SENSORY PRECONDITIONING IN THE GOLDFISH

A Thesis

Presented to

the Faculty of the Department of Psychology

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science

By

Mary Ellen Hayden

August, 1972

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ABSTRACT

Sensory preconditioning (SPC) has been demonstrated in organisms from humans to birds on the phylogenetic scale. Several attempts to precondition fish, however, have been unsuccessful. This study was an attempt to make use of phylogenetic trends discovered by Soviet experimenters to devise a successful SPC experiment with fish. Three experiments were conducted using an appetitive task to test for preconditioning effects. Although results of these tests were not uniformly statistically significant, the data were highly suggestive of some SPC effect. Possible modifications of the experimental design to further explore SPC in the fish are discussed.

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I. INTRODUCTION

Sensory preconditioning (SPC) has been shown to occur in organisms ranging in complexity from humans down to birds on the phylogenetic scale. However, several attempts to demonstrate the phenomenon in fish have proved unsuccessful. This study is a further effort to sensory precondition fish, in this case goldfish (Carassius auratus).

The usual SPC paradigm involves three stages:

1) Stage I, Preconditioning: This stage consists of numerous pairings of two neutral stimuli (S_1 and S_2). No reinforcement is given for any response during preconditioning.

2) Stage II, Training: A response is conditioned to S_2.

3) Stage III, Testing: A test is conducted to determine whether S_1 will elicit the response conditioned to S_2. If it does, sensory preconditioning is said to have occurred.

Seidel (1959) summarized American studies of SPC and discussed the battle that raged around the phenomenon with regard to SS-SR theories. He proposed the following difficulties in explaining sensory preconditioning in classical conditioning terms:

1) SPC violates at least three laws of classical conditioning: a) stable backward SPC has been demonstrated and appears as strong as simultaneous SPC, b) the strength of the association between S_1 and S_2 is not simply a function of number of preconditioning pairings, and c) the role of the response in SPC seems unimportant.

2) Reinforcement, as classically defined, appears to be unnecessary for SPC.

3) The phenomenon has not been demonstrated in an organism simple enough to make a symbolic functioning explanation untenable.

Successful experiments reviewed by Seidel included humans, dogs and rats as subjects. He also discussed an unsuccessful experiment with pigeons. American studies since that time have contributed little to an extention of SPC research to simpler organisms. An exception is the recent study by Holmes (1969) which attempted to elicit preconditioning in the goldfish. Four experiments were performed. Each experiment used four groups: an Experimental Group, a Backward Conditioning Control Group, and two Stimulus

Generalization Control Groups. Red and green lights of equal intensity were used as the two stimuli in all experiments except for a variation using yellow and green lights in Experiment IV. All experiments were counterbalanced for color.

Experiment I involved 20 pairings of S_1 and S_2 for all groups. The stimuli were presented successively for 5.65 sec. each. Mean intertrial interval was 1 min. In Stage II Experimental _S_s were trained in shuttleboxes to avoid shock on presentation of S_2. This response was extinguished with S_1 in Stage III. The Backward Control _S_s were trained with S_1 and extinguished with S_2. One Generalization Control Group was both trained and extinguished using S_1, and one was both trained and extinguished using S_2. The extent to which Backward and Generalization Controls differed provided a range within which differences between the Backward and Experimental Groups could be analyzed for SPC effects. No such effects were found.

Experiment II again involved four groups. In Stage I the Experimental and Backward Control Groups received 20 paired presentations of the two stimuli. Method of presentation was the same as before except the mean intertrial interval was increased to 3 min. Two Unpaired Control Groups received unpaired presentations of S_1 and S_2 during this stage. In Stage II Experimental Ss were trained in shuttleboxes to avoid shock on presentation of S_2 and then transferred to a discrimination problem with S_2^+ and S_1^- in Stage III. The Backward Control Group was trained with S_1 and then given a discrimination problem with S_1^+ and S_2^-. One half of the Unpaired Control Group was trained using red light, which became their S^+ in Stage III, and the other half was trained using green light, which became their S^+. Since the Experimental Ss discriminated as well as either Control Group in Stage III, there was no suggestion of SPC.

