truly noncontingent relationship between responding, not responding, and shock. Experiment 2 also employed a traditional (0,0) extinction procedure which provided an opportunity to compare IMSD and (0,0) extinction procedures. In addition the (0,0) extinction procedure permitted comparison of responding under the same contingency, (0,0) before and after avoidance conditioning (1,0) procedures.

The specific CS, and ITI illumination parameters were similar to those used by Woodard and Bitterman (1971, 1973). Both studies used as CS lights behind the end walls. During trials both ends were illuminated and between trials both ends were dark. There was dim overhead illumination. Because of the theoretical emphasis placed on feedback from shuttling by Woodard and Bitterman visual feedback was provided by a color change in Experiment 2. After a response was made the CS changed from red (or green) to green (or red).

Since shock level is an important parameter affecting probability of responding, Experiment 2 used the same shock level as that used by Woodard and Bitterman (1971, 1973), .65 VAC/cm. In Experiment 2 measurements were rms. Woodard and Bitterman did not specify how they measured voltage. The data from Blintz (1971), Gallon (1974) and Scobie and Herman (1972) indicated .65 VAC/cm (rms) is an effective shock level.

Method

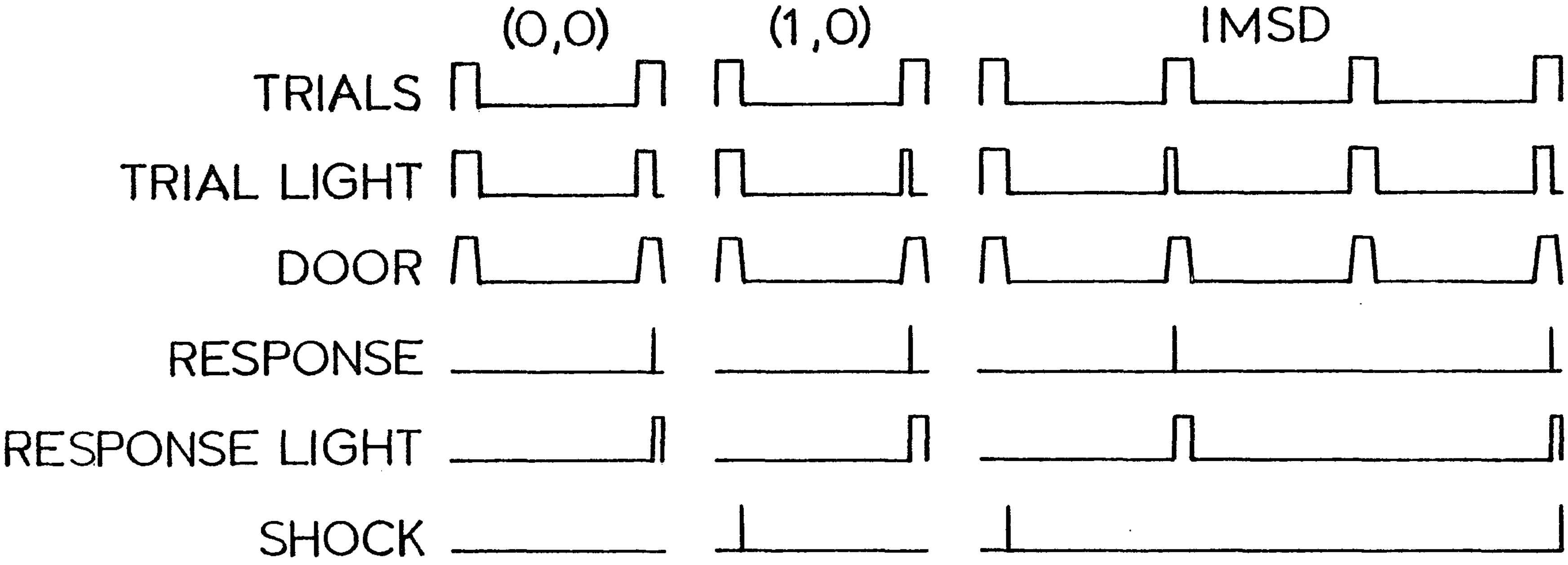
Subjects

Goldfish of uniform size but of unknown sex and age were obtained from a local supplier (Pic-A-Pet, New York, New York, 10034). Fish were maintained prior to the experiment as in Experiment 1. A total of 13 fish were were used but due to illness or apparatus malfunction four fish were eliminated. Of the nine fish used in the data analysis, four were replacement fish which began the experiment up to six weeks after the initial subjects. The mean length and standard deviation from the nose to the base of the caudal fin was 6.0 cm and 0.5 cm. respectively, for the nine subjects. Their mean dorsal to ventral extent was 1.9 cm with a standard deviation of 0.4 cm.

Apparatus

The shuttleboxes from Experiment 1 were used with some modifications. Shuttlebox length was fixed at 35 cm. Red (Kodak Wratten 25) and green (Kodak Wratten 58) filters were attached behind frosted Plexiglas end panels as illustrated in Figure 2. Each panel was vertically divided in half to provide a red and a green light in each end. Filters of the same color were placed in diagonally opposite sections of the end panels. Therefore, when swimming toward either end the same color light always remained on the same side of the fish. Each filter was illuminated from behind by a 10 watt incandescent lamp. The top of the shuttlebox was covered by a frosted Plexiglas sheet to provide more uniform illumination. A vertical motorized door, illustrated in Figure 2, prevented hurdle crossings during intertrial intervals and after the initial response during a trial. The door, designed to prevent injury, moved upward from a slot in the hurdle when it opened. Trials were initiated with the door opening and the onset of a red or a green light at each end of the shuttle-

Figure 11. Sequence of trial light, door opening and possible response and shock relationships under different contingencies. The trial duration was 15 sec, the upward and downward excursions of the door, 1 sec each, and the intertrial interval was 60 sec.


(0,0)
(1,0)
IMSD
TRIALS
TRIAL LIGHT
DOOR
RESPONSE
RESPONSE LIGHT
SHOCK

box. The door was fully open 1 sec after CS onset and started to close 1 sec before offset. By using the door and thereby permitting only one response per trial the relationship between responding and the contingency was more clearly defined. After a response, the trial light went off and a post-response light of the other color came on in each end. If no response had been made, at the end of the trial, the door closed and the cue lights were turned off. The stimulus lights were on for a total of 15 sec. If no response was made the trial light was 15 sec; if a response was made the combined duration of trial and response lights was 15 sec. The trial light was red and the response light green for five subjects. Conditions were reversed for the other four subjects. The ITI was always 60 sec.

On trials when shock was due, a 65 VAC/cm (rms) 60 Hz 400 msec in duration shock was delivered through stainless steel mesh electrodes at the end of the trial. The sequence of trial, light, and shock presentation are shown in Figure 12. The electrodes were attached to the sides of the shuttlebox. Shock density during the noncontingent extinction phases was programmed using a three-channel tape drive (Gerbrands model PT-JA). For each shock density (.5,.5), (1,1), etc. there was one punched three-channel tape. One channel of each tape timed the ITI and signalled the onset of a trial. The second channel was used to determine whether a shock would occur if no response was made during that trial. The third channel determined whether a shock would occur if a response was made. The second and third channels were programmed independently. For example, using the (.6,.6) shock density tape, on .6 of no response trials (channel 2) shock would occur. Independent of the no response sequence, .6 of the response trials (channel 3) were also programmed for shock. Thus, regardless of the number of responses made a total of twelve shocks were programmed. Because of the independence of channels, there could be a slight variation in the number of shocks delivered when a particular combination of response and no response trials occurred. The order of the sequences on channels 2 and 3 were determined by a Gellerman series. Each tape was continuous with a total of 6 blocks of 10 trials. The point at which a tape was initiated was varied among the six possible starting points from day to day.

The sequence of responses and shocks were recorded on a Rustrak four-channel event recorder. Counters were used to dtermine the frequency of the following conditions: shock or no shock on the previous trial, response or no response on the current trial, shock or no shock on the current trial. To determine the effect of shock elicited behavior these frequencies were used in the sequential analysis of the probabilities or responding vs. not responding given shock or no shock on the previous trial. Latencies were recorded on a printing counter (Scientific Prototype model

4048J).

Procedure

Fish were randomly selected from a community tank and adapted in individual tanks as in Experiment 1 for one week prior to the start of the experiment. Each fish received the following sequence of contingencies: operant level (0,0), avoidance 1 (1,0), noncontingent IMSD extinction 1, avoidance 2 (1,0), noncontingent IMSD extinction 2, and traditional extinction (0,0). Each contingency was in effect for 12 sessions with 20 trials per session. Between contingencies there was a transitional session with 10 trials from the previous contingency and 10 trials from the new contingency. Data from the transitional sessions are not included in the data analysis.

Shock density during noncontingent extinction was determined by each individual's mean shock density received over the last three avoidance sessions. If, for example, during these last three sessions (60 trials) a subject responded on 80 per cent and received shock on 20 per cent of the trials, shock density during noncontingent extinction would be 20 per cent (.2,.2). During this phase four shocks would be proportionally divided between response and no response trials during each sessions. If the subject responded on five trials, shock would occur on one (5 x .2 = 1) response and three (15 x .2 = 3) no response trials.

The cubicles which housed the fish and apparatus were the same as those used in Experiment 1 except that both cubicles were illuminated from 0800 to 2000 Eastern Daylight Time (EDT). Fish were run at the same time every day between 0900 to 1830 EDT. After the seasonal change to standard time, illumination and running schedules were altered by 15 min per week over a period of four weeks to adjust to Eastern Standard Time.

Demineralized water was used to replace evaporated water in individual tanks and shuttleboxes daily. Each week one-third of the water from the shuttleboxes was drained and replaced by aged tap water. Every other week approximately one-quarter of the water from individual tanks was drained and replaced with aged tap water. Outside filters on individual tanks were changed every four weeks. Inside filters, used overnight in shuttleboxes, were also changed every four weeks. Mean water temperature was 23.1° C and did not vary more than 0.5° C from day to day. Fish were transferred between shuttleboxes and individual tanks using nylon nets. At the end of each day fish were fed Tetramin dry flake fish foods.

Results

The effect of contingency on responding

Mean responses for all subjects are shown in Figure The repeated measures analysis of variance presented in Table 5 revealed a significant effect at the .01 level attributable to contingency manipulation. The pseudo-learn-

Figure 12. Mean number of responses for nine goldfish over blocks of three sessions under each contingency.

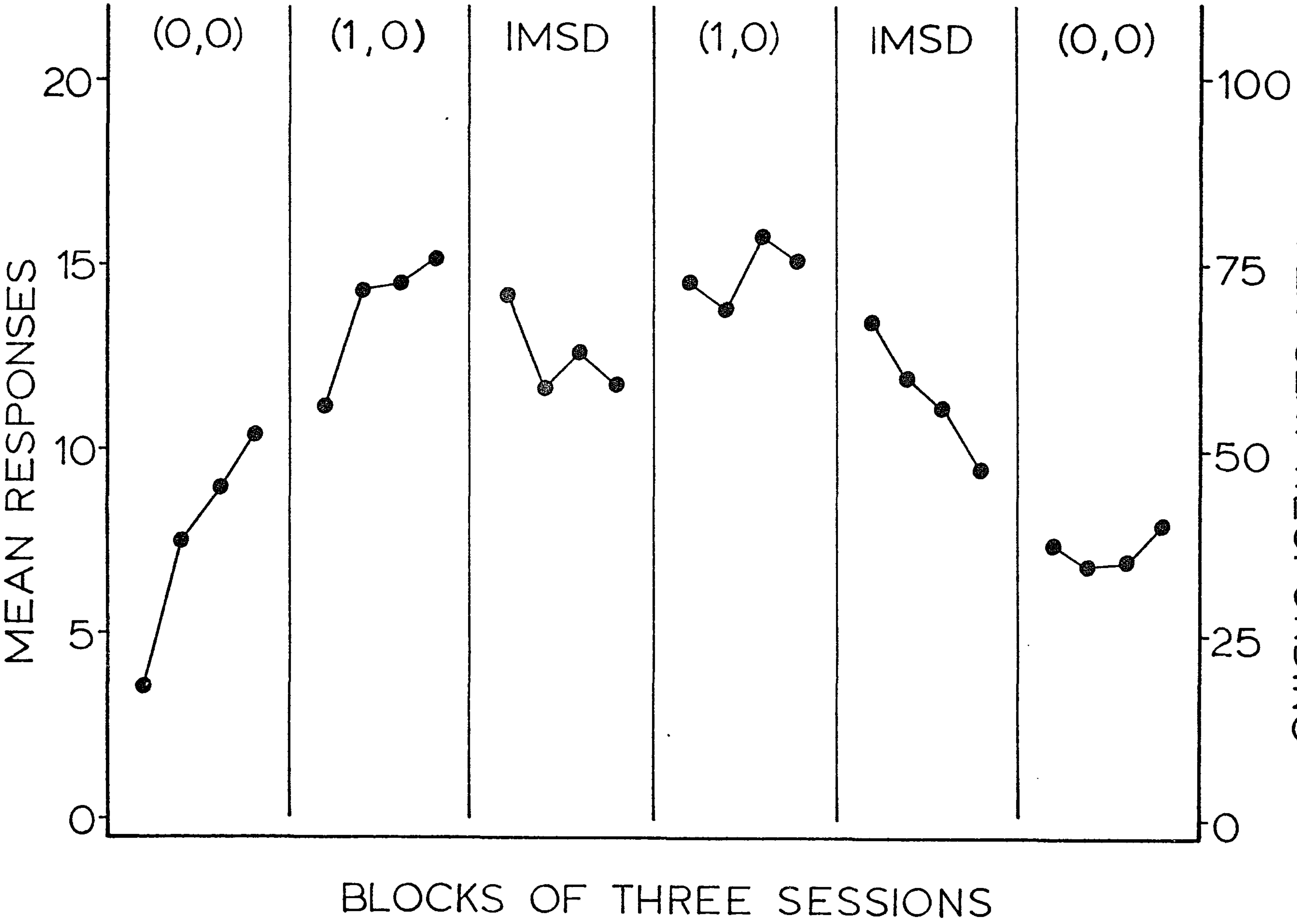

(0,0)
(1,0)
IMSD
(1,0)
IMSD
(0,0)
MEAN RESPONSES
0
5
10
15
20
PER CENT RESPONDING
0
25
50
75
100
BLOCKS OF THREE SESSIONS

Table 5

Analysis of Variance for Mean Responding during the Final Three Sessions of Each Contingency Phase

Source	_df_	_MS_	_F_
Between subjects	8	179	14.04*
Within subjects			
Contingency	5	84	6.55*
Error	40	13	

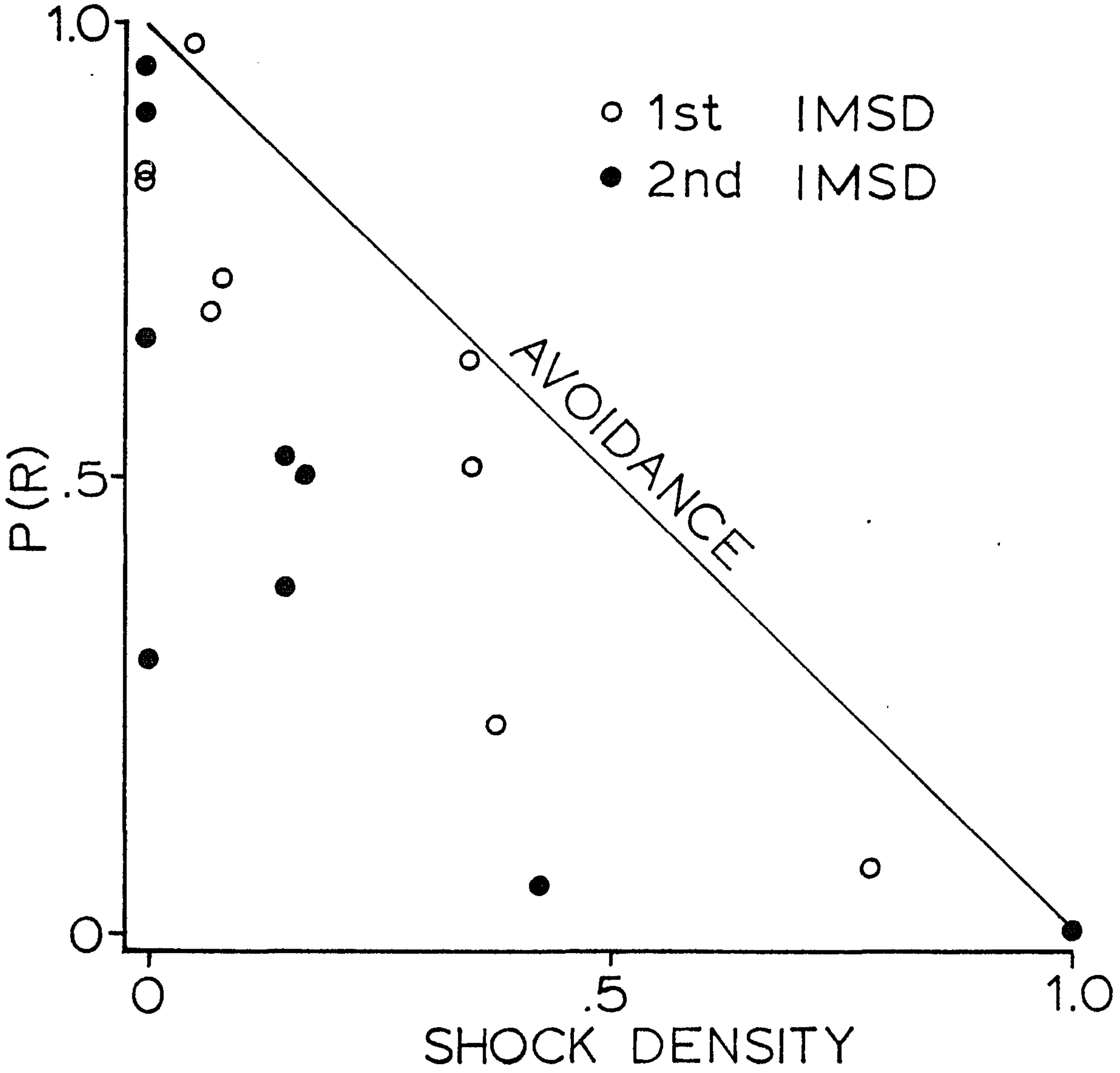
*$p < .01$

ing curve effect of Experiment 1 also occurred during the operant level phase of this experiment. Responding gradually increased from a mean of 3.7 during the first block of three sessions to 10.4 during the fourth block. After the avoidance contingency (1,0) was introduced responding increased to 15.3 during the final three sessions of avoidance. During noncontingent IMSD extinction, when shock was no longer contingent but density remained the same, responding decreased to a mean of 11.7. When the avoidance contingency was reintroduced responding increased to a mean of 15.3. Reintroduction of the noncontingent IMSD extinction procedure reduced responding to a mean of 9.8 which was lower than it had been at the end of the first extinction. Overall responding decreased further to 7.9 during the final three sessions of the traditional extinction phase when shock was absent on every trial (0,0). Means based on the last three sessions of each contingency were compared using the Neuman-Keuls test (Winer, 1971). There was a significant difference between the traditional extinction phase and each avoidance phase (p <.01).

The relationship between responding and shock density

Figure 13 shows the probability of responding as a function of shock density during noncontingent extinction when the probability of shock was matched to the probability of shock during the last three avoidance sessions. Due to

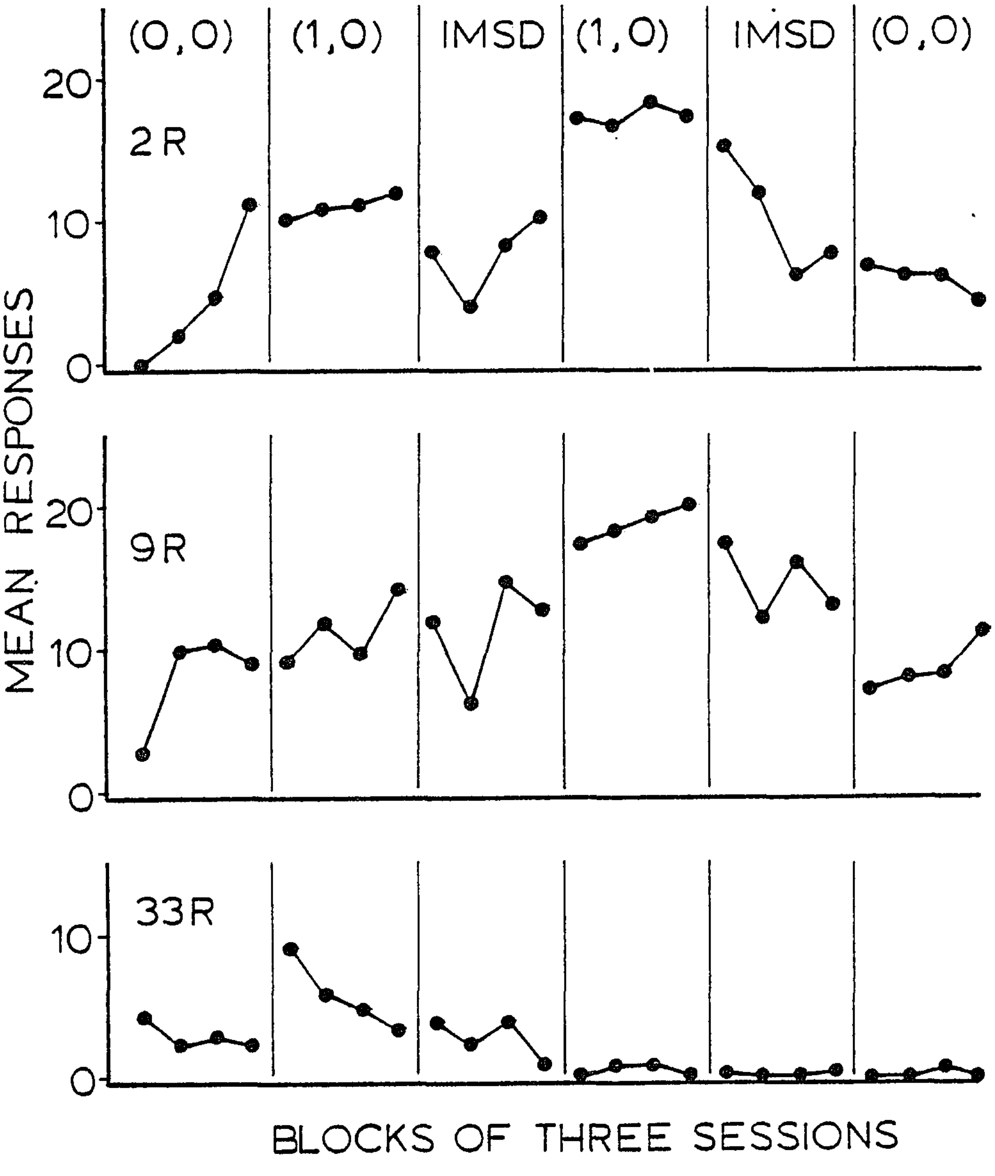
Figure 13. Probability of a response as a function of shock density during first and second IMSD extinction. The diagonal represents the locus of all possible response and shock combinations during avoidance. In IMSD extinction data points from individuals can only move directly upward or downward since shock density was unchanged.