In Experiment III the number of preconditioning pairings was increased to 60 given over a 3 day period. All Ss received paired presentations of the two stimuli. Stimulus duration was 10 sec. each, and the mean intertrial interval was 1 min. For Experimental Ss increased activity was classically conditioned to S_2, using shock as the US, and was then extinguished to S_1. Backward Control Ss were classically conditioned with S_1 and then extinguished with S_2. Conditioning and extinction were both to the same stimulus for the two Generalization Control Groups, with one group receiving S_1 and one group receiving S_2. Data obtained in Stage III indicated that the activity level of the Generalization Control Ss was slightly below that of the other two groups. The experimenter concluded, however, that the amount of generalization was too high in this experiment to make any statements about sensory preconditioning.

In the fourth experiment, Stage I proceeded exactly as in Experiment III. Classical methods were used in Stage II with shock as the US and increased activity as the response. Experimental Ss were conditioned to S_2 and then transferred to a discrimination problem having S_2^+ and S_1^-. For Backward Controls S_1 was used during conditioning and as the positive stimulus. No preconditioning was demonstrated.

Soviet experimenters have also been unsuccessful in attempts to demonstrate sensory preconditioning in fish. No details of these attempts are available in translation; however, Razran (1971) provides an excellent discussion of Russian SPC experiments using various animals from birds to humans. The emphasis throughout the Soviet work has been on evolutionary trends. Razran conceptualizes SPC as being mediated by orienting reactions which extinguish quickly and are inhibited by stimuli of high intensity and long duration. His discussion includes the following list of generalizations derived by Sergeyev, a prominent figure in Russian SPC research. This list provides useful guidelines for future experiments with lower organisms.

1) SPC has been demonstrated to some extent in turtles (Razran finds the data unconvincing), canaries, starlings, white mice, hedgehogs, bats, polecats, and chimpanzees. It could not be demonstrated in bony fish, frogs, salamanders, axolotls, amblystoma, or in puppies less than six months of age.

2) Maximum retention of S_1 response was: 14 days in birds, 15 in rodents, 19 in insectivores, 29 in bats, several months for carnivores, and one year for a baboon. Maximum effective interval between preconditioning and conditioning was: 3 days for birds, rodents and insectivores, 6 for bats, and 12 for carnivores.

3) In dogs, maximum preconditioning efficiency was attained in: 15 pairings when S_1 preceded S_2 by a few seconds and terminated when the latter

began, 20 pairings using simultaneous presentation of the two stimuli, and 30 pairings with an inter-stimulus interval of 30 sec. More than 30 pairings impaired efficiency, and S_1 acquired inhibitory properties after 50 pairings.

4) In SPC simultaneous and backward designs do not reduce efficiency as much as they do in simple classical and instrumental conditioning.

5) Prior habituation to S_1 has little effect on development of SPC, but prior habituation to S_2 makes preconditioning difficult or even impossible. This is in accord with the finding that SPC is more easily evoked when S_2 is more intense than S_1.

6) An S_1 of high intensity or long duration interferes with the orienting reaction and will, therefore, interfere with or nullify completely the formation of SPC.

7) In dogs and cats only the ablation of the association cortex abolishes and prevents SPC. With cortical-sensory and subcortical ablations it is preserved and new varieties are formed.