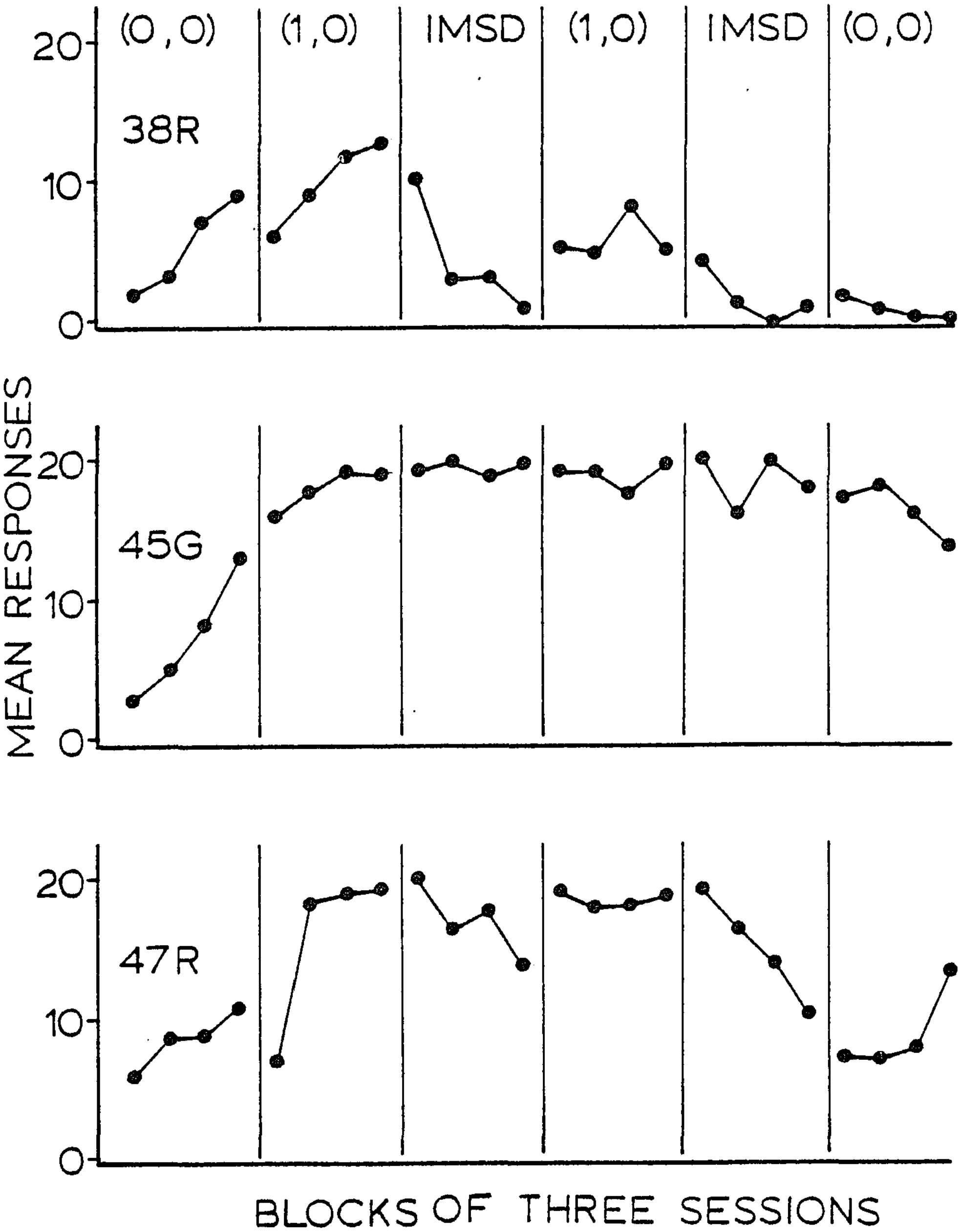

1.0
.5
0
P (R)
0
.5
1.0
SHOCK DENSITY
AVOIDANCE
○ 1st IMSD
● 2nd IMSD

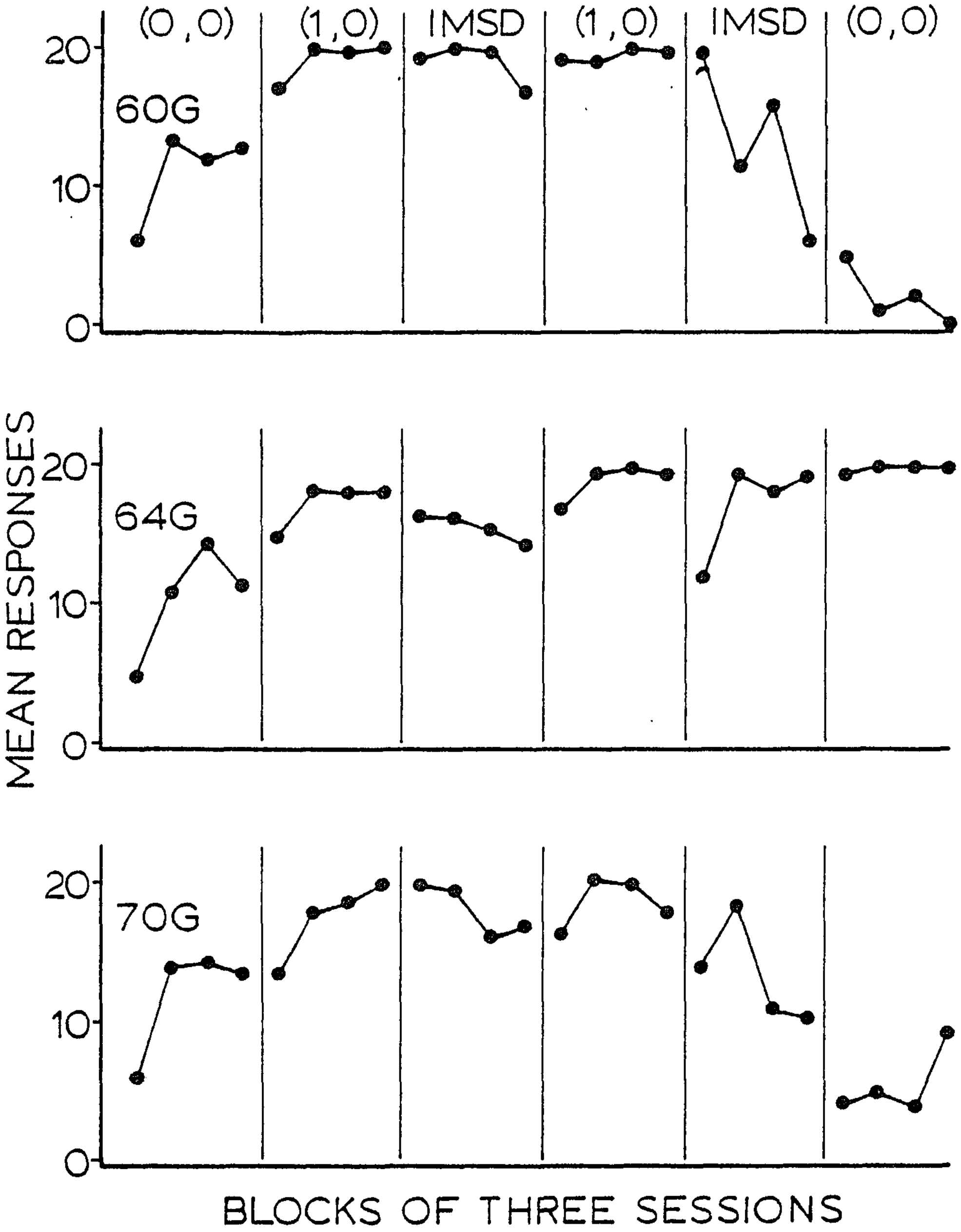
the independent programming of the $P(S|\bar{R})$ and $P(S|R)$ tapes, shock density varied slightly from that programmed. The mean variation between shock densities received during avoidance and noncontingent phases was less than .01. Based on the densities of the nine subjects the $P(S|\bar{R})$ was greater than the $P(S|R)$ by a mean of .03. The actual densities $P(S|\bar{R})$ and $P(S|R)$ values are presented in Appendix D. The diagonal of Figure 13 indicates the locus of all possible avoidance coordinates for the proportion of trials on which a response was made and the shock density received. For example, if a fish responded on 75 per cent of the trials, the shock density received would be .25. During noncontingent extinction, points representing proportion of response trials could only move upward or downward from the avoidance diagonal, since shock density was unchanged. Traditionally, response strength is evaluated by displacement upward from the x-axis of zero response strength. Because of the variability between fish in responding during avoidance, a more appropriate evaluation can be made by comparing displacement from the avoidance diagonal during noncontingent extinction. All but one fish, 45G, responded less frequently during the first noncontingent extinction than during the first avoidance. During the second noncontingent extinction all fish except 33R decreased responding. Fish 33R made one response during the last three noncontingent extinction trials and no responses during the last three avoidance sessions. Compared with avoidance responding all fish, except 33R, decreased from 2 to 29 responses over the last three noncontingent extinction sessions. Generally greater decreases occurred during the second IMSD noncontingent extinction. During both noncontingent IMSD extinction phases, decreases in the middle range of shock densities were larger than those at more extreme values. Thus the decrease in responding was not a simple function of shock density.

Individual differences in responding

Individual response curves over blocks of three sessions are shown in Figures 14, 15, 16. Although overall response levels varied between individuals, six of the nine fish showed similar changes in responding as a function of contingency manipulation. Subjects 64G, 45G, and 33R deviated from the general pattern of the other fish. Responding by 64G, was similar to other fish until the last two phases when there was no decrease during the second noncontingent extinction and during traditional avoidance. Subject 45G, like Neffinger and Gibbon's (1975) Class II subjects, maintained high response rates despite contingency manipulation. Responding remained high during the initial IMSD noncontingent extinction instead of decreasing. During the second IMSD noncontingent extinction at (0,0) responding became more variable and decreased slightly. Responding further decreased during traditional extinction, Figures 14 - 16. Individual mean responses over blocks of three trials under each contingency.


(0,0)
(1,0)
IMSD
(1,0)
IMSD
(0,0)
2R
9R
33R
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS


(0,0)
(1,0)
IMSD
(1,0)
IMSD
(0,0)
38R
45G
47R
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS


(0,0)
(1,0)
IMSD
(1,0)
IMSD
(0,0)
60G
64G
70G
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS

also at (0,0). Subject 33R responded at unusually low levels. Toward the end of the first IMSD extinction shuttling by 33R fell below operant level and did not recover during reconditioning.

Analysis of responding following shock vs. no shock

The occurrence or nonoccurrence of shock on trial n-1 may have an effect on response probability on trial n, even with long ITIs. In this section evidence for such an effect in the avoidance and IMSD phases is sought. The probabilities of responding following trials on which shock did not occur, $P(R_n|\bar{S}_{n-1})$, and following trials on which shock occurred, $P(R_n|S_{n-1})$, during the final three sessions of avoidance and noncontingent IMSD extinction are shown in Table 6. During both avoidance phases all subjects except 33R had $P(R_n|\bar{S}_{n-1}) > P(R_n|S_{n-1})$, i.e., a successful avoidance was usually followed by another successful avoidance. During the first and second avoidance phases the differences in these probabilities were respectively .27 and .47. The $P(R_n|\bar{S}_{n-1})$ could not be calculated for subject 33R which did not respond during the last three sessions of the second avoidance and consequently received shock on every trial. The $P(R_n|\bar{S}_{n-1})$ could not be calculated for subjects which responded on every trial and received no shock.

During noncontingent extinction the $P(R_n|\bar{S}_{n-1})$ was not consistently higher than $P(R_n|S_{n-1})$ as it was during avoidance. Five of the eight fish which received shock on at least one

Table 6

Mean Probability of a Response following No Shock $P(R_n | S_{n-1})$ and Shock $P(R_n | S_{n-1})$ during the Final Three Sessions of Avoidance and Individually Matched Shock Density (IMSD) Extinction

	Avoidance 1		IMSD 1		Avoidance 2		IMSD 2	
Subject	$P(R_n \| \bar{S}_{n-1})$	$P(R_n \| S_{n-1})$	$P(R_n \| \bar{S}_{n-1})$	$P(R_n \| S_{n-1})$	$P(R_n \| \bar{S}_{n-1})$	$P(R_n \| S_{n-1})$	$P(R_n \| \bar{S}_{n-1})$	$P(R_n \| S_{n-1})$
2R	.65	.40	.47	.51	.90	.67	.35	.64
9R	.67	.66	.57	.51	1.00	a	.63	a
33R	.00	.20	.11	.02	b	.00	a	.17
38R	.64	.53	.08	.00	.24	.22	.00	.11
45G	.96	.67	.98	1.00	.98	.33	.89	a
47R	.96	.67	.64	1.00	.94	.50	.47	.53
60G	1.00	.00	.82	a	1.00	.33	.31	a
64G	.92	.67	.72	.44	1.00	a	.95	a
70G	.98	a	.83	a	.94	.75	.42	.58

[a] This subject did not receive any shocks during the final three sessions of this phase.

[b] This subject received shock on every trial during the final three sessions of this phase.

but less than every trial during the first extinction phase had higher $P(R_n | \bar{S}_{n-1})$ than $P(R_n | S_{n-1})$. During the second noncontingent phase the $P(R_n | \bar{S}_{n-1})$ was always lower than the $P(R | S)$ with a mean difference of .16. The $P(R_n | \bar{S}_{n-1})$ did not remain higher than the $P(R_n | S_{n-1})$ during extinction as it did during avoidance.

The individual shock densities during extinction as well as the $P(R_n | \bar{S}_{n-1})$ and the $P(R_n | S_{n-1})$ are presented in Table 7, and Figure 17. Similar shock densities do not necessarily produce similar $P(R_n | \bar{S}_{n-1})$ and $P(R_n | S_{n-1})$ in all fish. For example, Table 7 shows that individual fish such as 45G and 47R both received shocks on 4 per cent of the trials but 45G had a $P(R_n | \bar{S}_{n-1})$ of .98 while 47R had a $P(R_n | \bar{S}_{n-1})$ of .64. Comparisons showing differences in responding could be seen in other fish such as 2R and 38R. The relationship between density during extinction and the probability of response following no shock is represented by the circles in Figure 17. Generally as shock density increased, responding decreased. Except for subjects receiving no shock, probabilities were lower during the second noncontingent extinction phase. In Figure 17, the probability of a response following shock as a function of shock density is represented by the triangles. Again there was a tendency for responding to decrease with increased density and for responding to be lower during the second extinction phase.

Table 7

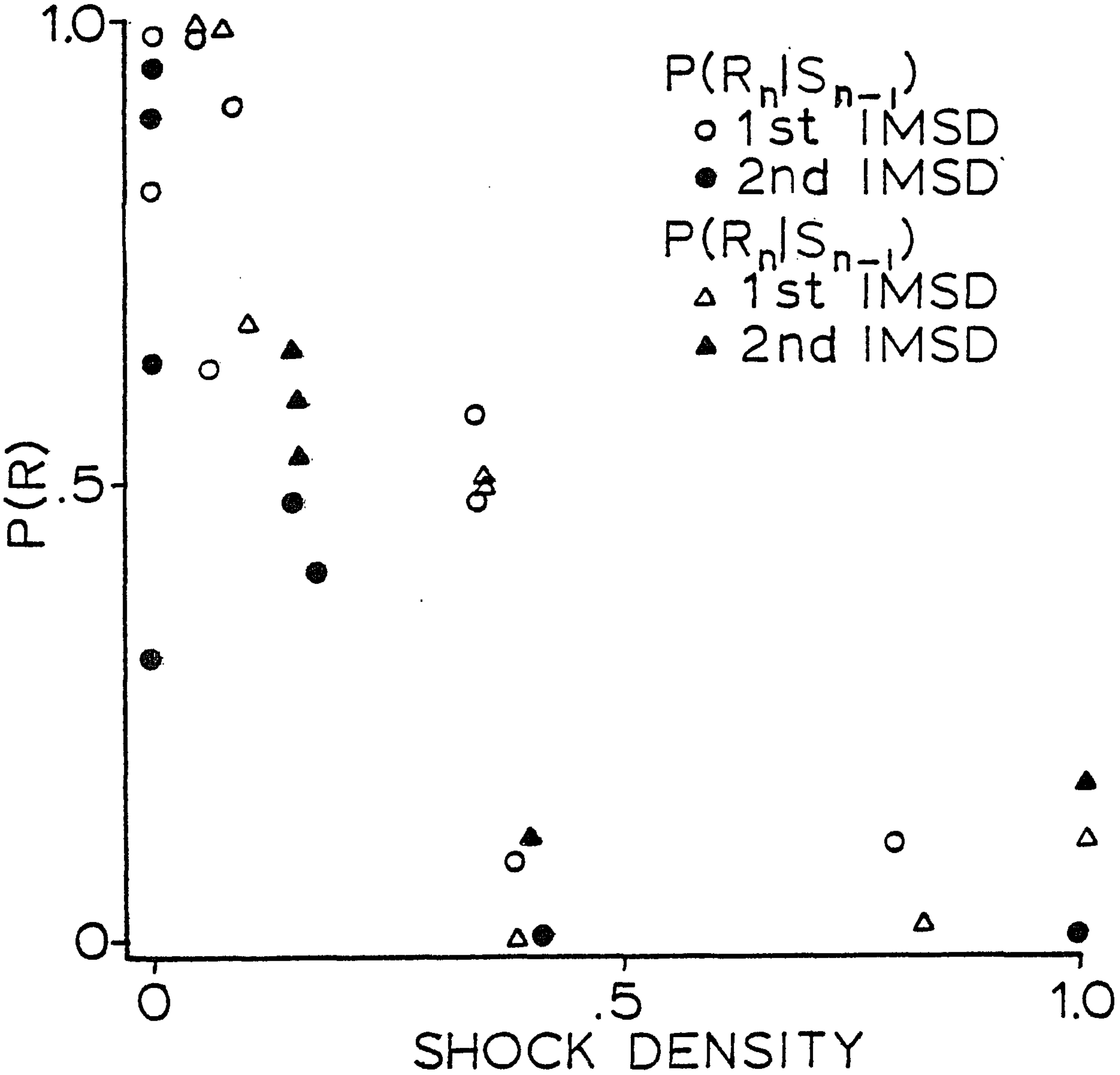
Shock Density and Mean Probability of Responding following No Shock $P(R_n|\bar{S}_{n-1})$ and Shock $P(R_n|S_{n-1})$ over the Last Three Sessions of Individually Matched Shock Density (IMSD) Extinction

	IMSD Extinction 1			IMSD Extinction 2		
Subjects	Shock Density	$P(R_n\|\bar{S}_{n-1})$	$P(R_n\|S_{n-1})$	Shock Density	$P(R_n\|\bar{S}_{n-1})$	$P(R_n\|S_{n-1})$
2R	.42	.47	.51	.11	.35	.64
9R	.31	.57	.51	.00	.63	a
33R	.75	.11	.02	1.00	b	.17
38R	.45	.08	.00	.40	.00	.11
45G	.04	.98	1.00	.00	.89	a
47R	.04	.64	1.00	.12	.47	.53
60G	.00	.82	a	.00	.31	a
64G	.12	.72	.44	.00	.95	a
70G	.00	.83	a	.11	.42	a

[a] This subject was given (0,0) in IMSD Extinction and was not scheduled for shock.

[b] This subject received shock on every trial during IMSD Extinction.

Figure 17. Probability of a response following no shock $P(R_n | \bar{S}_{n-1})$ and probability of a response following shock $P(R_n | S_{n-1})$ as a function of shock density during first and second individually matched shock density (IMSD) extinctions.


1.0
.5
0
P(R)
0
.5
1.0
SHOCK DENSITY
$P(R_n|S_{n-1})$
○ 1st IMSD
● 2nd IMSD
$P(R_n|S_{n-1})$
△ 1st IMSD
▲ 2nd IMSD

The effect of contingency on latency

Median latency scores for the last three days of each contingency and for each subject are shown in Table 8. A repeated measures analysis of variance did not reveal any significant difference due to contingency manipulation as presented in Table 9. Although there were no significant differences, the distribution of latencies over the last three sessions of each phase changed as contingencies changed. The median of the medians was found to be shortest during avoidance conditioning and longest during the noncontingent phases. Modal latencies for all subjects except 33R and 38R fell in the 2 - 4 sec interval during avoidance. For most subjects the distribution of latencies changed with modal latencies occurring later in the trial for other contingencies. Some subjects, such as 45R, and 47R and 70G continued to have modal latencies falling in the 2 - 4 sec interval during the extinction phases. For these fish the effect of the extinction procedure could be seen by overall decreases in frequency of responding rather than in longer modal latencies.

Discussion

The major findings of Experiment 2 were: 1) responding was highest during avoidance (1,0), 2) lower during matched extinction and 3) lowest during operant level (0,0) and traditional extinction (0,0). 4) There was no relationship between shock density and probability of responding during noncontingent phases.

Table 8

Median Latencies (sec) during the Final Three Sessions of Each Contingency

Subject	Contingencies					
	Operant level	Avoidance 1	IMSD Ext 1	Avoidance 2	IMSD Ext 2	No Shock Ext
2R	5.8	3.5	8.7	4.1	6.5	5.0
9R	4.3	4.5	6.4	3.7	5.0	4.1
33R	9.0	7.0	11.0	a	a	a
38R	7.0	5.1	3.3	7.0	5.8	a
45G	6.5	3.1	3.0	3.9	3.5	5.2
47R	5.3	3.5	3.7	7.0	3.4	3.6
60G	7.0	3.3	3.8	3.9	4.1	3.0
64G	6.7	4.2	5.3	3.4	4.7	4.3
70G	3.8	3.1	5.7	3.6	3.7	3.7
Median	6.5	3.5	5.3	3.9	4.7	4.3

[a] No responses were made during the final three sessions of this contingency.

Table 9

Analysis of Variance for Median Latencies of the Final Three Sessions of Each Contingency Phase

Source	_df_	_MS_	_F_
Between subjects	8	30.3	9.77*
Within subjects			
Contingency	5	4.8	1.54
Error	40	3.1	

*$p < .01$

Probability of Responding

Operant level. The pseudo-learning curve effect found in Experiment 1 was replicated in Experiment 2 despite methodological differences. In both experiments (Figures 5 and 12) responding increased over sessions in the absence of a reinforcer. A free-operant paradigm was used in Experiment 1 where trials were not defined. In Experiment 2 trials were explicitly defined by light onset and by the opening of a motorized door. Scobie and Fallon (1974) have specifically compared the effect of CS presence and absence on responding when no US was presented. They found responding was higher in the "nothing" group which was exposed to background illumination for the entire experiment. The probability responding for their CS-only group was lower after five sessions of 50 trials. This was lower than the .5 probability found at the end of 12 sessions of 20 trials during operant level of Experiment 2. The response-contingent hue change may have contributed to the higher response frequencies in Experiment 2. Zerbolio and Wickstra (1978a, 1978b) have shown that shuttling probabilities were higher when there was a response contingent hue change. As Scobie and Fallon found (1974), Zerbolio and Wickstra also found that more responses were made by the CS-only group than by the blank-trial group. Zerbolio and Wickstra (1978b) attributed these results to a combination of negative phototaxis and learning. The negative phototaxic effect was probably moderated by presenting the CS in both compartments and by having low level background illumination. The .5 probability of responding at the end of operant level again emphasizes the importance of recording baseline shuttling prior to introducing any contingencies when using goldfish.

Avoidance. Shuttling was highest during the two avoidance contingencies. This agrees with other studies of avoidance learning in goldfish. The probability of responding at the end of the first training was .79 and at the end of reconditioning was .76. These probabilities are comparable to those found by Zerbolio and Wickstra using similar procedures such as 20 trials per day and CS onset in both compartments. Although a few studies have obtained probabilities of avoidance responding as high as .90 (Walace & Socbie, 1976), group means for goldfish tend to be lower than those for rats and monkeys. This may be due to the large range of individual differences, species differences or procedural differences. Typically goldfish are not eliminated from experiments due to poor performance during early training phases. This procedure which is more frequently used with rats results in higher group means.

Differences in level of performance for goldfish have been shown by Wickstra and Zerbolio (1976a, 1976b) to be related to variables such as shock, choice of CS, and number of trials per day. For example, Wickstra and Zerbolio using CS onset in both end compartments and four sessions of 20 trials per day found mean response probabilities of approximately .75. Mean response probability during the fourth session of Experiment 2, which also used CS onset in both compartments and 20 trials per day, was .71.