Razran adds an additional generalization to the list:

8) Fragmentary evidence suggests SPC has evolved from birds to man in the following ways:

a) longer retention of its effects.

b) smaller number of preconditioning trials required. (An ontogenetic trend can also be seen here - in adult dogs 15 preconditioning presentations are required as opposed to 50 presentations in six-month-old puppies.)

c) greater efficacy of simultaneous and backward designs. (Backward sequences are effective in baboons and man, but in dogs this effectiveness is much reduced.)

d) longer interstimulus intervals.

e) more independence of S_1 from S_2. (In man, extinction of S_2 responses does not affect S_1 reactions; in baboons and dogs it does.)

f) less overt manifestations of the orienting reactions.

g) greater number of stimuli feasible in preconditioning combinations.

If Holmes' fish experiments are evaluated in terms of the above generalizations, several factors which could have adversely affected formation of SPC become evident. First, the use of red and green lights of equal intensity violates Generalization 5 which calls for S_2 to be more intense than S_1. Second, it is doubtful that 20 pairings of the two stimuli during Stage I in the first two experiments would have been sufficient in fish. Thirty to fifty pairings were effective in a Russian experiment with birds, and, considering Generalization 8b, one would expect more pairings to be required for fish. Third, American and Russian findings that backward SPC paradigms can be effective makes questionable the use of backward control groups in so crucial a role as they played here. However, in view of the phyletic trend (Generalization 8c), it is possible that an organism as simple as the fish might be capable of only forward SPC. An additional complication in this study was the problem of stimulus generalization. This could have been alleviated to some extent by the use of stimuli from different sense modalities.

The present work, then, is an attempt to manipulate the several experimental variables in such a way as to maximize conditions for formation of SPC in fish, using the phyletic trends enumerated by Razran as a guide.

II. EXPERIMENT I

Method

The subjects (Ss) were 18 experimentally naive 3-4 in. goldfish (Ozark Fisheries, Stoutland, Missouri) housed in groups of three. To minimize handling of the Ss, preconditioning, training and testing were all carried out in the home tanks which were 13x11x6 in. white opaque plastic containers. A 2x4 in. plastic feeding ring was attached to the right front corner of each tank. Black thread stretched across the top of each container provided grid marks for quantification purposes (see Figure 1). A 16:8 hr. daily light:dark schedule was maintained.

Each fish triad was randomly assigned to either the Experimental or Control Group, resulting in nine fish per group. Ss were given 10 days to acclimate to their environment. Complete food deprivation was maintained during the first 3 days. Beginning on the fourth day and continuing throughout the experiment, approximately 1/2 cc of TetraMin Staple Food for tropical fish was floated inside the feeding ring 4 times a day at 4-5 hr. intervals.