Avoidance was about the same as at the end of reconditioning. Inspection of the individual response curves suggested a reason for the lack of improvement during reconditioning. Some fish were making 19 or 20 responses at the end of the first avoidance. Their individual scores could not improve and therefore they could not contribute to an increase in the group reconditioning mean. Of these fish, 45G and 70G, showed slight decreases during reconditioning. Three fish who performed at lower levels during initial avoidance improved during reconditioning. Subjects 33R and 38R did not recover their previous response levels after the first IMSD extinction. After the first extinction their overall response level decreased gradually during the remaining three phases of the experiment.

Individually-matched shock density extinction (IMSD). During both IMSD extinction phases responding decreased over trials. Shuttling at the end of the second IMSD extinction was lower than at the end of the first IMSD extinction. During the last block of trials responding decreased to below final operant level. The relative changes in responding from avoidance to IMSD extinction were similar to those found by Coulson et al. (1969) and Smith (1974). Both studies found IMSD extinction decreased responding to a level intermediate between traditional (0,0) extinction and maximal shock (1,1) extinction. The decreases in responding in the study by Coulson et al. were greater than those found in Smith's study and in Experiment 2. Species differences could account for the differences between Coulson et al. and this study but they cannot account for the differences between Coulson et al. and Smith. Although both used rats in a Sidman procedure there were parametric differences. Smith and Coulson et al. respectively had session lengths of 100 min and 120 min with shocks of .4 sec and 1.5 mA and .5 sec at 1.0 mA. The R-S and S-S intervals for Smith were 20- and 5-sec and for Coulson et al. were 30- and 5-sec.

Other parameters which may have contributed to extinction differences were number of sesisons and sequence of contingencies. The minimum number of acquisition sessions in Smith's study was 27 while the minimum in the study by Coulson et al. was five. At the end of acquisition their subjects made between 3 and 5 responses per minute while Smith's subjects were making between 8 to 22. In Smith's shuttlebox experiment there was a minimum of nine acquisition sessions and subjects made 3 to 6 responses per minute at the end of the acquisition. Smith reconditioned his rats for a minimum of 10 sessions between extinction procedures while Coulson et al. presented two different extinction procedures successively and then reconditioned for five sessions. There were 12 reconditioning sessions between extinction procedures in Experiment 2. More extensive reconditioning may have made subjects in Experiment 2 and Smith's study more resistant to extinction.

The sequence of contingency manipulations may have also contributed to extinction performance. Coulson et al. found greater decreases in responding when IMSD followed sessions of (0,0) extinction. The percentage decrease from avoidance was always smaller when IMSD followed avoidance. They found that when an extended 15-session IMSD extinction followed avoidance that responding was initially high and then decreased. This suggests that responding extinguishes more slowly but eventually decreases to a low level when IMSD immediately follows avoidance. IMSD only followed avoidance in Smith's experiments and Experiment 2. Because Smith only presented five extinction sessions it is difficult to ascertain whether responding would have decreased further with additional sessions. Smith's data showed a downward trend during four of the nine IMSD extinction phases. In Experiment 2 there was a downward trend in 11 of the 18 IMSD phases. Perhaps if extinction was continued for more sessions in these experiments responding would have decreased to (0,0) extinction levels.

In Experiment 2 there was a greater decline in responding during the second extinction. Six of the nine fish decreased more during the second IMSD extinction procedure. Three of Smith's operant chamber subjects were given the sequence: (1,0), (0,0), (1,0), (IMSD), (1,0), (1,1), (IMSD), (1,0). In these three cases there was no relationship between levels of responding between the first and second IMSD extinction. Data from Coulson et al. cannot be compared because (0,0) extinction as well as IMSD was presented prior to reconditioning.

Although Wallace and Scobie (1977) studied goldfish in shuttleboxes the extinction procedures they matched the shock density to group data, not individual data. This procedure led to a greater decrease in responding than was found in Experiment 2. Some of this decrease is probably due to the greater number of extinction trials used by Wallace and Scobie. However, when data from both experiments are compared after an equal number of trials, Wallace and Scobie's fish decreased responding more rapidly. Wallace and Scobie used a massed procedure of 100 trials per day while 20 trials per day were used in Experiment 2. It has generally been found that massed extinction procedures lead to more rapid extinction. Capaldi, Leonard and Ksir (1968) noted that in many massed studies the ITI between the last rewarded extinction trial and the first reconditioning trial was different than the ITI between nonrewarded trials. Capaldi et al. manipulated these two types of ITI's and found more rapid extinction when the intervals were different. Wallace and Scobie started extinction procedures on the day following the last acquisition session so that ITI between the last extinction trial and the first reconditioning trial was 24 hours whereas between extinction trials the mean ITI was 70 sec. In Experiment 2 there were transition sessions between contingency phases. In transition sessions 10 trials from the "old" contingency were followed by 10 trials from the "new" contingency. ITI's remained constant throughout the transition session and within all other sessions. Based on this difference in procedures between Wallace and Scobie and Experiment 2, Capaldi et al. would predict faster extinction in Wallace and Scobie's experiment.

Another factor leading to greater resistance to extinction is the effect of the preconditioning contingency. When nonrewarded trials are given prior to conditioning, using positive reinforcement, there is increased resistance to extinction. This has been labeled the "initial nonreinforcement effect". Using rats in a straight alley, Mellgren, Seybert, and Dyck (1978) found that nonrewarded trials prior to continuous reward trials led to greater resistance to extinction than with continuous reward only. Only Experiment 2 used an extended operant level. The other cited studies using IMSD or group-MSD began with an acquisition sessions.

Traditional (0,0) Extinction. During (0,0) extinction responding decreased to levels lower than during IMSD extinction. This result agrees with other studies of extinction procedures (Coulson et al., 1969; Neffinger & Gibbon, 1975; Smith, 1974). Responding was also lower than during the last seven operant level sessions but did not decrease to initial operant level. Increasing the number of (0,0) extinction sessions probably would not have decreased shuttling further since five of the last six group means were between 7.0 and 7.4 responses. When Coulson et al. followed IMSD extinction with (0,0) extinction there was a more abrupt decrease in responding than was found in Experiment 2. In other studies (Coulson et al., 1969; Neffinger & Gibbon, 1975; Smith, 1974) some rats stopped responding during (0,0) extinction. Subject 60G was the only goldfish in Experiment 2 that decreased substantially from 20 responses in final avoidance to zero in (0,0) extinction. The higher response frequency by goldfish in (0,0) extinction may be due to either comparative variables such as species and apparatus interactions or learning varibles or a combination of both.

Other goldfish studies have found that responding does not stop when a (0,0) extinction procedure is used. In the only other goldfish experiment that included the sequence operant level, conditioning, and extinction response probability decreased to a mean of .25 (Woodard & Bitterman, 1973). Final operant level after three sessions of 10 trials had been .30. When an operant level has not been included response probabilities at the end of (0,0) extinction usually are similar to the probability of ITI responding. For example, Scobie and Fallon (1974) recorded ITI responses of

.17 and final (0,0) extinction probabilities of .15.

Scobie and Fallon have shown that CS termination is an important variable affecting level of responding during extinction. Response-contingent CS termination led to higher response probabilities than noncontingent termination during extinction. It is difficult to determine whether the subjects in Experiment 2 responded to the CS as if it were contingent or noncontingent. The entire CS, initial hue plus response-contingent hue change, was of constant duration and could not be terminated by the fish. The hue change itself was response-contingent. Greater attention to either the contingent or noncontingent properties of the CS could partially determine response level in extinction. Further research manipulating these CS properties is needed to ascertain the role of this type of CS during extinction.

Shock density. Woodard and Bitterman (1973) proposed that shuttlebox avoidance was controlled by conditioned activation due to the pairing of shock and the CS. This implies that shock density per se is an important controlling variable. Increased density increased the number of CS-US pairings and therefore should strengthen the shuttling response. Decreased density would reduce the number of pairings and should weaken responding. Wallace and Scobie (1977) demonstrated that partially reinforced classical conditioning is an effective extinction procedure with goldfish in shuttleboxes. This poses a logical problem for

Woodard and Bitterman's explanation. Increased responding during avoidance reduces the number of CS-US pairings. If responding is high and shock density low response strength should weaken instead of remaining at a high rate as it did during the avoidance phase.

The dominant role of response-reinforcer contingencies has recently been questioned in the operant literature. Studies have shown that response-independent and response-produced shock can maintain responding (Stretch, 1972). For example, Morse and Kelleher (1970) found that monkeys would pull a chain if it resulted in shock delivery every 30 sec. If they did not respond a shock was delivered every 60 sec. This appears to support the Woodward and Bitterman proposal that shock rather than the response-reinforcer contingency controls behavior. However studies generally show that high shock densities tend to suppress responding while low densities maintain responding. McKearney (1972) found this effect using monkeys in operant chambers, when shock delivery was determined by VI or response-independent schedules following Sidman acquisition. Woodward and Bitterman could argue that avoidance data from other species are not relevant and their explanation is only appropriate for avoidance learning by goldfish in shuttleboxes. Data from Wallace and Scobie (1974) have shown that moderately high amounts of responding occurred when classical and punishment contingencies were combined. However, unlike Woodward and Bitterman's (1971) study, responding decreased when only noncontingent shock, (1,1) was given on every trial. Wallace and Scobie also found that when group shock density was the same as during avoidance but no longer contingent, responding declined.

Experiment 2 provides individual data (Figure 14) which suggests little or no orderly relationship between shock density and overall responding values. However, contrary to Woodard and Bitterman (1973) fish receiving the highest densities tended to respond least frequently. If classical conditioning controlled shuttling, response strength should have been higher in these fish and lower in the low density fish. Generally, both high and low densities suppressed behavior. Some of Neffinger and Gibbon's (1975) subjects were sensitive to the change from a contingent to a non-contingent relationship while other, Class II rats, were sensitive to a contingency change shock density interaction. When their Class II rats received noncontingent shocks at densities of 0, .25, .5, .75 and 1.0 response probability almost matched shock density. This relationship was not found in Experiment 2, instead there tended to be an inverse relationship between responding and shock density. Shock tended to have a more suppressive effect on goldfish shuttling.

$\underline{P(R_n | \bar{S}_{n-1}) \text{ and } P(R_n | S_{n-1})}$. There was a slight tendency for fish to respond more frequently on trials following no shock than shock during avoidance and IMSD extinction. The

$P(R_n | S_{n-1})$ may be higher when a Sidman or fixed-cycle avoidance procedure is used. Church and Getty (1972) in their analysis of shock-induced response distributions noted that shock-induced effects are probably less apt to occur in a trial situation. Data from Steiner (1971) and Scobie and Fallon (1974) also fail to show shock-induced responding. Both studies found low response frequencies in an interval following US presentation. Experiment 3 will further analyze the $P(R_n | \bar{S}_{n-1})$ and $P(R_n | S_{n-1})$ with (1,1) and (.5,.5) shock.

Latency

Although there are few data on goldfish latencies in shuttleboxes, latency as a measure is theoretically important. Bolles et al. (1977) suggested that very regular, short latencies in shuttleboxes may indicate that escape and/or avoidance responses are elicited by fear. They found that rats responded with short latencies during all trials. Bolles et al. suggested that fear accrued rapidly at the same rate on each trial and thus elicited the response at the same time on each trial. Although latencies remain unchanged probability of responding improved. Another explanation they cite but do not support, relates to the reinforcing effect of responding early. Shock was always delivered at the end of the interval regardless of whether a response was made. Responding early or late in interval did not alter shock probabilities.

Neffinger and Gibbon (1975) however found that all their rats responded near the end of interval during avoidance. Although this discrimination was not quite as sharp during (0,0), (.5, .5), or (1,1) there still was a strong temporal discrimination shown by Class I contingency-sensitive subjects. For these subjects probability of responding was independent. Class II subjects, who were sensitive to shock density responded with either timed responses at the end of the interval or short latencies during noncontingent phases.

Like the rats in Bolles et al.'s study, most fish in this study tended to respond with short latencies during shuttlebox avoidance. However, the latency was not invariant over trials. Even during the final three avoidance sessions a large portion of responses fell outside the modal bins. Although Bolles et al. do not present comparable data on variability they state that the short latencies occur on all trials on which a response was made. Goldfish in this experiment did not show the timing behavior shown by Neffinger and Gibbon's rats.

This failure by goldfish to develop longer timed latencies was also found by Steiner (1971). At the end of 12 sessions the response distribution across intervals within the fixed cycle was flat. Fish would only respond more frequently in the last interval under one of the following conditions: if a CS signalled the final interval or if a response was only effective during the last interval. Scobie and Fallon (1974) found significantly shorter latencies for the instrumental group than for the noncontingent classical group with a 20-sec CS. Differences between groups were not significant if a 10-sec CS was used. They also found a correlation between latency and probability of responding. This same relationship between increased probability of responding and shorter latencies was found in Experiment 2 avoidance. The relationship between contingency, noncontingency and latency will be further discussed in Experiment 3.

EXPERIMENT 3

The Effects of Pre-exposure with Noncontingent Shock and Punishment on Shuttlebox Behavior

Experiment 2 found most fish were sensitive to the response-reinforcer contingency manipulation and there was a pseudo-learning effect during operant level testing. Whether this pseudo-learning effect is limited to pre-exposure with (0,0) or whether it occurs with other noncontingent procedures is of interest for the following reasons. First, Woodard and Bitterman emphasized the role of shock density rather than contingencies. They would expect more shuttling with (1,1) than with (0,0). Second, pre-exposure with (1,1) is in some respects similar to the fear-conditioning paradigm. Fear conditioning studies with goldfish have shown that unavoidable shock has a residual effect on subsequent avoidance. Experiment 3 examined the role of noncontingent shock before avoidance. Avoidance was followed by IMSD and (0,0) extinctions and finally punishment (0,1) as shown in Table 10.

If shock density primarily determines response probability, fish should continue responding even if they are punished. Although punishment has rarely been studied in goldfish, Woodard and Bitterman (1973) and Wallace and Scobie (1977) included a punishment phase immediately followed avoidance training. Woodard and Bitterman found a decrease in shuttling after the (0,1) contingency was introduced. In a procedure that permitted repeated shuttling during the CS if fish responded once during a punishment trial, they were likely to continue responding. These multiple responses led Woodard and Bitterman to minimize the role of punishment. Instead they felt that discriminated Pavlovian conditioning was responsible for controlling shuttling. In the Wallace and Scobie experiment the number of avoidance training trials for each fish varied although each had reached an undefined asymptote. When the punishment contingency was in effect responding decreased substantially. Both of these experiments only presented group data. The individual data from Experiment 2 showed that certain subjects maintained a high level of responding even after a change to IMSD and (0,0) extenction following avoidance conditioning (cf. Neffinger & Gibbon, 1974: Class II subjects). Introducing a punishment contingency following extinction may further clarify the conditions under which high responding persists.

Experiment 3 also compared the effect of two different densities of noncontingent shock on shuttlebox responding. Following an operant level phase, groups were assigned to either (0,0), (.5,.5) or (1,0) noncontingent shock. This phase was followed by (1,0) avoidance training and then individually-matched-shock-density extinction. If as Bitterman and his colleagues (Greenway & Bitterman, 1972; Woodard & Bitterman, 1971, 1973) suggested, shock density and conditioned activation control responding, then different points on the diagonal should produce different rates of responding. By using points on the diagonal, shock density can be varied while maintaining noncontingency $P(S|\bar{R}) = P(S|R)$. Bitterman and his colleagues would expect responding to be highest in the (1,1) group, lower in the (.5, .5), and lowest in the (0,0) group during pre-avoidance.

Based on their discriminated avoidance explanation of shuttlebox responding, introduction of the avoidance contingency should not increase shuttling in the (1,1) group but increase it in the (0,0) and (.5,.5) groups. If classical conditioning is responsible for shuttling during a (1,0) avoidance contingency then a change from preavoidance (1,1) would be viewed as a change from 100% reinforced classical conditioning to discriminated classical conditioning (Woodard & Bitterman, 1973). Such a change to discriminated classical conditioning might initially lead to reduced responding followed by an increase to levels obtained under (1,1). If there were no residual effects, principles of operant conditioning would predict an increase in all pre-avoidance groups after the introduction of the (1,0) avoidance contingency. After extended training all pre-exposure groups should increase to similar asymtotic levels of responding.

The fear-conditioning literature, however, indicates that pre-exposure to unavoidable shock can have residual effects on avoidance performance. Seligman, Maier and Solomon (1971) cite a number of studies using dogs and rats in which the learned helplessness effect was found. Prior exposure with unavoidable shock led to reduced responding during avoidance. Fear-conditioning studies using goldfish have found both interference effects (Padilla, Padilla, Ketterer, & Giacalone, 1970; Pinckney, 1967) and facilitating effects (Frumkin & Brookshire, 1969; Gallon, 1972) on subsequent avoidance.

Most studies which have examined the effect of various shock densities have used between-group designs contrasting avoidance with other points in the contingency square. Some studies followed this comparison of (1,0) vs. other densities with (0,0) extinction while others have not. Olson, Davenport and Kamichoff (1971) for example compared (1,0) avoidance with partial reinforcement schedules. In this particular case a partial reinforcement of 50% was equivalent to (1,.5), a 0% schedule was (1,1) and a 100% schedule was (1,0) avoidance. These authors held $P(S|\bar{R})$ constant while they varied $p(S|R)$. Thus responding did not always prevent shock, but failures to respond were always shocked. Others refer to partial schedules as those in which the $P(S|R)$ is varied while the $P(S|\bar{R})$ is held at zero. This inconsistency in terminology again emphasizes the need for a system classifying the $P(S|\bar{R})$and $P(S|R)$ separately such as in the contingency square of Gibbon, et al. (1974). Olson, et al. used female rats in a standard operant chamber. During 320 trials of acquisiton over two days significant differences between groups emerged. Responding was highest in the (1,0) group, lowest in the (1,1) group and intermediate in the (1,.5) group.

Following (1,1) extinction the (1,0) and (1,.5) groups decreased responding while the (1,1) group increased slightly. During an avoidance phase which followed extinction all groups showed large increases in responding. In a related, but more detailed parametric study Davenport, Olson and Olson (1971) found similar results. Using contingencies of (1,0), (1,.25), (1, .5), (1,.75) and (1,1) they found significant differences between the (1,0) and (1,.25) groups and all other groups. In general, as $P(S|R)$ increased, responding decreased. Following (1,1) extinction all groups except the (1,1) groups decreased responding.

Galvani (1973) used the same contingency points as Olson et al., (1971), but used gerbils as subjects. Male adult gerbils were used in a tilt-shuttlebox with a tone as CS. As with rats, responding was highest in the avoidance (1,0) group and lowest in the (1,1) group. These findings were essentially replicated in a more recent study (Galvani, Twitty, & Foster, 1975). Regardless of whether there was a 30-sec or 90-sec ITI the authors found that gerbils assigned to the avoidance contingency responded more frequently than those assigned to the partial (1,.5) group.

One of the more complete investigations was undertaken by McGinnis and Theois (1972) in two experiments which manipulated the number of shocked, no-response trials. They used adult female rats in a one-way shuttlebox with contingencies equivalent to (.1,0), (.2,0), (.4,0), (.7,0) and (1,0). All subjects received a light plus noise CS and received a minimum of 50 acquisition trials. They found that as the $P(S|\overline{R})$ increased the number of trials to criterion increased. All groups except (.1,0) eventually reached asymptotic levels with probabilities greater than .9. During extinction less than half the subjects stopped responding in 150 trials. The mean number of trials before a failure to respond was 61.8. There were no consistent differences between groups indicating that varying $P(S|\overline{R})$ did not systematically affect extinction.

Neffinger and Gibbon (1975) successively presented (1,0) and partial contingencies to rats in operant chambers. Response probability during the partial contingencies decreased as the contingency coordinates moved further from the avoidance point (1,0) on the contingency square. Contingency-sensitive, Class I, subjects decreased responding to near zero with points on the diagonal of independence. Class II subjects, which were both contingency- and shock-density sensitive increased responding as the shock density of the point on the diagonal increased. Responding for all subjects was high during (1,0) avoidance.

A few fish studies have investigated contingency points other than (1,0). Woodard and Bitterman (1971) compared (0,0) with (1,0) for 10 trials per day for 13 days. Responding was higher in the avoidance group than in the (0,0) group. Following this the fish received shock on every trial for 12 days. During the (1,1) procedure fish originally given (1,0) decreased slightly while the original (0,0) group increased. This was followed by a traditional (0,0) extinction during which all fish decreased responding. In a later experiment Woodard and Bitterman (1973) compared (1,0) with (1,1). After 14 sessions of 10 training trials in each session, avoidance groups responded more frequently than classical (1,1) groups. After 10 days of (0,0) extinction all groups had decreased substantially.

Scobie and Fallon (1974) studied the effect of noncontingent shock on subsequent acquisition or extinction using goldfish. The Scobie and Fallon experiment used a factorial design in which the presence and absence of the CS and the US were manipulated during five pretreatment sessions. This was followed by five avoidance sessions. The CS was an overhead light and the US was shock. At the end of the pretreatment control phase, groups which did not receive shock, CS-only and no CS/US, responded more frequently than those who did. The highest response frequency occurred in the no CS/US group. Initially there were differences between the groups when the avoidance contingency was introduced. By the third session all groups were responding more frequently than during pretreatment. At the end of the fifth session of avoidance all pretreatment groups except US-only were responding with a probability of greater than .8. The delivery of noncontingent shock without a CS led to a slightly lower level of avoidance responding while the delivery of noncontingent shock with an unpaired CS did not.

While Scobie and Fallon studied the effect of noncontingent shock on subsequent avoidance, Marsh and Paulson (1968) compared the effect of an avoidance contingency vs. noncontingent shock on responding during training and subsequent extinction. Goldfish were used in a shuttlebox with light as a CS. Two groups were trained on an avoidance contingency (1,0) while a third group received a shock density of .5 independent of responding. Shock was randomly delivered over trials so that $P(S|\bar{R})$ and $P(S|R)$ were uncontrolled, and unknown. After five sessions of fifty trials each there were small differences between contingent and noncontingent groups. During extinction the group which was given (1,0) in acquisition and traditional (0,0) extinction with a response-terminated CS showed little decrease in responding. The greatest decrease in responding occurred in the group which received (1,0) during acquisition and in extinction was given a response-independent CS termination for the first 25 trials and a response-dependent CS termination for the last 25 trials. The .5 acquisition group with a response-independent CS responded at an intermediate level during extinction. The authors concluded that noncontingent shock resulted in no decrement in shuttling during training but could lead to resistance to extinction. Unfortunately the experimental design which used different CS procedures for different groups both in acquisition and in extinction weakens the authors' conclusions.

All of these studies using rats and gerbils indicate that responding is highest on a maximal avoidance contingency. Neffinger and Gibbon (1976) and McGinnis and Theois (1972) found lower responding when $P(S|\bar{R})$ was less than 1. It has also been shown (Davenport et al., 1971; Galvani, 1973; Galvani et al., 1975; Neffinger & Gibbon, 1975; and Olson et al., 1971) that as ($P(S|R)$ is increased responding decreases. In general responding tends to be highest with a (1,0) contingency and lowest with a (1,1) contingency. When (0,0) groups were compared to (1,1) groups (Scobie & Fallon, 1974) responding was higher in the (0,0) if the subjects were goldfish. Neffinger and Gibbon (1975) found equivalent responding in both conditions with Class I rats and higher responding with higher shock density points on the diagonal of independence with Class II rats.

Design Rationale

Experiment 3 was designed to further investigate the role of the response-reinforcer contingency and the effects of noncontingent shock delivery. Following (0,0) operant level fish were assigned to either (0,0), (.5,.5) or (1,1) on the diagonal of independence. This provided an opportunity of study the effect of various noncontingent shock densities and determine whether performance under (1,1), which like classical conditioning results in shock on every trial, was superior to the (0,0) and (.5,.5) groups. Pre-exposure to shock also permitted examination of the question of whether pre-exposure would facilitate or interfere with subsequent avoidance using foldfish. Experiment 3 used the IMSD extinction procedure where shock density remained the same although the response-reinforcer contingency was no longer in effect. This was followed, as in Experiment 2, by (0,0) traditional no-shock extinction providing a comparison of extinction procedures as well as the effect of the (0,0) contingency in operant level and extinction. Finally punishment, a maximal contingency infrequently studied using goldfish, was investigated.

Method

Subjects

Goldfish similar to those used in Experiment 2 were obtained from the same local supplier. They were of unknown sex and age. Twenty fish were randomly assigned to either a (.5,.5) or (1,1) preavoidance condition. Illness or apparatus malfunction caused two subjects from the former and one from the latter condition to be discarded. They were replaced with new naive fish while the experiment was in progress. The (0,0) group had six subjects. The mean length for fish used in this experiment was 5.8 cm with a standard deviation of 0.4. The mean dorsal to ventral width was 1.8 cm with a standard deviation of 0.03.

Apparatus

The same apparatus was used as in Experiment 2.

Procedure

Goldfish were randomly selected from a community tank and adapted to individual tanks prior to the start of the experiment. The sequence of contingencies for each group is presented in Table 10. Although the (0,0), (.5,.5) and (1,1) groups all have the same number of sessions prior to the avoidance phase, the (0,0) group is on the same contingency for both operant level and preavoidance. As in Experiment 2 each contingency was in effect for 12 sessions with 20 trials per session. Between each contingency there was a transitional session with 10 trials from the previous contingency followed by 10 trials from the new contingency. Data from transitional sessions were not included in the data analysis. During noncontingent extinction shock density was individually determined by the shock density over the last three avoidance trials as in Experiment 2. Environmental conditions were maintained identically to those in Experiment 2.

Results

The effect of contingency on responding

The mean number of responses over blocks of three sessions are shown in Figure 18. A repeated measures

Table 10

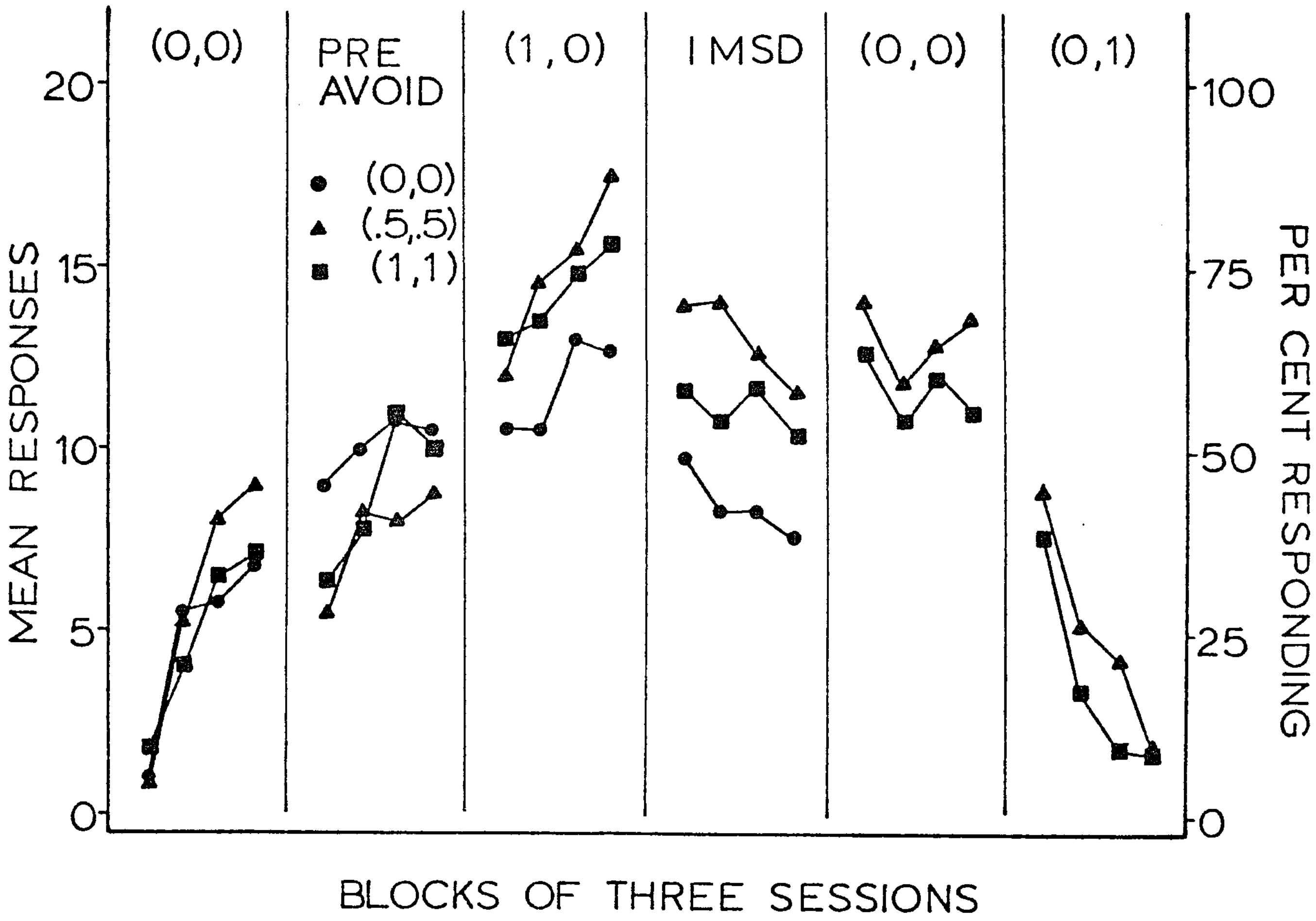
Sequence of Experimental Treatments as Specified by the Contingency Coordinates $P(S|\bar{R}), P(S|R)$

Group	N	Operant level	Preavoidance	Avoidance	IMSD Extinction	No Shock Extinction	Punishment
(0,0)	6	(0,0)	(0,0)	(1,0)	a		
(.5,.5)	10	(0,0)	(.5,.5)	(1,0)	a	(0,0)	(0,1)
(1,1)	10	(0,0)	(1,1)	(1,0)	a	(0,0)	(0,1)

Note: Group (0,0) was added as a control group while the experiment was in progress and was not given No Shock Extinction or Punishment.

[a] Shock density was individually matched to that received during the final three sessions of avoidance conditioning. During IMSD Extinction $P(S|\bar{R}) = P(S|R)$.

Figure 18. Mean number of responses over blocks of three sessions under each contingency for the (0,0), (.5,.5) and (1,1) groups. (N = 26.)


(0,0)
PRE AVOID
(1,0)
IMSD
(0,0)
(0,1)
● (0,0)
▲ (.5,.5)
■ (1,1)
MEAN RESPONSES
0
5
10
15
20
PER CENT RESPONDING
0
25
50
75
100
BLOCKS OF THREE SESSIONS

analysis of variance presented in Table 11 indicated that there was a significant effect at the .01 level attributable to contingency manipulation. Although there are some differences in responding between the three groups as shown in Figure 11, there was no significant group effect. There was a significant group X contingency interaction effect. During the initial operant level session all groups had a mean of less than one response per session. Responding montonically increased to 6.9, 9.2, and 7.3 mean responses for the (0,0), (.5,.5) and (1,1) groups during the final three operant level sessions. As in the previous studies this pseudo-learning curve effect occurred despite the absence of shock.

The pseudo-learning curve effect continued in the (0,0) group during the preavoidance phase. The introduction of shock in the other groups initially led to a decrease in responding. The (1,1) group eventually increased responding to a rate higher than during operant level while the (.5,.5) group never reached a level higher than final operant level performance. During the last block of three preavoidance sessions the (0,0) group had the highest mean frequency.

During avoidance all groups increased during the first block of trials. Groups (1,1) and (.5,.5) monotonically increased during avoidance. Group (0,0) decreased during the third block. Response levels for all groups were higher at the end of avoidance than at the end of any other contingency. During the last block of avoidance sessions

Table 11

Analysis of Variance for Mean Responses during the Final Three Sessions of Each Contingency

Source	*df*	*MS*	*F*
Between subjects			
Groups	2	46.64	1.25
Subjects within groups	23	37.43	
Within subjects			
Contingency	5	515.04	49.81*
Groups x Contingency	10	36.50	3.53*
Contingency x Subjects within groups	115	10.34	

*$p < .01$

responding was highest in the (.5,.5) group with a mean of 17.6 responses. The (0,0) and (1,1) groups increased to means of 13.0 and 15.4 respectively during the final avoidance block.

When fish were changed to IMSD extinction responding decreased. From the last three avoidance sessions to the last three noncontingent extinction sessions the means decreased by 5.9, 4.9, and 5.0 responses for the (0,0), (.5,.5) and (1,1) groups respectively. After the (.5,.5) and (1,1) groups were switched to traditional (0,0) extinction, responding initially increased but stayed at the same level overall.

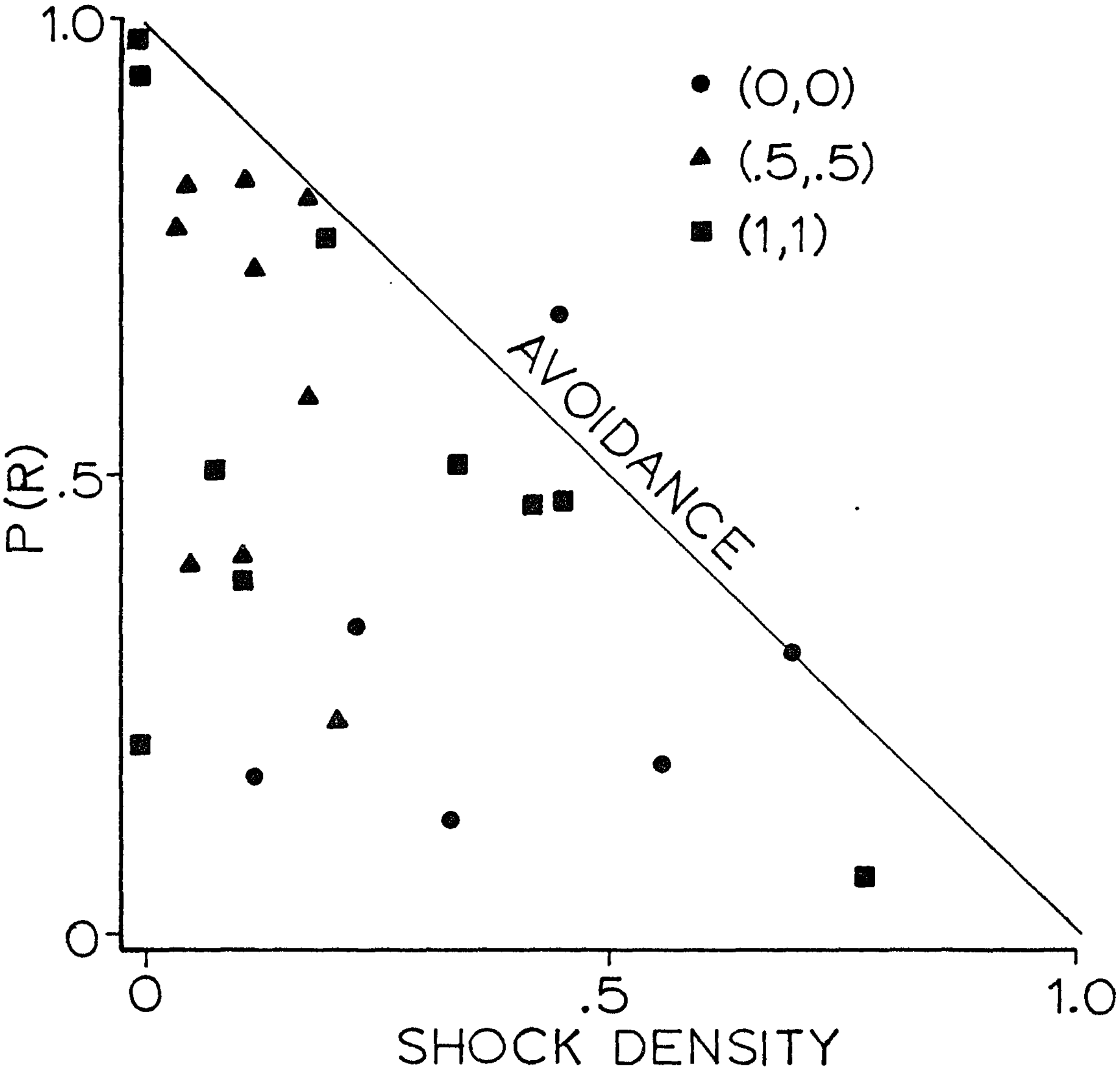
The introduction of the punishment (0,1) contingency led to decreases during the first punishment session and responding continued to decrease until the last session. During the final block the mean number of responses had decreased to 2.1 for the (.5,.5) group and 1.8 for the (1,1) group. A Neuman-Keuls test of paired comparisons indicated that there were significant differences at the .01 level between the following groups: punishment and all other contingencies, avoidance and all other contingencies, operant level and traditional (0,0) extinction. Comparisons of groups within each contingency found a significant difference between groups only during IMSD extinction.

The relationship between responding and shock density

Figure 19 shows the probability of responding as a function of shock density (percentage of shocked trials) during the last three IMSD extinction sessions. As in the the similar graph, Figure 13 of Experiment 2, the diagonal represents the density of shock that occurs with a given probability of responding during avoidance. All but two subjects, one each from the (0,0) and (.5,.5) groups, shifted their probabilities of responding downward during the IMSD extinction phase. The largest single decrease in P(R) from the end of avoidance to the end of IMSD extinction was .88 to .17 for Subject 104. There was no uniform downward displacement from the diagonal either between groups or within groups. However the (1,1) group tended to displace downward less and variability in the (0,0) group seemed greatest.

As in the previous experiment, the independent programming of $P(R|\bar{S})$ and $P(R|S)$ sometimes caused actual shock densities to vary from those programmed. Over all subjects the mean $P(R|S)$ was .003 higher than the $P(R|\bar{S})$. The shock densities received varied by a mean of .01 from the shock densities received in avoidance. Individual shock densities are presented in Appendix E.

Figure 19. Probability of a response as a function of shock density during first and second individually-matched-shock-density (IMSD) extinction. The diagonal represents the locus of all possible response and shock combinations during avoidance. In IMSD extinction data points from individuals can move directly upward or downward since shock density was unchanged.


1.0
.5
0
P(R)
0
.5
1.0
SHOCK DENSITY
AVOIDANCE
● (0,0)
▲ (.5,.5)
■ (1,1)

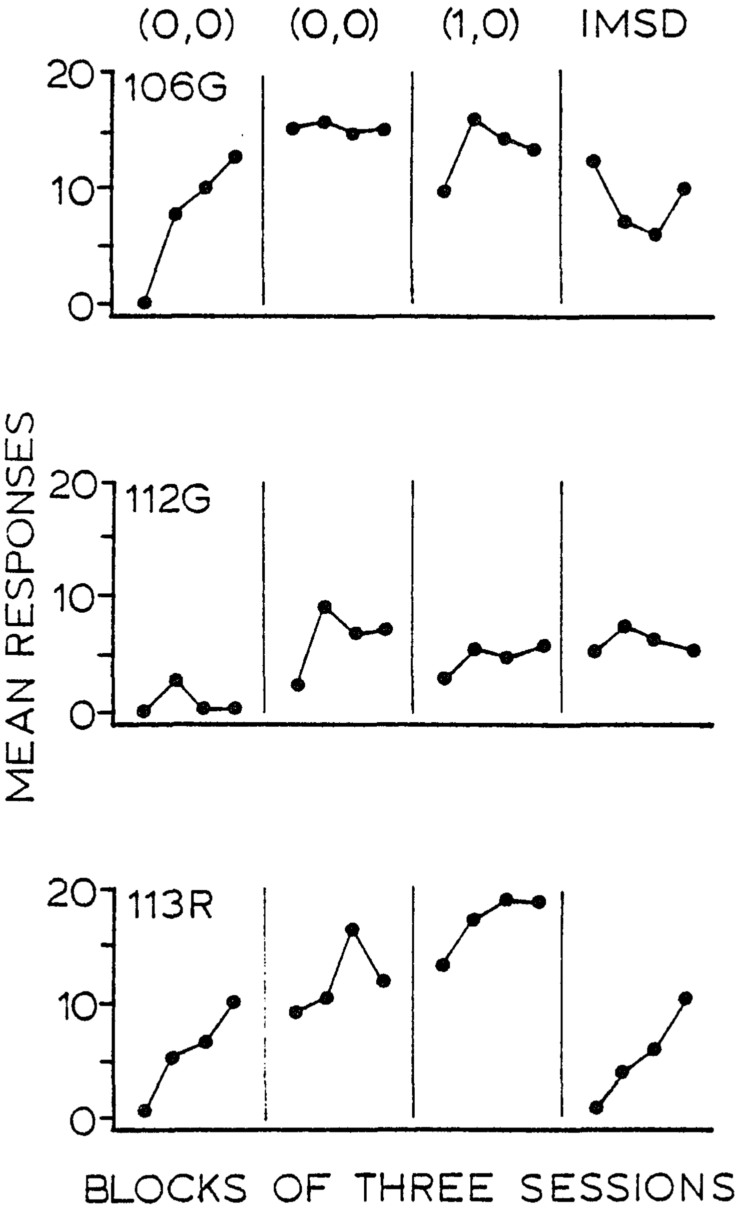
Individual Differences in Responding

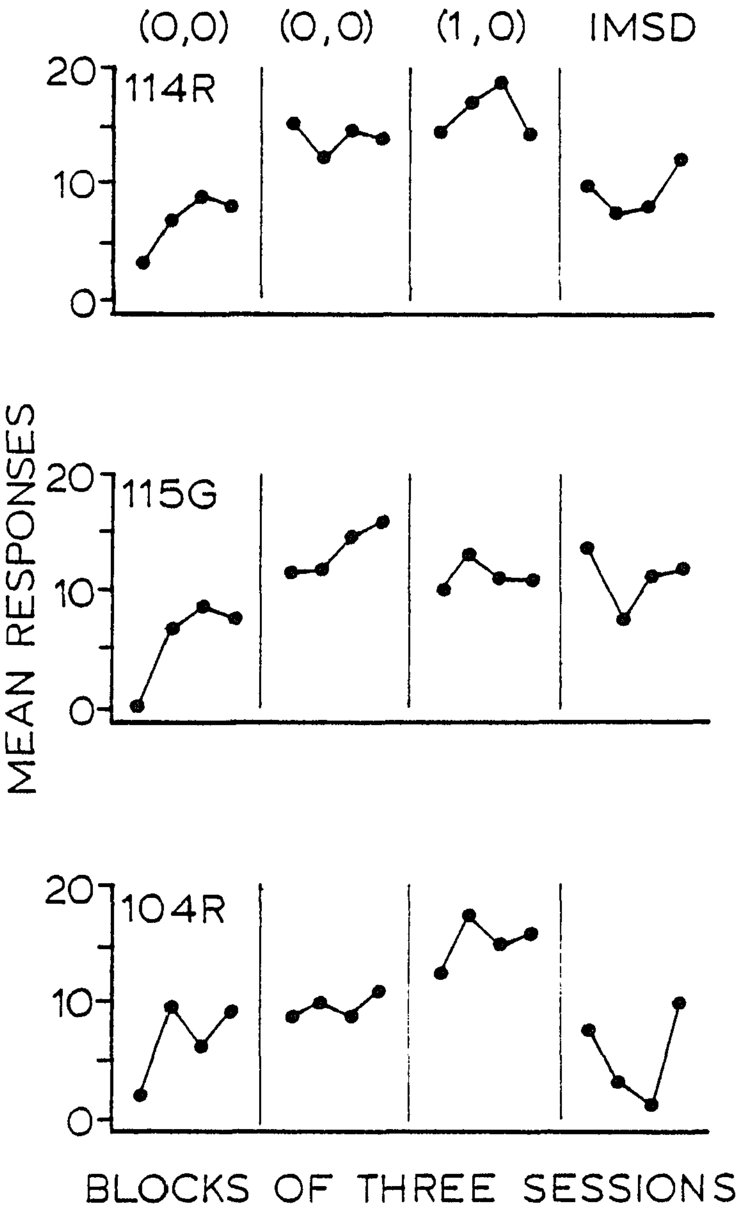
Although 23 of 26 subjects in each group followed the pattern of highest response probabilities during avoidance, lower during the extinctions and lowest during punishment there were individual differences. Individual response curves over blocks of three sessions are presented in Figures 20 to 28. Differences can be seen in the very first phase, operant level (0,0). During the last block of operant level mean daily responses ranged from 1.3 for fish 31G to 14.3 for fish 20R.

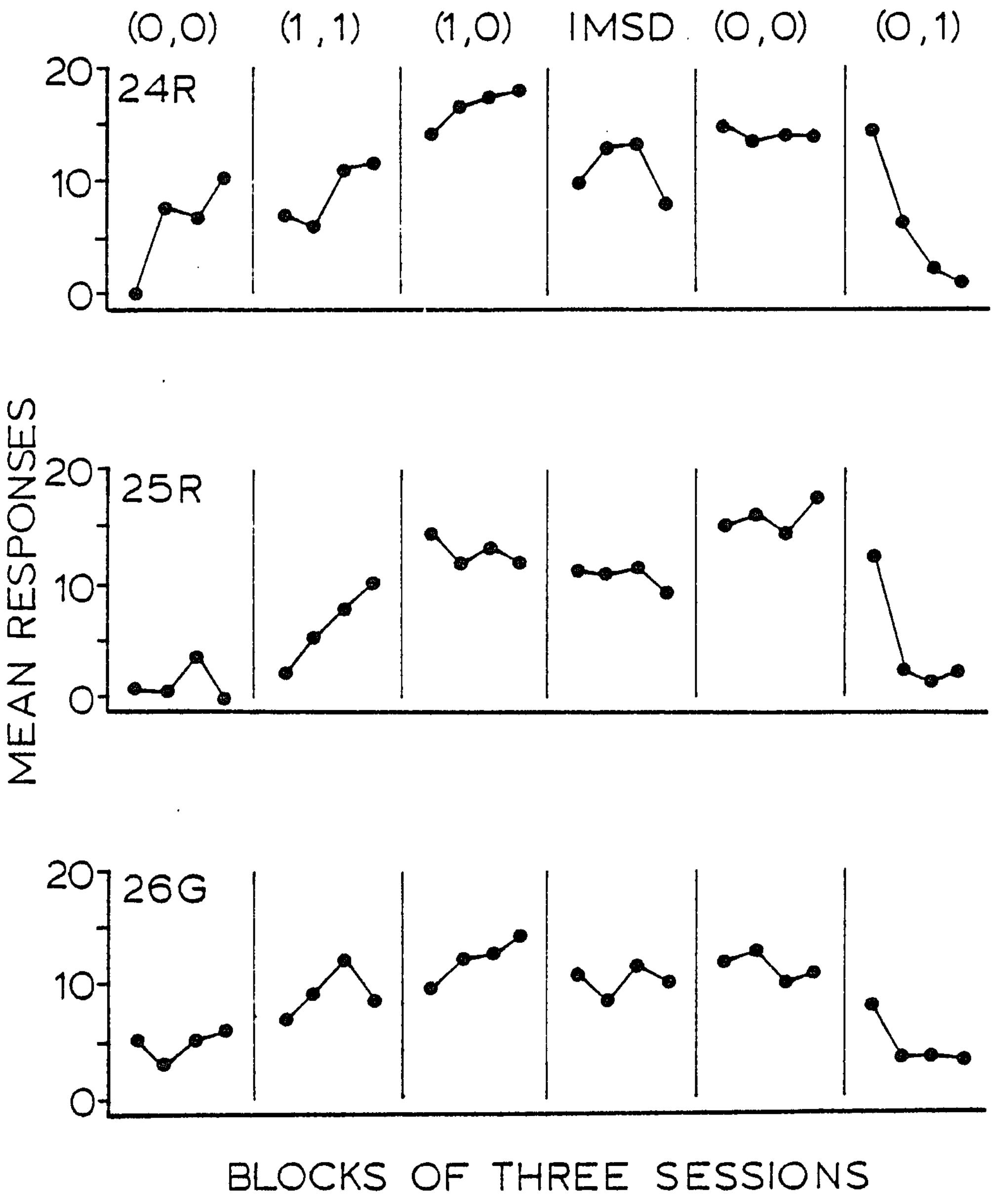
During preavoidance 18 of the 26 fish had higher response frequences at the end of preavoidance compared with the end of operant level. The smallest proportion of increases occurred in the (.5,.5) group where only four of ten subjects increased. In the (1,1) group eight of ten subjects increased and in the (0,0) group all six subjects increased. Among fish which increased some showed monotonic increases over sessions while others were more irregular.

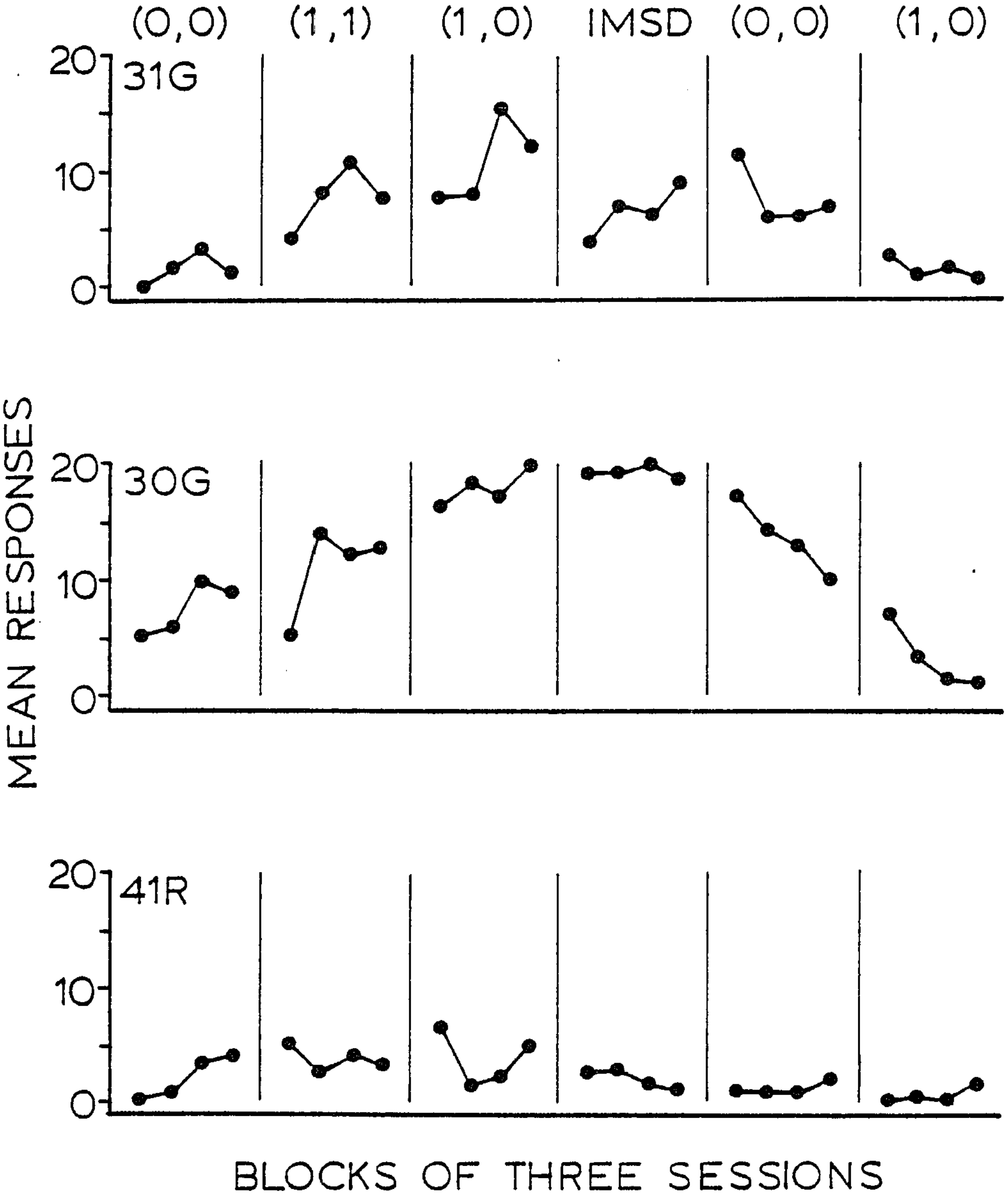
During the first three avoidance sessions subjects assigned to the (0,0) group were least likely to increase responding while those in the (1,1) group were most likely to increase. Only four of the six (0,0) fish increased during the first avoidance block while nine of the ten (.5,.5) fish increased and all ten (1,1) fish increased. Only the four (0,0) subjects which initially increased

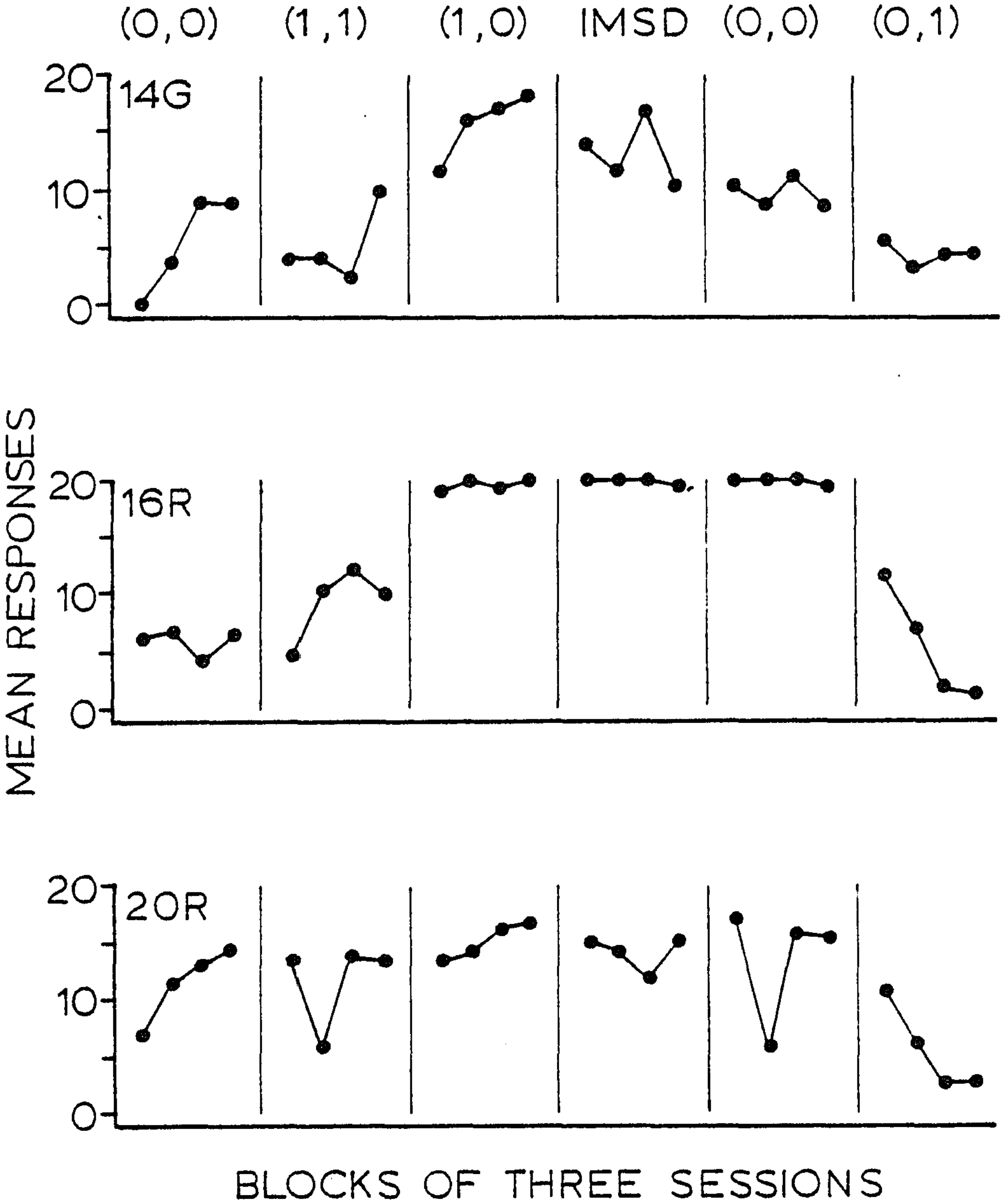
Figures 20-28. Individual mean number of responses over blocks of three sessions under each contingency.

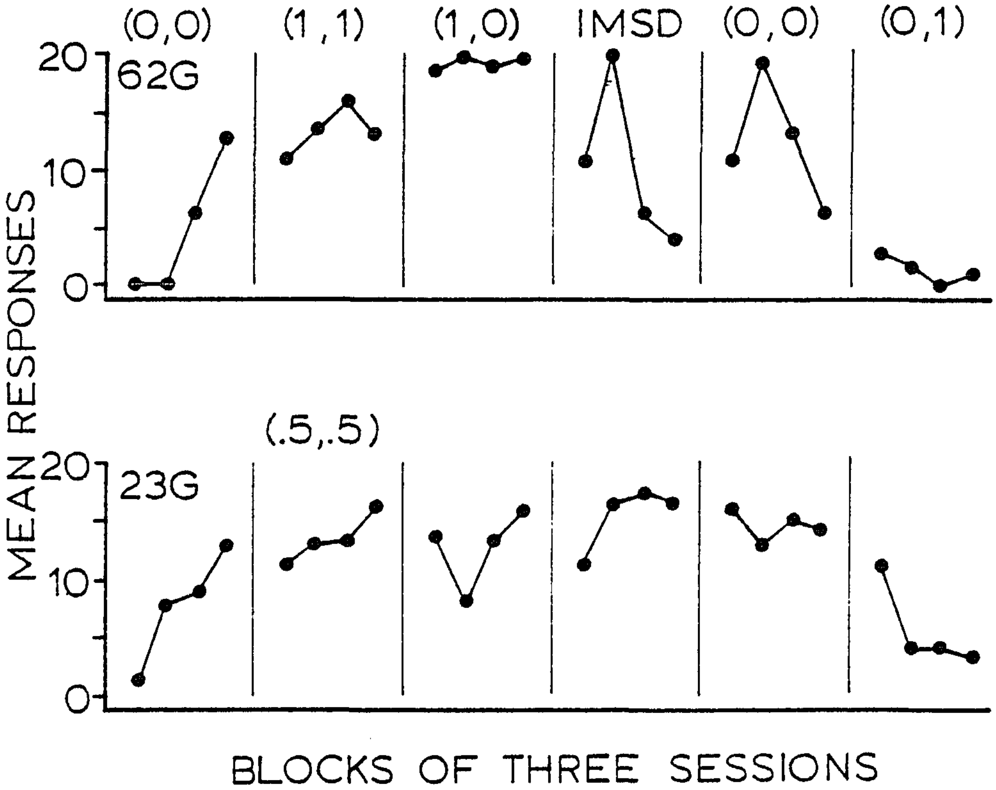

(0,0)
(0,0)
(1,0)
IMSD
106G
112G
113R
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS

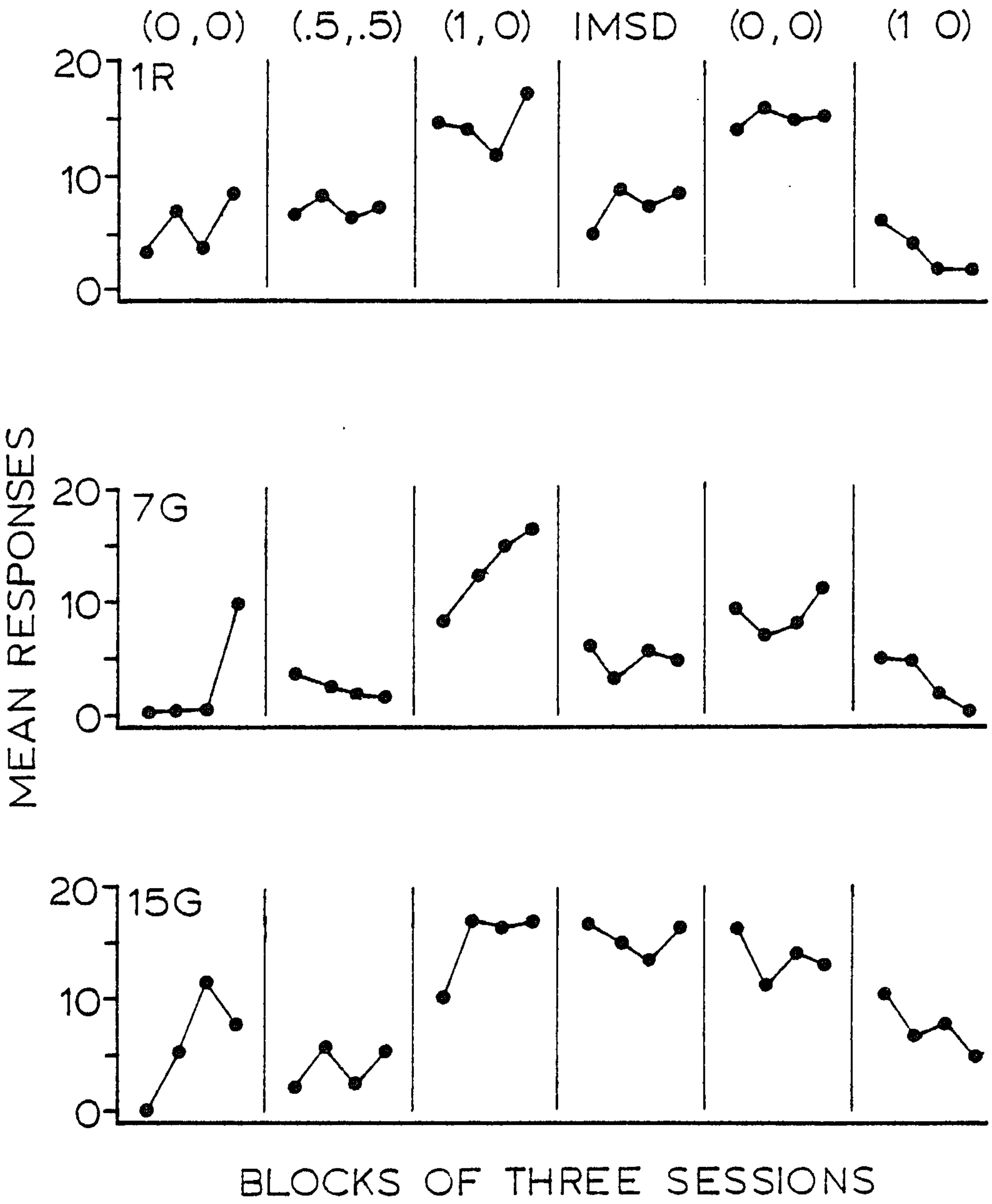

(0,0)
(0,0)
(1,0)
IMSD
114R
115G
104R
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS

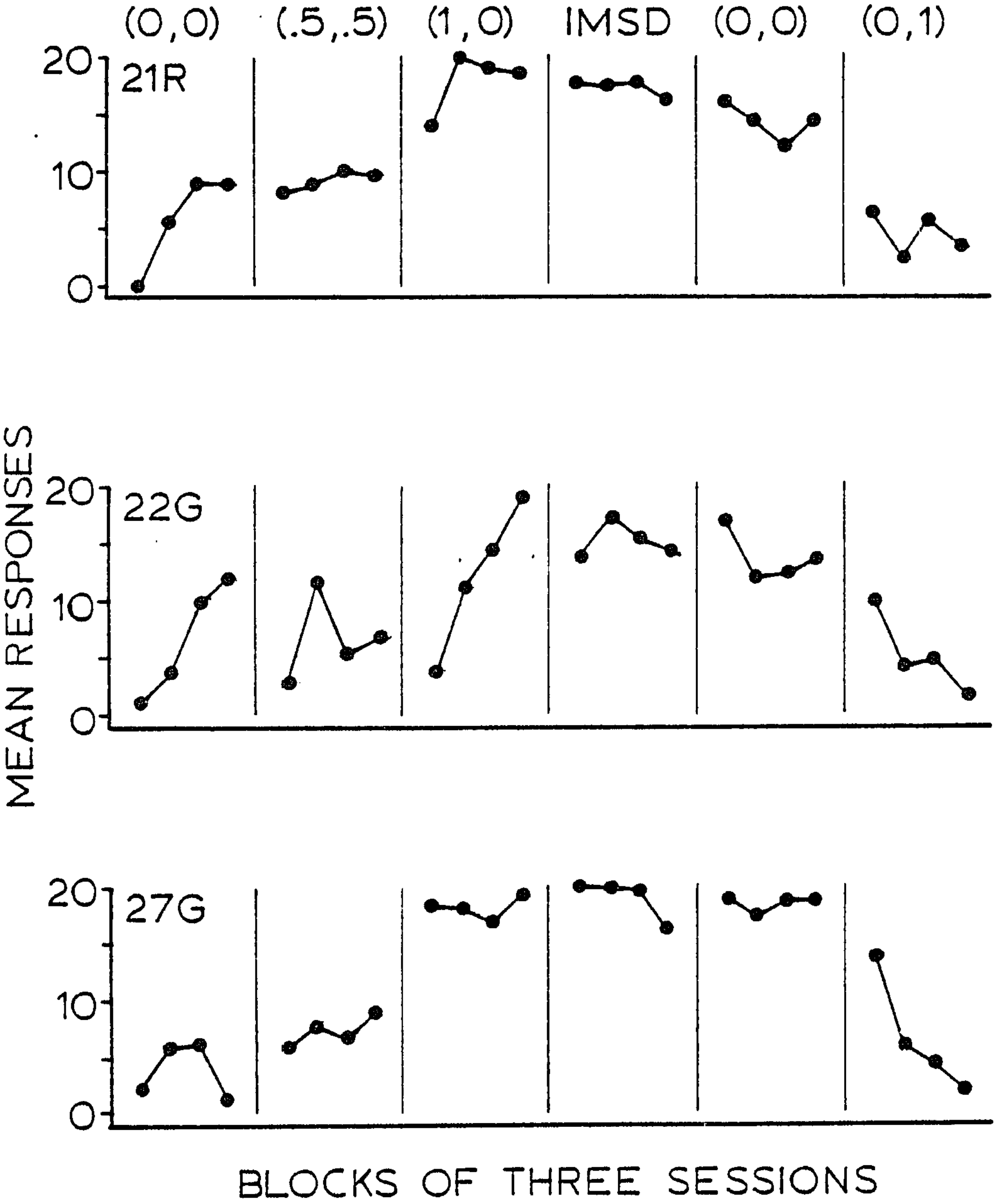

(0,0)
(1,1)
(1,0)
IMSD
(0,0)
(0,1)
24R
25R
26G
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS

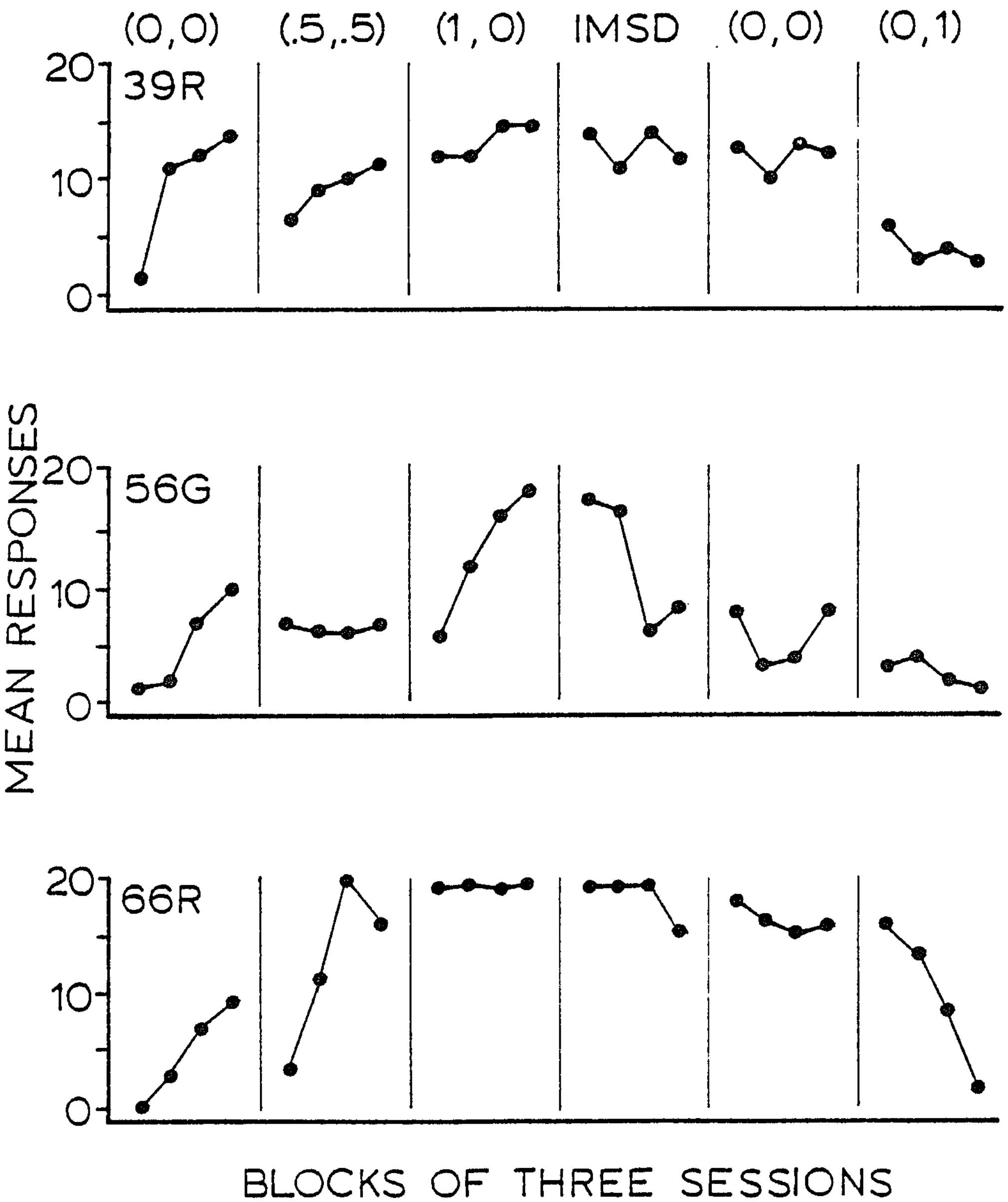

(0,0)
(1,1)
(1,0)
IMSD
(0,0)
(1,0)
31G
30G
41R
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS


(0,0)
(1,1)
(1,0)
IMSD
(0,0)
(0,1)
14G
16R
20R
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS


(0,0)
(1,1)
(1,0)
IMSD
(0,0)
(0,1)
62G
(.5,.5)
23G
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS


(0,0)
(.5,.5)
(1,0)
IMSD
(0,0)
(1 0)
1R
7G
15G
0
10
20
MEAN RESPONSES
BLOCKS OF THREE SESSIONS


(0,0)
(.5,.5)
(1,0)
IMSD
(0,0)
(0,1)
21R
22G
27G
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS


(0,0)
(.5,.5)
(1, 0)
IMSD
(0,0)
(0,1)
39R
56G
66R
20
10
0
MEAN RESPONSES
BLOCKS OF THREE SESSIONS

responding in avoidance surpassed the frequencies of their last preavoidance block during their last avoidance block. In the (.5,.5) group all but one fish had higher avoidance frequencies during the last avoidance block than during the last preavoidance block. In the (1,1) group all subjects were higher during avoidance. Some fish in each group immediately started responding more frequently in avoidance and monotonically increased over sessions. Others varied from day to day. Neither of these response patterns appear to be related to response probability in operant level. Some high avoidance responders had high operant levels, such as 14G. Others, most notably 31G, had low probabilities prior to the introduction of the avoidance contingency.

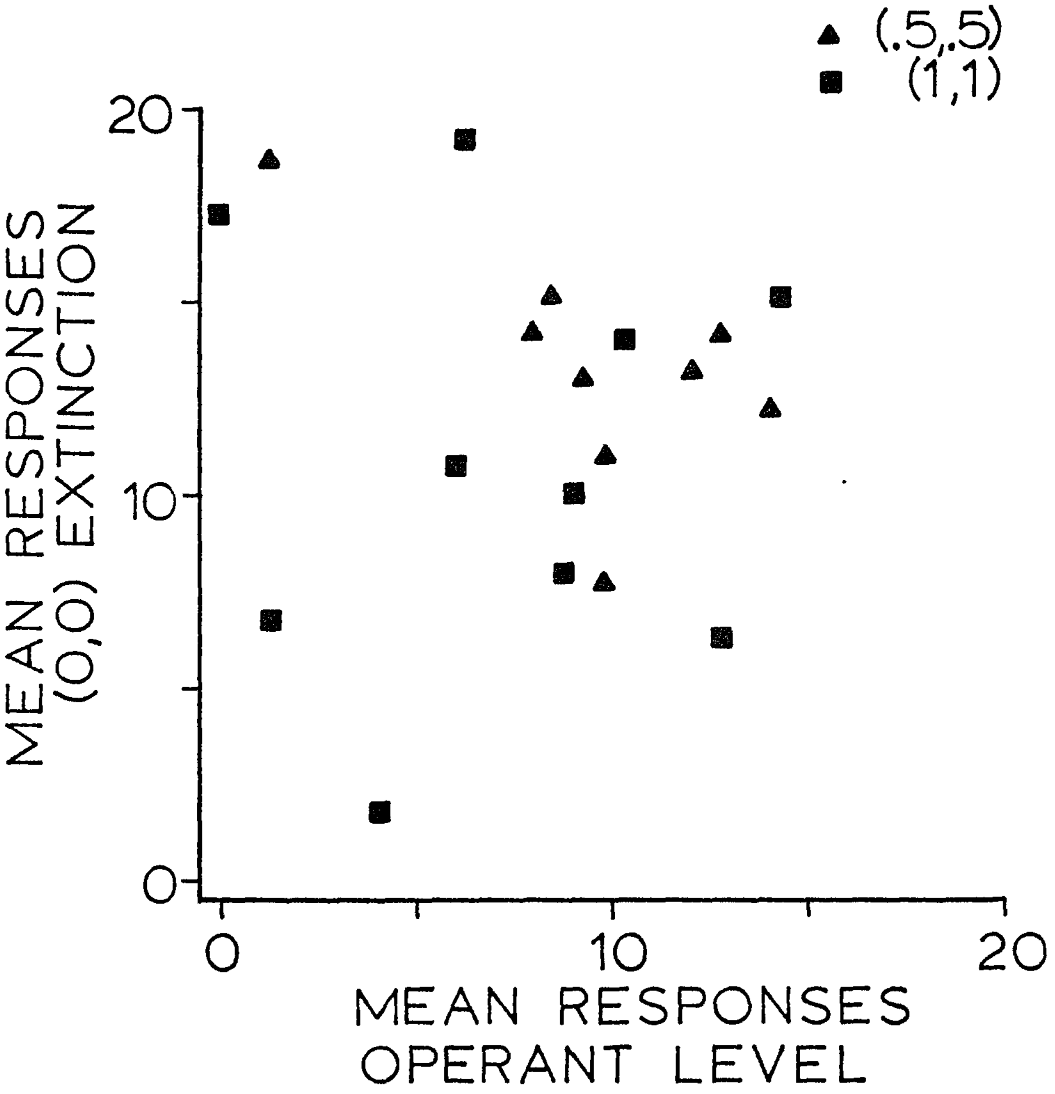
Most subjects in all groups showed a decrease in responding during IMSD extinction. Comparing the last block of avoidance and the last block of IMSD extinction five of the six from (0,0) and nine of the ten from (.5,.5) and ten of the ten from (1,1) decreased. Among (.5,.5) subjects, the fish least sensitive to the avoidance contingency, 23G, was the only subject which did not decrease responding during IMSD extinction. The two (0,0) subjects which did not decrease responding during ISMD extinction (112G, 115G) also did not increase responding during avoidance.

Introduction of the traditional extinction procedure did not have a large effect on response probabilities: some increased, some decreased, but many stayed at approximately the same level. Six of the ten (.5,.5) group decreased further while only three of the ten (1,1) fish decreased. There did not appear to be a definite relationship across subjects or groups between responding under the (0,0) contingency in operant level and the (0,0) contingency in traditional avoidance. Figure 30 shows a scatter-plot for (.5,.5) and (1,1) subjects. A Pearson's r for the (.5,.5) group was calculated (*r* = -.57) indicating a tendency for low responding during operant level to be correlated with higher responding during traditional extinction. The scatter-plot of all (1,1) subjects indicates no linear relationship between responding in operant level and traditional extinction (*r* = .04).

During punishment all subjects in both groups decreased responding. All but two fish, 24R and 66R, decreased in the first punishment block and the final punishment block shows that all but one fish responded less at the end of punishment. Two of the (.5,.5) fish and four of the (1,1) fish responded less during the final punishment block than during the initial operant level block.

During avoidance and both extinction procedures subject 16R maintained responding similar to the class II subjects in Experiment 2. Despite the noncontingent delivery of shock and then withdrawal of all shock responding remained as high as during avoidance. However, when the punishment

Figure 29. Relationship between mean responding for each fish during (0,0) operant level and (0,0) extinction.


▲ (.5,.5)
■ (1,1)
20
10
0
MEAN RESPONSES
(0,0) EXTINCTION
0
10
20
MEAN RESPONSES
OPERANT LEVEL

contingency was introduced responding decreased as would be expected of subjects under stimulus control of the contingency.

Analysis of responding following shock vs. no shock

The mean probability of a response on trials following a shock trial $P(R_n|S_{n-1})$, and the probability of a response on trials following a no-shock trial, $P(R_n|\bar{S}_{n-1})$, during the final three sessions of contingencies with shock are given in Table 12. During the preavoidance phase when data only from the (.5,.5) group could be analyzed, six of ten fish had $P(R_n|\bar{S}_{n-1}) > P(R_n|S_{n-1})$ with mean probabilities of .45 and .35, respectively. This small difference in probabilities when $P(S|\bar{R}) = P(S|R)$, suggests that the presence or absence of shock on the previous trial does not have a large effect. During avoidance response probabilities were higher following no shock on the previous trial for all groups. Only for 4 of 26 fish was $P(R_n|S_{n-1}) > P(R_n|\bar{S}_{n-1})$. One was from the (0,0) group while there were two each from the other groups. Successful avoidance rather than failure was most apt to lead to a successful avoidance on the next trial. During IMSD extinction the $P(R_n|\bar{S}'_{n-1})$ remained higher for all groups; however, the difference between probabilities decreased, ranging from .05 to .19. The number of individuals responding more frequently following shock increased to ten. Four of these were from the (0,0) group, three from (.5,.5) and three from (1,1). During punishment the

Table 12

Mean Probability of a Response following No Shock $P(R_n\ \bar{S}_{n-1})$ and Shock $P(R_n\ S_{n-1})$ during the Final Three Sessions of Selected Contingencies

Group	Preavoidance		Avoidance		IMSD Extinction		Punishment	
	$P(R_n\ \bar{S}_{n-1})$	$P(R_n\ S_{n-1})$	$P(R_n\ \bar{S}_{n-1})$	$P(R_n\ S_{n-1})$	$P(R_n\ \bar{S}_{n-1})$	$P(R_n\ S_{n-1})$	$P(R_n\ \bar{S}_{n-1})$	$P(R_n\ S_{n-1})$
(0,0)								
104R	.62	a	.86	.60	.11	.00	b	
106G	.72	a	.56	.19	.11	.12	b	
112G	.49	a	.28	.14	.64	.15	b	
113R	.73	a	.94	.67	.06	.12	b	
114R	.70	a	.78	.65	.22	.23	b	
115G	.82	a	.61	.55	.55	.60	b	
(.5,.5)								
1R	.43	.43	.88	.72	.43	.39	.08	.67
7G	.07	.10	.82	.89	.24	.37	.00	c
15G	.32	.20	.89	.53	.77	1.00	.26	.12
21R	.37	.49	.93	.25	.75	.67	.16	.12
22G	.40	.29	.98	.17	.75	.50	.15	.17
23G	.79	.54	.77	.78	.80	.50	.11	.22
27G	.54	.35	.96	.67	.73	1.00	.06	.17
39G	.61	.60	.76	.56	.68	.51	.13	.08
56R	.13	.46	.94	.83	.34	.25	.08	.00
66R	.78	.07	.98	.02	.90	.67	.06	.33
(1,1)								
14G	d	.51	.92	.83	.71	.56	.26	.10
16R	d	.51	1.00	c	.96	c	.08	.00
20R	d	.68	.89	.52	.64	.78	.15	.00
24R	d	.60	.88	.89	.60	.11	.04	.17
25R	d	.00	.41	.33	.57	.26	.12	.11
26G	d	.42	.77	.59	.51	.30	.15	.11
30G	d	.63	1.00	c	.92	c	.04	.11
31G	d	.38	.71	.45	.49	.57	.10	.13
41R	d	.42	.04	.14	.00	.06	.06	.00
62G	d	.63	1.00	c	.18	c	.00	.00

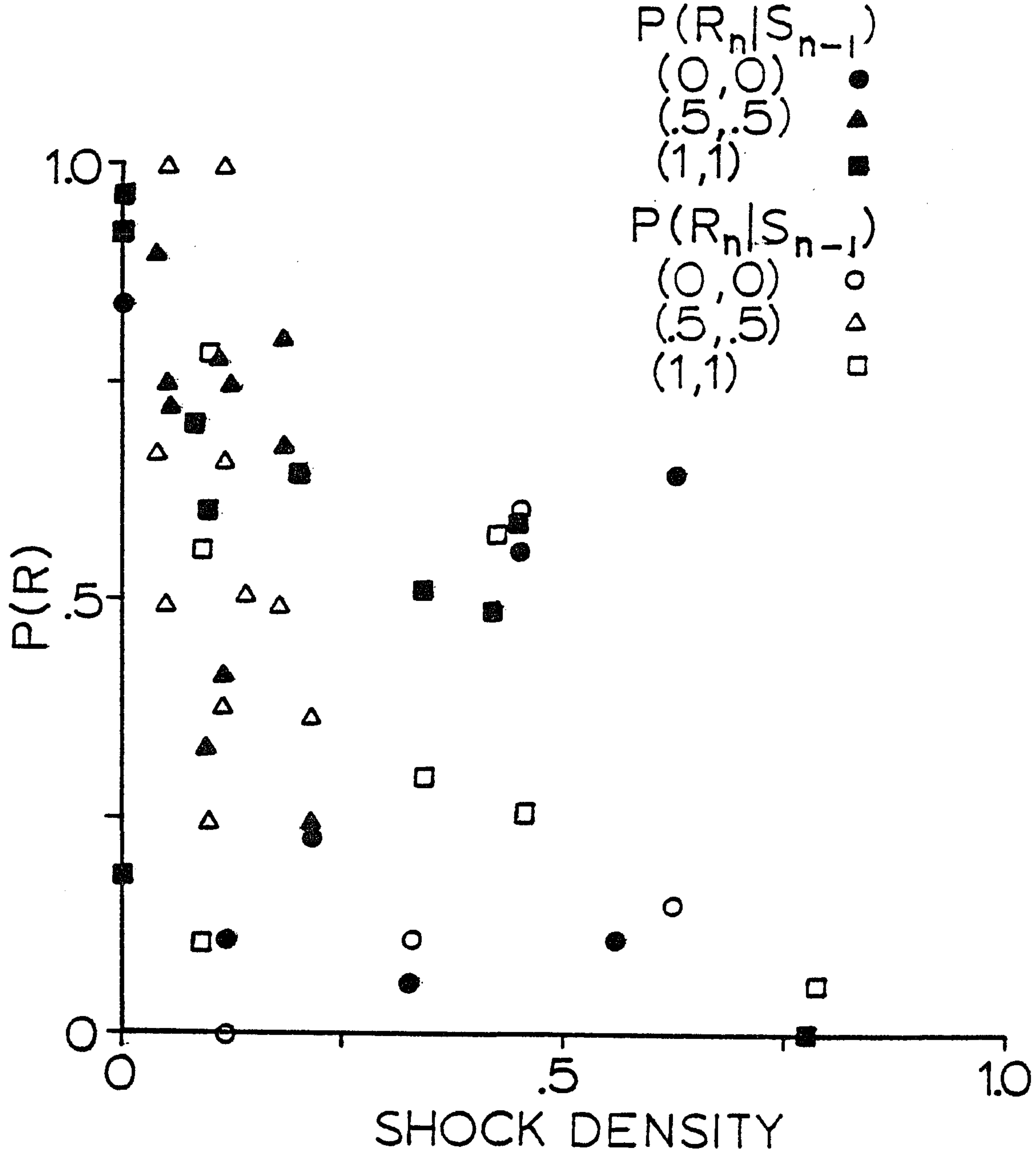
[a] Group (0,0) did not receive shock during preavoidance.

[b] Group (0,0) was not exposed to the punishment contingency.

[c] This subject did not receive shock during the final three sessions of this contingency.

[d] Group (1,1) received shock on every trial during this phase.

Figure 30. Probability of a response following no shock $P(R_n | \bar{S}_{n-1})$ and probability of a response following shock $P(R_n | \bar{S}_{n-1})$ as a function of shock density during individually matched shock density extinction (IMSD).


P(R_n|S_n-1)
(0,0) ●
(.5,.5) ▲
(1,1) ■
P(R_n|S_n-1)
(0,0) ○
(.5,.5) △
(1,1) □
1.0
.5
0
P(R)
0
.5
1.0
SHOCK DENSITY

mean difference between probabilities was small (.03). There was a reversal for the (.5,.5) group with $P(R_n|\bar{S}_{n-1})$ equal to .11 and the $P(R|S)$ equal to .19. This was the only phase in Experiment 3 during which mean responding in a group was higher following shock than following no shock. This occurred although only five of the ten individuals responded more following shock. In the (1,1) group, two subjects responded more frequently following shock while the remaining eight did not. Thus, typically subjects respond more frequently following no shock than following shock. This tendency is greatest during avoidance, less during noncontingent procedures, and even less or reversed when the contingency is punishment.

In Table 13 the shock densities as well as the probability of responding following shock and no shock are presented for individual subjects during the noncontingent phases. Figure 30 shows these probabilities as a function of shock density during noncontingent extinction. Again, as in the previous experiment identical shock densities do not necessarily lead to similar $P(R_n|S_{n-1})$. During preavoidance, although subjects in group (.5,.5) had identical or almost identical shock densities the $P(R_n|\bar{S}_{n-1})$ ranged from .07 to .79. On trials following shock the $P(R_n|S_{n-1})$ ranged from .07 to .60. During IMSD extinction fish with similar shock densities such as 1R and 15G did not have similar response probabilities, either after shock or after no shock.

Table 13

Shock Density and Mean Probability of Responding following No Shock $P(R_n|\bar{S}_{n-1})$ and Shock $P(R_n|S_{n-1})$ during the Final Three Sessions of Preavoidance and Individually Matched Shock Density (IMSD) Extinction

Group	Preavoidance			IMSD Extinction		
	Shock density	$P(R_n|\bar{S}_{n-1})$	$P(R_n|S_{n-1})$	Shock density	$P(R_n|\bar{S}_{n-1})$	$P(R_n|S_{n-1})$
(0,0)						
104R	.00	.62	a	.12	.11	.00
106G	.00	.72	a	.56	.11	.12
112G	.00	.49	a	.63	.64	.15
113R	.00	.72	a	.33	.06	.12
114R	.00	.70	a	.21	.22	.23
115G	.00	.82	a	.45	.55	.60
(.5,.5)						
1R	.54	.43	.43	.11	.43	.39
7G	.53	.07	.10	.21	.24	.37
15G	.53	.32	.20	.11	.77	1.00
21R	.52	.37	.49	.12	.75	.67
22G	.52	.40	.29	.05	.75	.50
23G	.53	.79	.54	.18	.80	.50
27G	.27	.54	.35	.05	.73	1.00
39G	.50	.61	.60	.18	.68	.51
56R	.55	.13	.46	.10	.34	.25
66R	.45	.78	.07	.04	.90	.67
(1,1)						
14G	1.00	b	.51	.08	.71	.56
16R	1.00	b	.51	.00	.96	a
20R	1.00	b	.68	.20	.64	.78
24R	1.00	b	.60	.09	.60	.11
25R	1.00	b	.54	.45	.57	.26
26G	1.00	b	.42	.28	.64	.78
30G	1.00	b	.63	.00	.92	a
31G	1.00	b	.38	.42	.49	.57
41R	1.00	b	.42	.78	.00	.06
62G	1.00	b	.63	.00	.18	a

[a] This subject did not receive shock during this phase.

[b] This subject received shock on every trial during this phase.

Figure 30 shows that there is a slight tendency for the P(R) to decrease as shock density increases. This tendency was seen both following shock and no-shock trials. A direct relationship between increased responding given increasing shock densities was not found as Woodard and Bitterman (1973) might have expected. Although such a relationship characterized Neffinger and Gibbon's (1975) rats, goldfish in this study (including those with a high P(R) during extinction phases) did not show such a relationship.

The effect of contingency on latency

The repeated measures analysis of variance shown in Table 14 indicated that there was a significant effect due to contingency manipulation. Mean median latencies for each contingency were individually compared using the Neuman-Keuls test. There were significant differences at the .01 level between punishment and all other contingencies except initial (0,0) operant level. Operant level latencies were also significantly different from those during avoidance and traditional (0,0) extinction.

Table 15 shows that latencies were relatively long during operant level and were shorter during preavoidance. During preavoidance the (.5,.5) group with unpredictable noncontingent shock had longer latencies than the two predictable groups. Median latencies decreased in all groups during avoidance with the biggest decrease in the (.5,.5) group.

Table 14

Analysis of Variance for Median Latencies during the Final Three Sessions of Each Contingency

Source	*df*	*MS*	*F*
Between subjects			
Groups	2	0.94	0.09
Subjects within groups	23	10.58	
Within subjects			
Contingency	5	31.25	13.24*
Groups x Contingency	10	1.19	0.50
Contingency x subjects within groups	115	2.36	

*$p < .01$

Table 15

Median Latencies (sec) during the Final Three Sessions of Each Contingency

Group	Contingencies					
	Operant level	Preavoidance	Avoidance	IMSD Ext.	No shock Ext	Punishment
<u>(0,0)</u>						
104R	5.7	6.2	3.4	8.3		
106G	6.1	5.1	5.0	3.2		
112G	11.6	8.3	8.7	5.9		
113R	5.3	4.4	3.6	5.7		
114R	5.5	4.9	4.9	8.1		
115G	7.0	4.9	4.3	5.5		
<u>Mdn</u>	5.9	5.6	4.6	5.8		
<u>(.5,.5)</u>						
1R	8.4	6.0	4.9	6.4	4.1	7.8
7G	7.8	5.7	7.0	6.4	5.3	12.8
15G	7.3	9.5	3.7	5.7	5.1	5.7
21R	5.4	5.3	3.4	3.8	3.6	4.5
22R	5.3	9.4	5.4	5.2	6.9	8.3
23G	5.2	3.2	4.5	3.5	2.9	5.4
27G	9.9	4.6	3.3	3.2	2.9	4.5
39G	5.7	7.0	4.6	6.0	6.2	8.4
56R	5.6	8.9	4.0	5.5	5.0	9.5
66R	7.0	3.6	3.2	4.6	4.3	7.0
<u>Mdn</u>	6.4	5.8	4.2	5.4	4.6	7.4
<u>(1,1)</u>						
14G	7.1	6.4	4.7	4.5	6.9	5.3
16R	6.4	4.5	2.3	3.1	3.0	9.3
20R	3.9	3.5	3.6	2.9	3.3	5.7
24R	4.9	3.4	4.5	4.3	3.2	7.6
25R	12.8	4.9	5.7	5.4	4.1	5.7
26G	4.8	5.4	5.0	6.6	5.4	7.4
30G	7.7	5.0	4.0	4.6	5.5	10.1
31G	11.2	7.2	4.6	4.8	6.4	6.9
41R	7.7	9.0	7.0	12.0	8.7	10.0
62G	4.5	5.8	3.0	8.5	7.8	5.7
<u>Mdn</u>	6.8	5.0	4.6	5.1	5.4	7.2

During ISMD extinction latencies decreased although they were still longer than avoidance latencies. The longest latencies for all groups occurred during punishment.

Discussion

Experiment 3 replicated Experiment 2 and provided new data on manipulation of contingencies involving shock.

Probability of Responding

Operant level. The pseudo-learning effect was replicated. The general shape (a slight negative acceleration over session blocks) was the same as in Experiment 2. The final mean response probability for all subjects pooled was slightly lower in this experiment than in Experiment 2, i.e., a probability of .52 compared to .34. The effect was observed over additional sessions in the (0,0) group.

Preavoidance. Manipulating shock density noncontingently following operant level and prior to avoidance training provided an opportunity to examine within group effects due to shock as well as the relationship between shock density and succeeding contingency manipulations. The major trends observed during preavoidance were: 1) initially decreased responding when shock was introduced in the (.5,.5) and (1,1) groups followed by increasing response probability, although the differences among groups were not significant statistically; and 2) with zero shock, the mean pseudo-learning curve grew in a monotonic fashion for an additional three blocks of three sessions, and turned downward for the first time in the final block of three sessions. Woodard and Bitterman would not have predicted the relatively high response probability of the (0,0) group and the comparable probabilities of the other groups. Their classical conditioning explanation would predict that higher shock densities would lead to more rapid acquisition while lower densities would result in lower response levels. There was no relationship between shock density and responding if all three groups are considered a continuum. However, data from other experiments in the fish literature can explain some of these results.

Responding was suppressed in both the (.5,.5) and (1,1) groups when shock was initially introduced in the preavoidance phase. The final level of responding during operant level provides a baseline against which the suppressive effects of shock introduction can be seen. Similar results have been obtained by other investigators using goldfish. When Woodard and Bitterman (1971) introduced contingent (1,0) or noncontingent yoked-control shock following operant level, responding declined. When a Pavlovian procedure followed a yoked-control procedure decreased responding did not occur. This indicated that the introduction of shock, not a change in shock density suppressed behavior. Woodard and Bitterman replicated this finding in a later study (1973). Scobie and Fallon (1974) found that introduction of an avoidance contingency initially suppressed responding in groups which had previously received

CS-alone, US-alone or neither. Suppression did not occur when avoidance followed pretreatment with unpaired CS's and US's. Thus the suppression effect was greatest when a US was introduced although introducing a CS probably further suppressed responding.

Responding in the (0,0) group is probably higher because conditions were identical during (0,0) operant level and (0,0) preavoidance. A monotonic increase continued until the seventh block of three sessions. This provides further evidence supporting the pseudo-learning effect with goldfish in the shuttlebox. The combined operant level (0,0) and zero shock preavoidance condition of Experiment 3 provided a longer baseline than any reported in the goldfish literature. Studies using free-operant procedures did not result in monotonic increases over as many sessions (Experiment 1) or did not include as many subjects (Steiner, 1971). Previous studies showing comparable effects using trials with light as a CS have been limited to five sessions (Scobie & Fallon, 1974; Zerbolio & Wickstra, 1978a, b). Consequently, the continued growth of the pseudo-learning curve found in Experiment 3 was not expected.

The lower response frequency in the (.5,.5) group is probably related to the predictability of shock. The CS complex for the (0,0) group never signalled shock while the CS complex always signalled shock for the (1,1) group. There was no relationship between the CS and shock delivery for the (.5,.5) group. Seligman, Maier, and Solomon (1971) in a review of the literature have reported that predictability of shock is important in determining behavior. For example, shocks delivered on a VI schedule caused more suppression with a CER paradigm than more frequent, predictable shocks. In Experiment 3, the (.5,.5) group with unpredictable shock did not increase as much as the (1,1) group. Even with a gradual increase over sessions during preavoidance responding in the (.5,.5) group remained below operant level. Sage-Day (1976) using rats in an operant chamber also found lower response probability when the CS was not a reliable predictor of shock.

Avoidance. During the first block of avoidance sessions shock initially suppressed responding for half the fish in the (0,0) group. Responding then recovered and was higher during he rest of avoidance than during preavoidance. Toward the end of avoidance responding decreased in three of six (0,0) fish. The final response level in this group was lower than that found at the end of the first avoidance phase in Experiment 2. This may be a residual effect due to the extended number of operant level sessions and would be interesting to investigate further.

Both the (.5,.5) and (1,1) groups increased responding when the (1,0) contingency was introduced. Prior experience with noncontingent shock did not produce an interference effect (learned helplessness) as had been found with dogs and rats. There may have been a slight facilitation effect although it should be noted that even during operant level mean responding in the (.5,.5) group was higher than the

(0,0) group. The higher responding in the (.5,.5) group during final avoidance might be related to the higher operant level of the group, a facilitation effect or an interaction of the two. Many studies with goldfish have found a facilitating effect of fear-conditioning but others have not. For example, Padilla et al. (1970) found that a large number of fear-conditioning trials with unavoidable shock usually led to interference . However, Gallon (1972) found facilitation using a smaller number of fear-conditioning trials. Even with a larger number of trials with unavoidable shock the interference effect only occurred if the interval between fear trials and initial avoidance testing did not exceed 72 hours (Padilla et al., 1970). Frumkin and Bookshire (1969) found that there was an interaction between facilitation and good vs. poor performers. There was no difference between the fear-conditioning group and a US-only control if the fish were poor performers. Fear conditioning facilitated avoidance for good performers while exposure to the US-only did not. The authors concluded that a fatigue effect from the US in fear conditioning might lead to an interference effect in poor performers which masked facilitation in good performers.

Although the number of fear-conditioning trials has been shown to be a factor there was no interference effect in Experiment 3 despite the large number of trials in preavoidance. The number of trials on a given day may be more important than the total number of trials over days. Only 10 or 20 shocked trials occurred in this experiment during regular preavoidance sessions. Although avoidance testing occurred immediately following noncontingent shock during the transition session only 5 or 10 shocks were presented during the ten preavoidance trials.

The role of response choice has been show to be important in determining whether facilitation or interference will occur (Weiss, Krieckhasus, & Conte, 1968). When competing responses such as freezing occur during fear conditioning interference results. Bolles (1970) has argued that acquisition in avoidance is facilitated if the response studied is a species-specific defense reaction (SSDR). If responses in fear-conditioning and shuttling are SSDRs, facilitation should result. Shock intensity also determines in part the organism's reaction to fear conditioning. All studies of shock intensity using goldfish (see the Introduction to Experiment 2) indicate that the shock level used in Experiment 3 would not cause freezing.

If a response does not have a high probability of occurrence, manipulation prior to fear conditioning can increase its probability and reduce an interference effect. Seligman et al. (1971) refer to the procedure of pretraining with avoidance prior to fear conditioning as "immunization." Although fish from Experiment 3 did not have previous avoidance experience, the shuttling opportunity during the operant level phase may have had an immunizing effect. Perhaps it is not the contingent responding during avoidance per se but the opportunity to acquire a high probability of shuttling that is the important factor in immunization. Richardson, Shumak, and Harvey (1977) compared the effect of restrained vs. free-swimming later acquired the avoidance response more rapidly. Subjects in studies designed to demonstrate learned helplessness are usually confined or restrained during the fear-conditioning stage. Although this may not directly lead to learning an incompatible response it does reduce the probability of acquiring a shuttling response.

Individually-matched-shock density extinction. All groups decreased responding during IMSD extinction. The response probabilities of the groups in IMSD were related to their order during avoidance, not during preavoidance since the group order of responding in avoidance and IMSD were parallel. The avoidance contingency (1,0) may have altered shuttling sufficiently so that residual effects from preavoidance were minimized.

The mean decrease from (1,0) to IMSD sessions was the greatest for the (0,0) groups. The decrease was larger for the (0,0) group in Experiment 3 than for subjects in the first IMSD extinction in Experiment 2. This is probably due to this group's decrement in responding during the final avoidance sessions. Whether the avoidance decrement is related to the larger number (25) of sessions on (0,0) cannot be determined from the data.

Traditional (0,0) extinction. There was very little difference in mean number of responses for the (.5,.5) and

(1,1) groups during extinction. However, inspection of individual response curves shows that 6 of 10 (.5,.5) fish decreased responding while only 3 of 10 (1,1) fish decreased. Other studies would have predicted a greater decrease in responding when (0,0) extinction followed IMSD extinction. When Coulson et al. (1969) immediately followed IMSD with (0,0) extinction a more abrupt decrease in responding occurred. Neffinger and Gibbon (1975) and Smith (1974) found that rats often stopped responding with the traditional (0,0) extinction procedures. Neffinger and Gibbon found the (0,0) contingency was even effective with Class II rats. These rats are more sensitive to shock density per se and may have stopped responding because no shock was delivered rather than because the contingency was altered. A few fish in this study appeared to be insensitive to the contingency change in IMSD. Some of those had been high responders and were assigned to (0,0) during IMSD. If they matched shock density as Neffinger and Gibbon's Class II rats did with a (0,0) extinction they should have stopped responding. Fish 16R continued to respond at high levels during (0,0) IMSD and (0,0) traditional extinction. Fish 30G continued to respond at a high level during (0,0) IMSD extinction but decreased during (0,0) traditional extinction even though the procedures were identical.

Fish in Experiment 3 did not decrease responding as much as the fish in Experiment 2. Those fish may have learned to discriminate more readily between the presence and absence of an avoidance contingency because of the repeated acquisition/ extinction procedure. Seven of the nine Experiment 2 fish decreased responding during (0,0) extinction while only nine of twenty fish from Experiment 3 decreased responding.

Punishment. Introduction of the punishment contingency led to a decline in responding. This decline was greater and more rapid than in other situations using goldfish (Wallace & Scobie, 1977; Woodard & Bitterman, 1973). Although operant conditioning procedures predict this it can also be accounted for by Woodard and Bitterman's discriminated classical activation explanation. They proposed that since light alone was never paired with shock it functioned as a CS- inhibiting responses. Once a response was made the light with feedback became a CS+ and additional responses were made. This is supported by their data showing that fish made more total responses than initial responses. The more rapid decline to a lower level in Experiment 3 as well as the higher number of total responses observed by Woodard and Bitterman can be explained by procedural differences. Studies other than Experiment 3 introduced punishment immediately after avoidance, not after extinction. They also permitted multiple responses so that only the final response was punished. There are more apt to be residual effects from the avoidance contingency when punishment immediately follows avoidance than when punishment follows extinction. It was probably more difficult for fish in the other studies to discriminate the contingency change, particularly since multiple responses were allowed. During early punishment sessions fish may have identified extra nonpunished responses as successful avoidance responses. The use of the response-contingent door and hue change of Experiment 3 should have provided greater congruence between the contingency as specified by the experimenter and as perceived by the subject.

Some high responders decreased shuttling very little during IMSD and (0,0) extinction and initially appeared to be contingency insensitive. However introducing the punishment contingency resulted in a rapid decline in responding. Individual data from subject 16R provide an example of this. It is possible that these fish only alter responding when the contingency change is to a maximal contingency such as (1,0) and (0,1) but not with points on the diagonal. Further research with additional diagonal points and partial contingencies would serve to clarify this.

Responding following shock vs. no shock

Goldfish had higher probabilities following no shock, $P(R_n | \bar{S}_{n-1})$ than following shock, $P(R_n | S_{n-1})$. This was most pronounced during avoidance, less during the noncontingent procedures of (.5,.5) preavoidance and IMSD extinction, and least during punishment. A shock activation explanation, such as that proposed by Woodard and Bitterman, would expect more responding following shock. Differences in ITIs between Woodard and Bitterman's studies and this series of experiments cannot account for the failure to find shock-induced effects. Since the mean ITI they used was presumedly effective in supporting activation, than the shorter ITI used in these experiments should have also supported activation.

There was no direct relationship between shock density and the probability of a response following shock. Instead of increased shock leading to a general activation and subsequent high P(R) there was an inverse relationship between shock density and P(R). These data from Experiments 2 and 3 weaken the classically conditioned shock activation explanation of avoidance behavior of goldfish in shuttleboxes.

Latency

As found in Experiment 2 latencies were shortest during avoidance and longer during noncontingent procedures. The longest latencies occurred during punishment. Mean responding and median latency for each phase are inversely related. This agrees with Scobie and Fallon's (1974) goldfish data but is at variance with data from studies using rats (Bolles et al., 1974; Hineline & Herrnstein, 1970; Neffinger & Gibbon, 1975). Each of these studies found a different latency pattern but none found a relationship between latency and response probability. This difference may be due to both procedural, apparatus and species differences. Bolles et al. (1976) used a shuttlebox but found that short latencies persisted even when responding was not frequent. Steiner (1971) and Hineline and Herrnstein both used a fixed-cycle-avoidance procedure. Hineline and Herrnstein found gradual changes in latency patterns over sessions but the patterns were independent of proficiency in responding. Steiner found flat latency distributions with the same procedure. Perhaps with additional training, patterns similar to those found by Hineline and Herrnstein would emerge. The negative relationship between latency and responding found in Experiments 2 and 3 might be limited to shuttlebox studies with ITI's using goldfish. Before generalization concerning goldfish behavior can be made further parametric research with a variety of procedures is necessary.

GENERAL DISCUSSION

These experiments as a series provide further evidence of the importance of response-reinforcer contingencies in avoidance learning by goldfish. They have also shown that shuttling occurs as a species typical behavior which can modify the interpretation of the response-reinforcer contingency. In Experiments 2 and 3 manipulating the presence and absence of response-reinforcer contingencies correlated with changes in responding. Specifying contingencies by the coordinates of a "contingency square" (Gibbon et al., 1974), responding was highest during (1,0) avoidance and lowest during (0,1) punishment. Noncontingent treatments with shock did not enhance responding relative to operant level (Experiment 3) and reduced responding from that supported by the maximal avoidance contingencies (Experiments 2 and 3).

Decrements in responding followed when the response-reinforcer contingency was reduced to zero while shock density remained the same. The IMSD extinction results, as well as those during noncontingent shock in the preavoidance phase, indicated that shock density per se did not determine responding. Neffinger and Gibbon (1975) found that as distance from the maximal avoidance contingency increased, responding decreased. Their rats stopped lever pressing at points on the diagonal of independence. In Experiments 2 and 3 fish did not cease shuttle responding with IMSD points on the diagonal. Coulson et al. (1971) and Smith (1974) also found that responding did not stop during extinction with matched, response independent shock density even though they did not insure that $P(S|\bar{R}) = P(S|R)$. However, precise control of these probabilities may not be important in extinction unless the probabilities are quite unequal. Further research with points near the diagonal will be necessary to determine this. The intermediate level of responding in extinction when the IMSD procedures were used may relate to the discriminability of differences between avoidance and extinction (Smith, 1973). The use of identical shock densities in avoidance and IMSD extinction probably made the contingency change more difficult to detect than the change to (0,0), (.5,.5) or (1,1) as in Neffinger and Gibbon's study. Even when points on the diagonal were arbitrarily assigned to subjects during preavoidance, responding did not produce the same behavior. Whether this is a species difference or due to procedural variables is not known as this time. Even when fish received 12 sessions of 20 trials each at the same point on the diagonal, (0,0), but at different states in the experiment, different levels of responding resulted. Such order effects are emphasized by the differences between operant level and traditional extinction.

The change in shuttling during avoidance, punishment and both IMSD and (0,0) extinction can be accounted for by the principles of operant conditioning since the response-reinforcer contingency determines response probability. Alternatively, however, it can be considered that Mower and Jones' (1945) discrimination hypothesis can account for the differences between IMSD extinction and avoidance. For most of the data the former is the most parsimonious explanation supported by the largest body of empirical data.

Woodard and Bitterman (1973) offered discriminated, classically conditioned activation as an explanation for shuttling as a form of general activity. Neither Scobie and Fallon (1974) nor Steiner (1971) found that shuttling was highly probable immediately following shock. Also Gormezano and Kehoe (1975) feel that one of the two requirements for classical conditioning is that the UR and CR must be similar. Evidence for such similarity is lacking in goldfish. Goldfish also do not seem to be activated by the occurrence of shock on a previous trial since the $P(R_n | S_{n-1})$ was not high in Experiments 2 or 3. In addition, the noncontingent shock density during preavoidance did not correlate with higher responding. The result that would be most difficult for Woodard and Bitterman to explain was the high probability of responding in the (0,0) group since shock could not activate these fish.

Changes during avoidance and punishment might still be explained as discriminated classical conditioning. In Experiments 2 and 3 the use of a response-contingent hue change in CS made feedback more salient and therefore may have aided in the discrimination of response feedback which distinguished CS+ from CS-. However, others (Scobie & Fallon, 1974; Zerbolio & Wickstra, 1978a, 1978b) found that feedback from a response-contingent CS change was less important than the presence or absence of the avoidance contingency. Responding was always higher in the avoidance groups and lower in the classical groups regardless of whether the CS change was response contingent.

Another finding important for the study of shuttlebox avoidance was the replication of the pseudo-learning curve in a free operant paradigm and its extension to a discrete trial situation. This clearly emphasizes the importance of an operant level control group to monitor responding so that increases are not erroneously attributed to "learning."

This unusual phenomenon is not the pattern observed in many other species where a habituation-like decrease in responding occurs. As Bolles (1970) has advocated, it is important to be aware of species-typic repertoires. The pseudo-learning effect emphasizes this need in shuttlebox learning research with goldfish. Other instances of this are the suggestions of CS phototaxic effects by Zerbolio and Wickstra (1978a, 1978b) and the large individual variability found both by Agranoff and Davis (1968), and in Experiments 1, 2, and 3. Susceptability to classical conditioning in shuttleboxes under certain circumstances may be another species-typical behavior. The extent of the classical conditioning component may depend on the parameters in a given experiment.

The results of these experiments and others suggest further research for identifying variables and procedures controlling shuttling. Since goldfish appear sensitive to the order of treatments, other sequences of contingencies including traditional (0,0) extinction before IMSD extinction should be investigated. The use of an omission paradigm to assess the eliciting properties of the CS would provide further information on the classical conditioning component. The role of explicit feedback could be further studied by comparing the type of response-contingent CS change used in these experiments with a CS change which was not response-contingent during operant level, avoidance and IMSD extinction. If responding was as high in the noncontingent CS change groups during avoidance and as low in IMSD when the CS+ and CS- were less discriminable, this would further weaken Woodard and Bitterman's position.

Although these experiments have emphasized problems in the study of avoidance learning using goldfish, they have implications for learning in general. First they demonstrate the usefulness of the contingency square in analyzing the relationships between contingencies. This is particularly evident when comparing the effects of various points on the diagonal of independence. All points along the diagonal are equally noncontingent and might produce iso-contingency curves of similar response patterns if shock density or order of treatments were unimportant. However, they did not. Further investigations are needed to determine whether this is specific to goldfish or whether it is true of other species. It also serves to remind experimenters that the subjective perception of the contingency by the subject may not match the contingency specified by the experimenter. Killeen (1978) has recently proposed a signal detection model for determining subjective probabilities. This model combined with the specification of contingencies using coordinates from the contingency square provides another method for determining iso-contingency contours. This series of three experiments has shown that the response-reinforcer contingency is important in avoidance learning by goldfish in shuttleboxes but that there are certain species-typic behaviors which interact with this such as the pseudo-learning effect to produce the observed behavior.

FOOTNOTES

1. In avoidance studies using goldfish in shuttleboxes with discrete trials the terms CS and US are often used. This usage is a matter of convention and is not meant to imply that avoidance conditioning is controlled by classical processes.

APPENDIX A

Table A1

Sequence of Procedures for Experiment 1

Day	Procedure
1	Fish moved in the evening from group tanks to individual tanks in the light or dark cubicle.
2 - 9	Fish adapted to initially assigned illumination conditions.
10 - 15	Fish tested daily in shuttleboxes during 50-min operant level recording sessions, each session beginning at a different hour in the test period.[a] At the end of the fifteenth day fish were transferred to the other cubicle in their individual tanks.
16 - 23	Fish adapted to reversed illumination conditions.
24 - 29	Fish tested daily in reversed illumination condition.

[a] Each subject was rotated one hour forward in the running schedule on successive days. For example, fish L6A1 was tested at 1030 on Monday, 0930 on Tuesday, 1430 on Wednesday, etc.

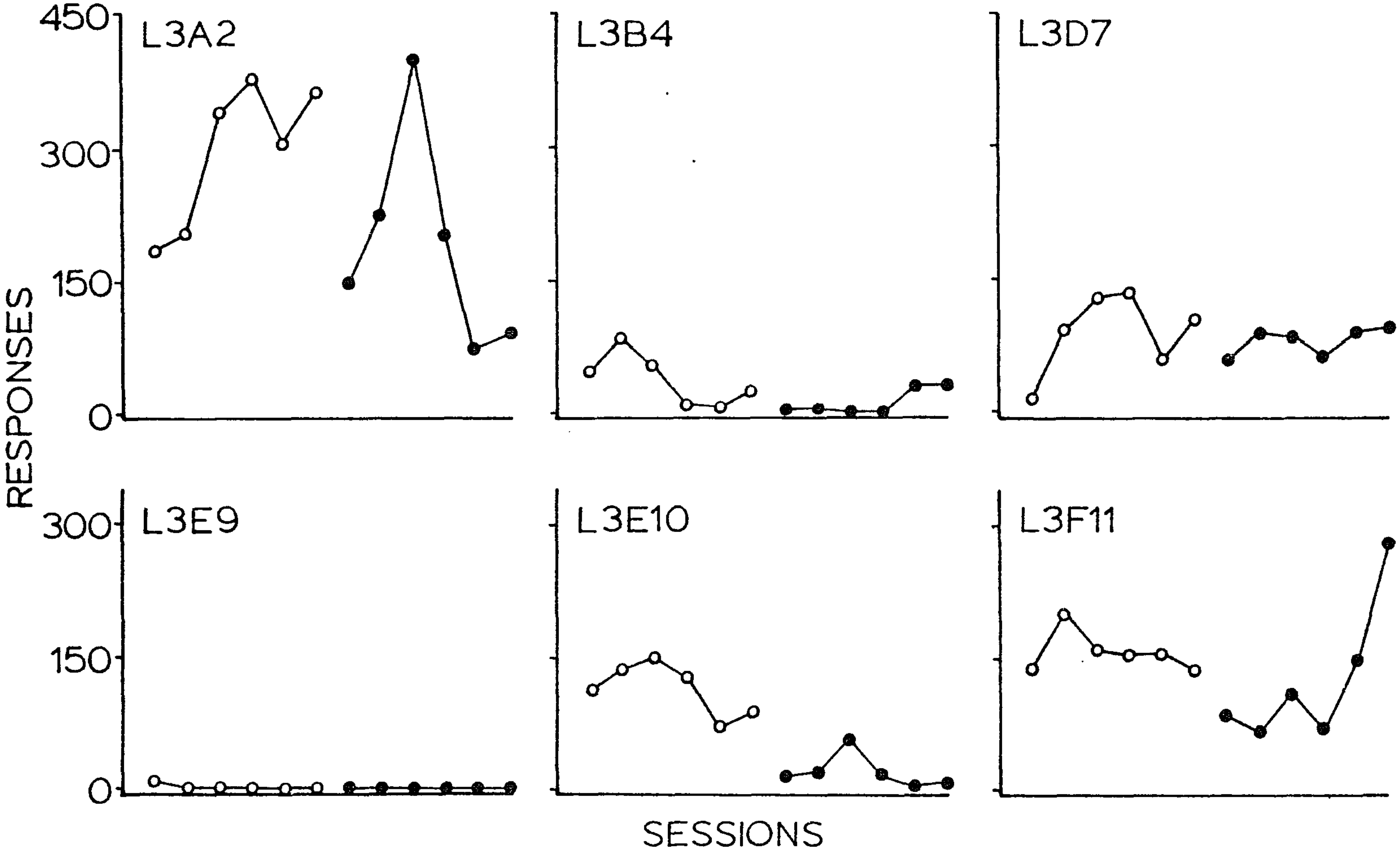
Table A2

Schedule for Experiment 1

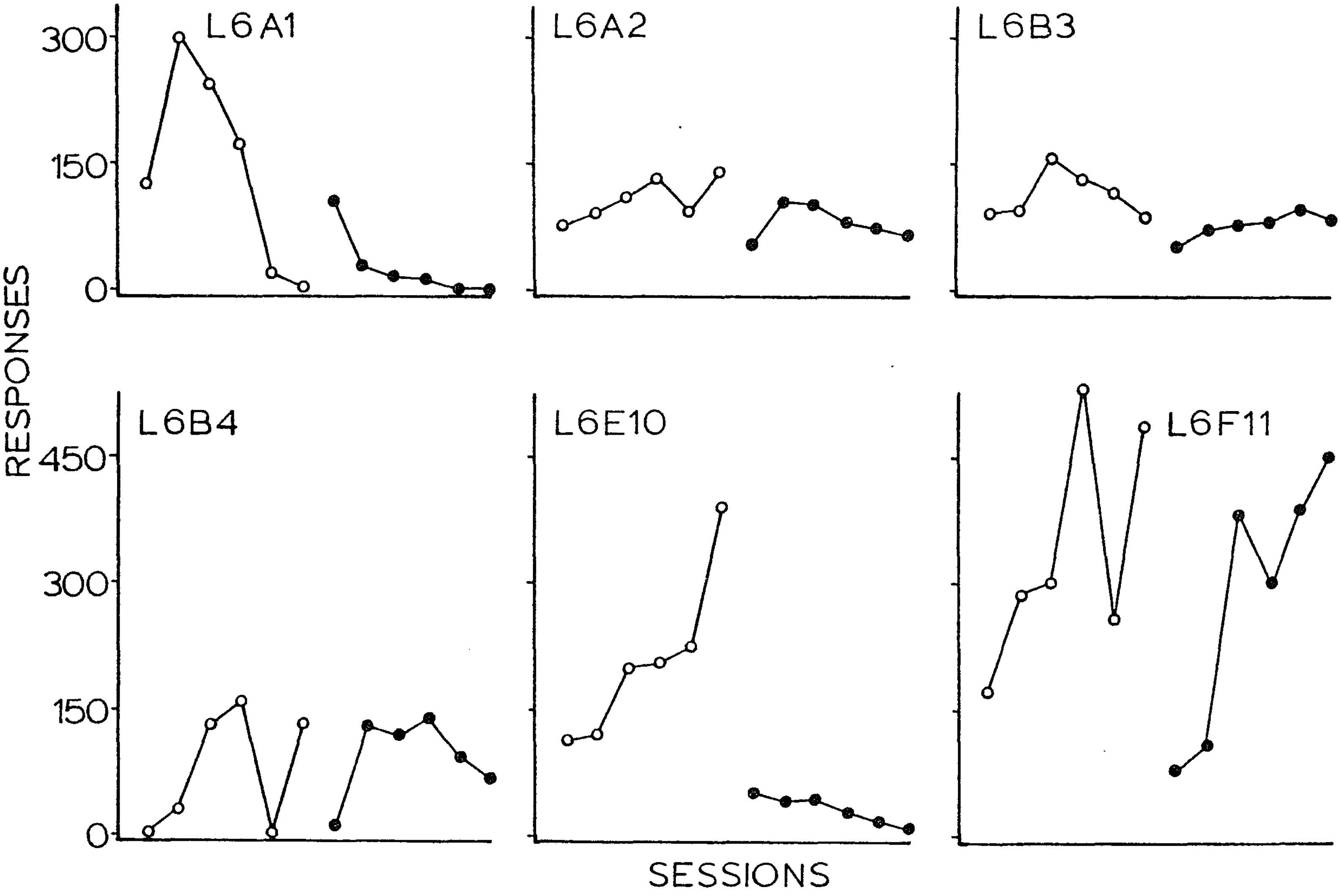
Date (1971)	Procedure
Aug 7 - Aug 15	Fish from the A group adapted to either light (LA) or dark (DA).
Aug 14 - Aug 22	Fish from the B group adapted to either light (LB) or dark (DB).
Aug 16 - Aug 21	LA and DA groups tested in intial conditions.
Aug 21 - Aug 29	LA and DA groups adapted to reversed conditions.
Aug 23 - Aug 28	LB and DB groups tested in intial conditions.
Aug 28 - Sep 5	LB and DB groups adapted to reversed conditions.
Aug 30 - Sep 4	LA and DA groups tested in reversed conditions.
Sep 4 - Sep 12	LC and DC groups adapted to intial conditions.
Sep 6 - Sep 11	LB and DB groups tested in reversed conditions.
Sep 11 - Sep 19	LD and DD groups adapted to initial conditions.
Sep 13 - Sep 18	LC and DC groups tested in initial conditions.
Sep 18 - Sep 26	LC and DC groups adapted to reversed conditions.
Sep 20 - Sep 25	LD and DD groups tested in initial conditions.
Sep 25 - Oct 3	LD and DD groups adapted in reversed conditions.
Sep 27 - Oct 2	LC and DC groups tested in reversed conditions.
Oct 2 - Oct 10	LE and DE groups adapted to initial conditions.
Oct 4 - Oct 9	LC and DC groups tested in reversed conditions.
Oct 9 - Oct 17	LF and DF groups adapted to initial conditions.
Oct 11 - Oct 16	LE and DE groups tested in initial conditions.
Oct 16 - Oct 24	LE and DE groups adapted to reversed conditions.
Oct 18 - Oct 23	LF and DF groups tested in initial conditions.
Oct 23 - Oct 31	LF and DF groups adapted to reversed conditions.
Oct 25 - Oct 30	LE and DE groups tested in reversed conditions.
Nov 1 - Nov 6	LF and DF groups tested in reversed conditions.

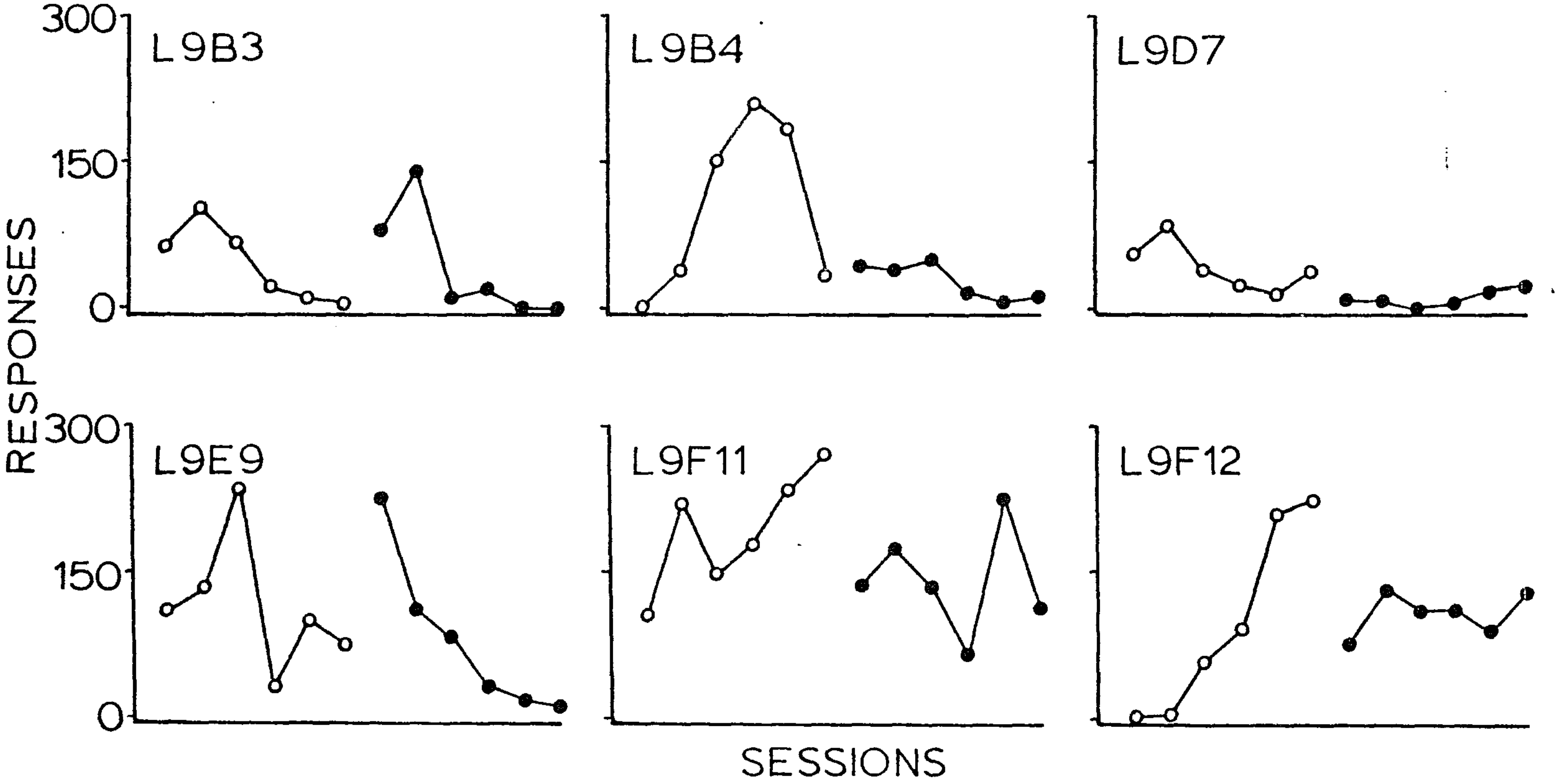
APPENDIX B

Figures B1 - B6. Individual response curves under light and dark conditions during 50-min operant level testing sessions.



RESPONSES
SESSIONS
L3A2
L3B4
L3D7
L3E9
L3E10
L3F11
450
300
150
0
300
150
0


L6A1
L6A2
L6B3
L6B4
L6E10
L6F11
RESPONSES
SESSIONS
0
150
300
450


RESPONSES
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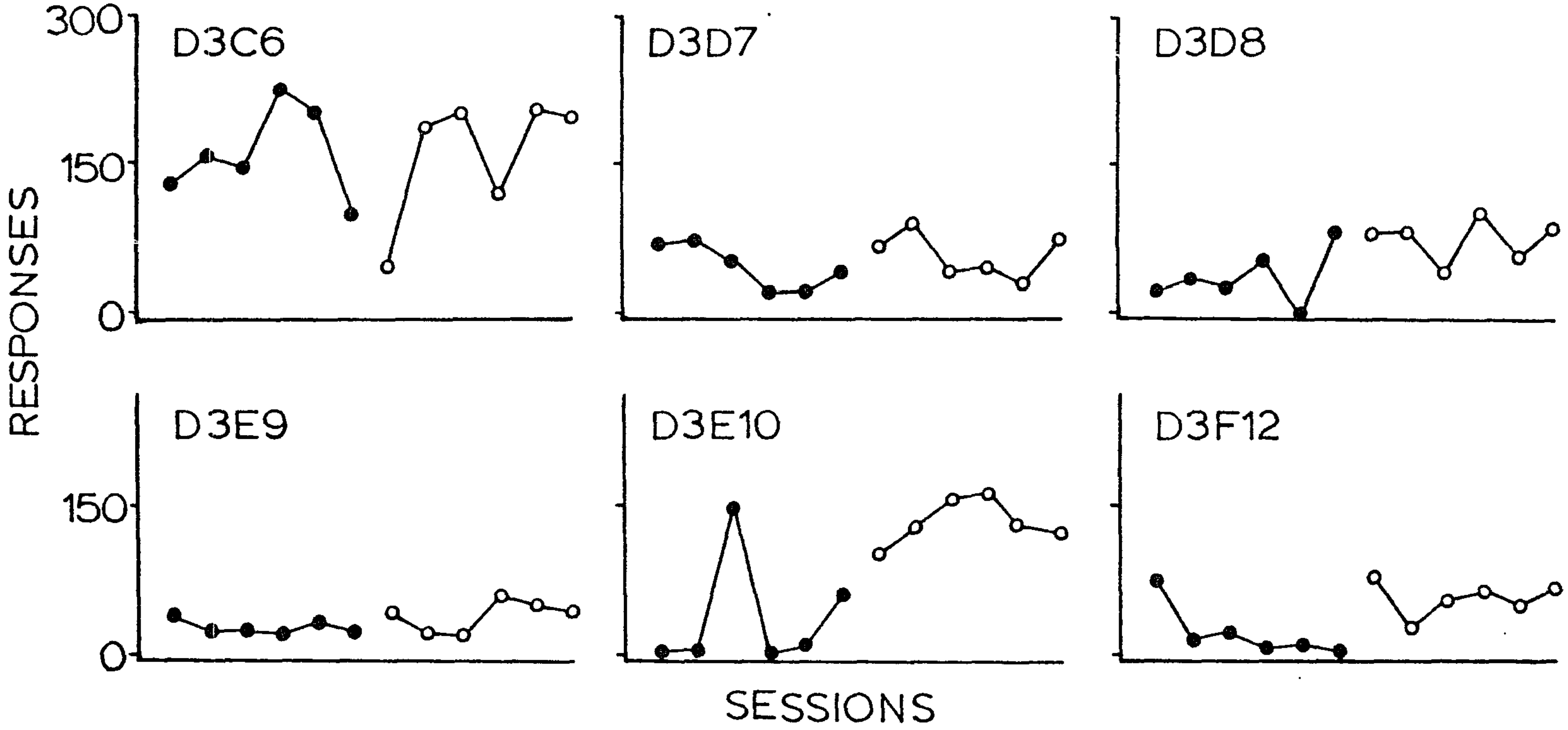
L9B4
L9D7
300
150
0
L9E9
L9F11
L9F12
SESSIONS


RESPONSES
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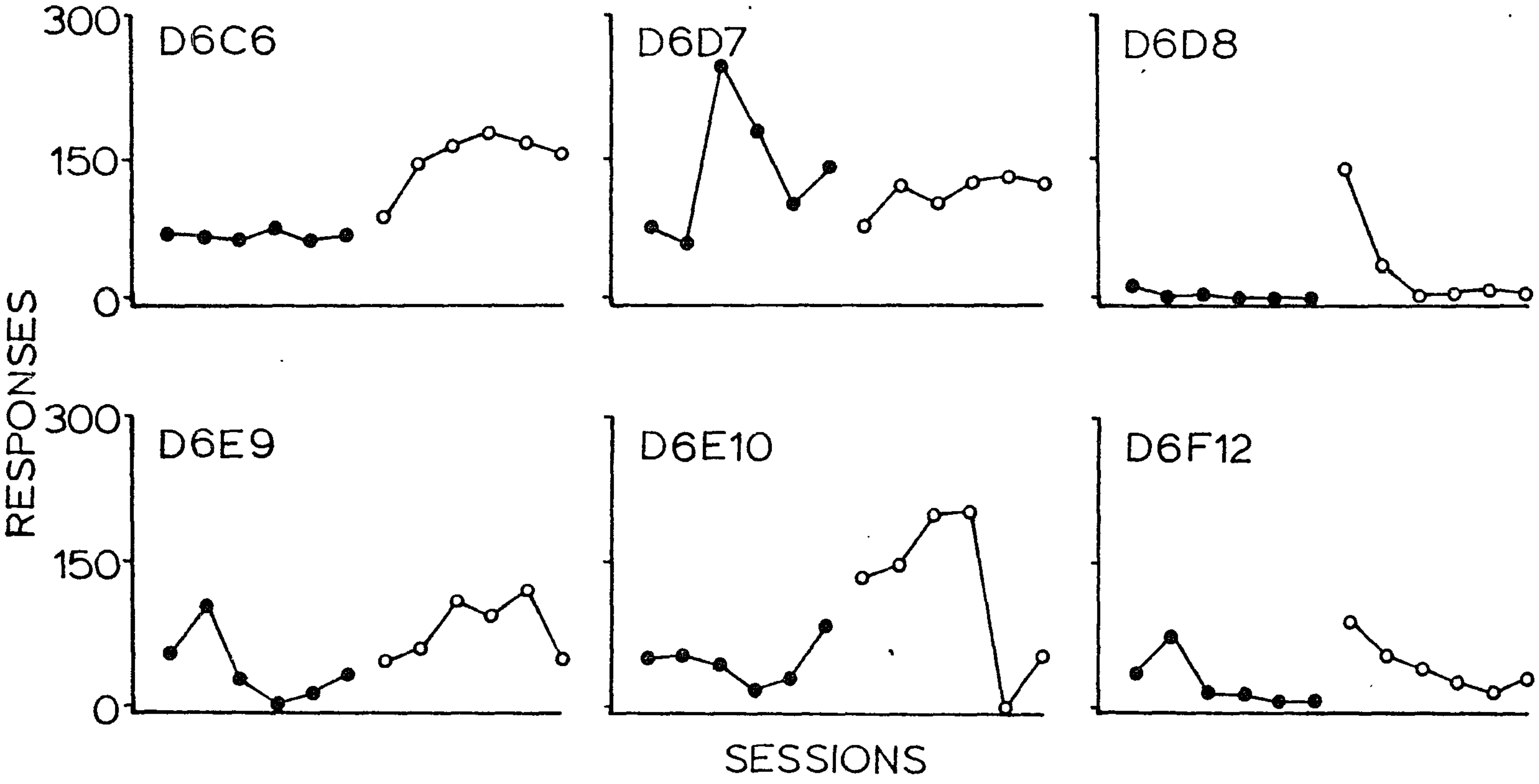
150
0
D3C6
D3D7
D3D8
D3E9
150
0
D3E10
D3F12
SESSIONS


300
150
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300
150
0
RESPONSES
D6C6
D6D7
D6D8
D6E9
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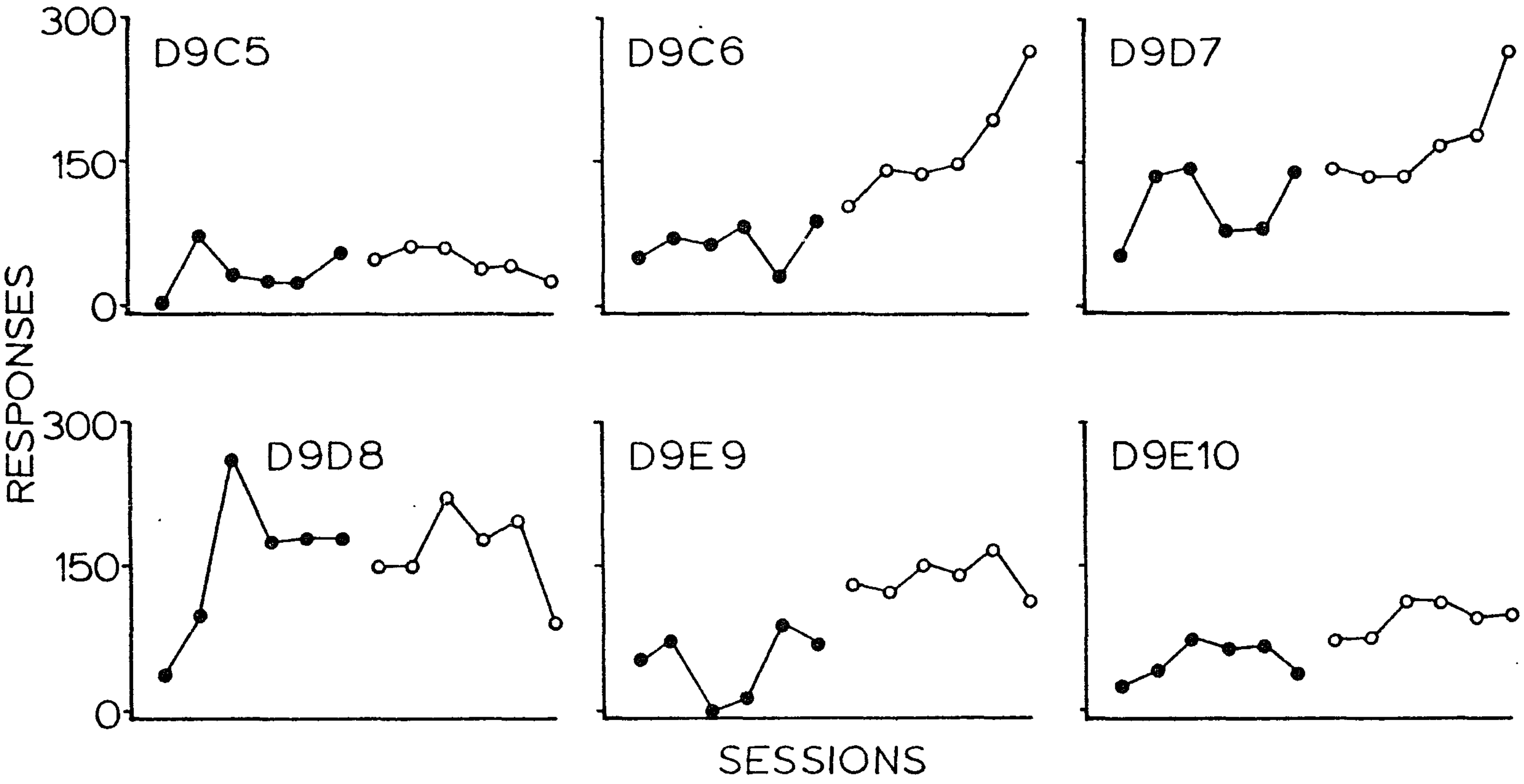
D6F12
SESSIONS


D9C5
D9C6
D9D7
D9D8
D9E9
D9E10
300
150
0
300
150
0
RESPONSES
SESSIONS

APPENDIX C

Table C

Median Latency of First Response (sec)

Group	Initial Illumination						Reversed Illumination					
	Sessions											
	1	2	3	4	5	6	1	2	3	4	5	6
LD35	177	135	100	66	120	51	520	192	219	67	100	88
LD65	191	49	41	54	129	78	336	187	106	52	64	44
LD95	193	230	288	234	96	134	303	280	164	64	269	559
DL35	144	124	167	107	40	183	38	16	20	25	14	10
DL65	340	207	222	250	94	106	57	38	30	13	56	8
DL95	598	98	100	116	86	194	107	41	22	22	22	7
Combined Groups												
35 cm	98	136	114	82	82	67	149	23	72	42	52	40
65 cm	298	125	128	139	94	106	153	112	58	20	56	14
95 cm	289	144	118	194	94	138	185	56	38	49	66	42
Light	215	134	103	90	96	94	404	220	114	78	64	100
Dark	316	126	121	138	83	164	63	28	22	20	16	10

Note. Median latencies are rounded to the nearest second.

APPENDIX D

Table D

Mean Shock Frequency, Shock Density, $P(S\mid\bar{R})$, and $P(S\mid R)$ Scheduled and Received during IMSD Extinctions

	IMSD Extinction 1					IMSD Extinction 2				
Subject	$P(S\mid\bar{R}),P(S\mid R)$		Density	Shocks/Session		$P(S\mid\bar{R}),P(S\mid R)$		Density	Shocks/Session	
	Due	Received	Received	Due	Received	Due	Received	Received	Due	Received
2R	(.40,.40)	(.43,.39)	.42	8.0	8.9	(.15,.15)	(.15,.12)	.11	3.0	2.8
9R	(.30,.30)	(.37,.27)	.31	6.0	5.7	(.00,.00)	(.00,.00)	.00	0	0
33R	(.80,.80)	(.77,.62)	.75	16.0	14.1	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0
38R	(.40,.40)	(.42,.36)	.45	9.6	8.0	(.40,.40)	(.38,.41)	.40	8.0	8.2
45G	(.05,.05)	(.00,.05)	.04	1.0	1.0	(.00,.00)	(.00,.00)	.00	0	0
47R	(.05,.05)	(.07,.05)	.04	1.0	1.0	(.10,.10)	(.14,.11)	.12	2.0	2.3
60G	(.00,.00)	(.00,.00)	.00	0	0	(.00,.00)	(.00,.00)	.00	0	0
64G	(.10,.10)	(.08,.12)	.12	2.0	2.2	(.00,.00)	(.00,.00)	.00	0	0
70G	(.00,.00)	(.00,.00)	.00	0	0	(.10,.10)	(.14,.09)	.11	2.0	2.8

APPENDIX E

Table E

Mean Shock Frequency, Shock Density, P(S|R̄), and P(S|R) Scheduled and Received during Noncontingent Phases having Shock

Group	Preavoidance					IMSD Extinction				
	P(S|R̄),P(S|R)		Density	Shocks/Session		P(S|R̄),P(S|R)		Density	Shocks/Session	
	Due	Received	Received	Due	Received	Due	Received	Received	Due	Received
(0,0)[a]										
104R						(.10,.10)	(.04,.09)	.08	2.0	2.3
106G						(.50,.50)	(.61,.48)	.56	10.0	11.2
112G						(.80,.80)	(.64,.60)	.63	16.0	12.6
113R						(.25,.25)	(.33,.33)	.33	5.0	6.6
114R						(.25,.25)	(.22,.25)	.23	5.0	4.7
115G						(.50,.50)	(.43,.47)	.45	10.0	19.0
(.5,.5)										
1R	(.50,.50)	(.57,.49)	.54	10.0	10.8	(.15,.15)	(.10,.13)	.11	3.0	2.3
7G	(.50,.50)	(.54,.45)	.53	10.0	10.5	(.20,.20)	(.21,.22)	.21	4.0	3.5
15G	(.50,.50)	(.54,.52)	.53	10.0	10.7	(.10,.10)	(.10,.11)	.11	2.0	2.2
21R	(.50,.50)	(.55,.45)	.52	10.0	10.1	(.05,.05)	(.09,.04)	.05	1.0	1.0
22G	(.50,.50)	(.55,.49)	.49	10.0	10.7	(.10,.10)	(.17,.10)	.12	2.0	2.3
23G	(.50,.50)	(.62,.48)	.53	10.0	10.6	(.20,.20)	(.15,.18)	.18	4.0	3.7
27G	(.50,.50)	(.50,.45)	.48	10.0	9.5	(.05,.05)	(.17,.04)	.05	1.0	0.9
39G	(.50,.50)	(.51,.49)	.50	10.0	9.2	(.25,.25)	(.13,.21)	.18	5.0	3.3
56R	(.50,.50)	(.63,.41)	.55	10.0	10.8	(.10,.10)	(.01,.16)	.10	2.0	2.0
66R	(.50,.50)	(.53,.40)	.45	10.0	9.7	(.05,.05)	(.00,.04)	.04	1.0	0.8
(1,1)										
14G	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.10,.10)	(.04,.09)	.08	2.0	1.5
16R	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.00,.00)	(.00,.00)	.00	0	0
20R	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.20,.20)	(.19,.20)	.20	4.0	4.4
24R	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.10,.10)	(.08,.10)	.09	2.0	2.1
25R	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.40,.40)	(.43,.47)	.45	8.0	8.9
26G	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.30,.30)	(.35,.27)	.34	6.0	6.8
30G	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.00,.00)	(.00,.00)	.00	0	0
31G	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.40,.40)	(.43,.36)	.42	8.0	8.4
41R	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.80,.80)	(.78,.80)	.78	8.0	8.0
62G	(1.0,1.0)	(1.0,1.0)	1.00	20.0	20.0	(.00,.00)	(.00,.00)	.00	0	0

[a] Group (0,0) received no shock during preavoidance.

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