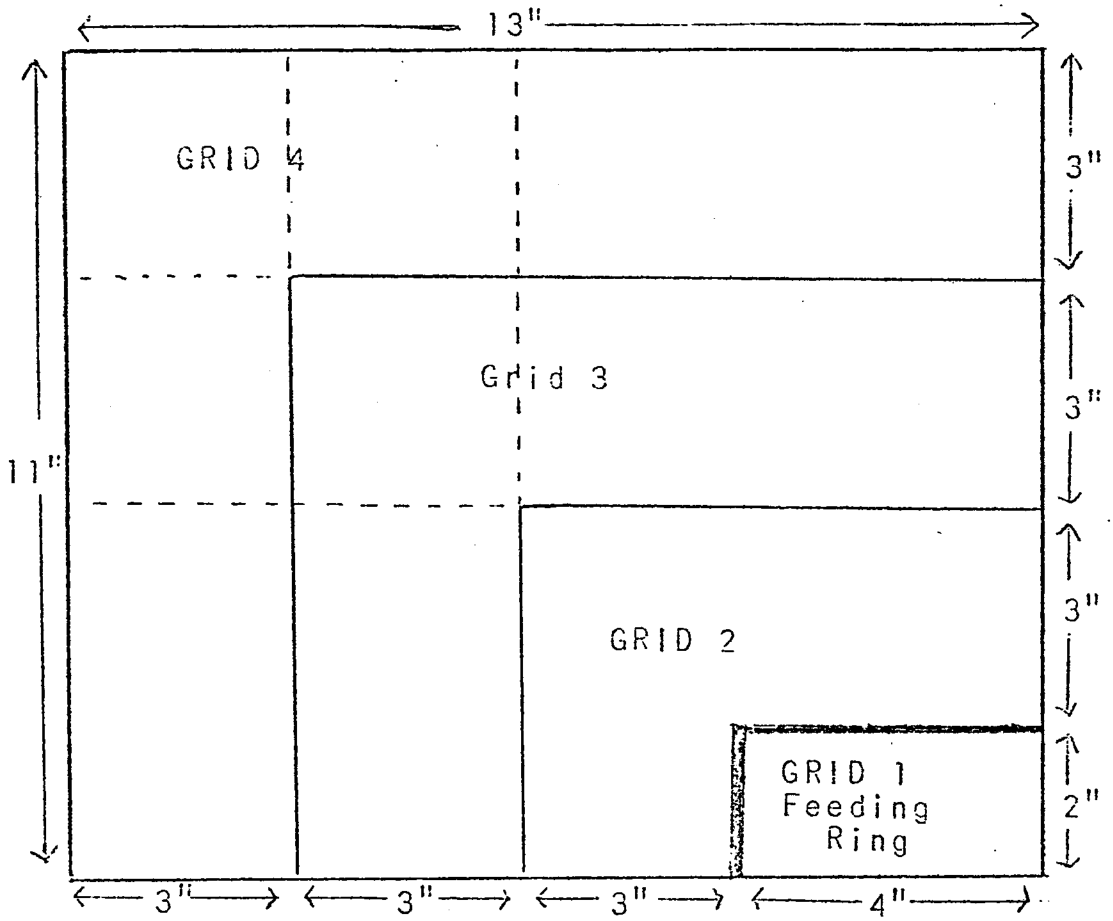
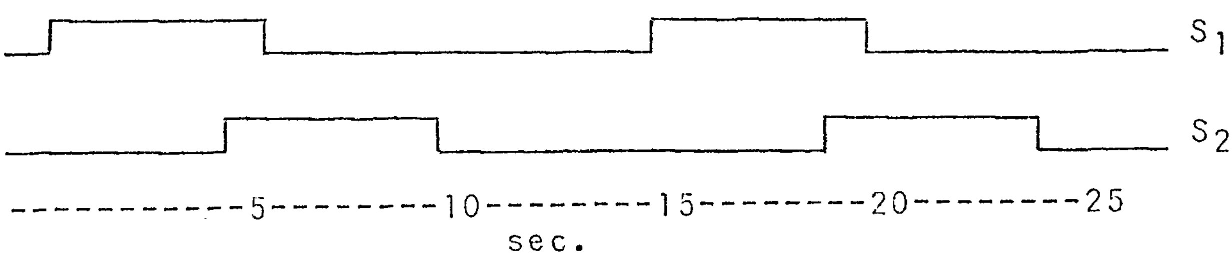


Figure 1. Diagram of tank used for housing, preconditioning, training, and testing of fish in Experiments I and II.

On the eleventh day preconditioning of the Experimental Group was begun. Before each preconditioning session a Metaframe aquarium light with two 25 watt white bulbs was placed 1 in. above the tank. S_1 was a 5 sec. presentation of this light. S_2 was bubbles created by insertion of the air hose of a small Miracle aerator into the center of the tank with the tip near the bottom. The aerator hose was plain tubing without an airstone, and the bubbles caused by this apparatus were large and quite vigorous. S_2 appeared to elicit a much stronger reaction from the Ss than did S_1, which is the desired intensity relationship in SPC. Neither stimulus seemed aversive to the fish. S_2 was of 5 sec. duration and overlapped S_1 by 1 sec. Intertrial intervals were 5 sec. The following diagram illustrates the paradigm used for preconditioning:



The Experimental Group received a total of 60 preconditioning pairings in 3 days. The choice of 60 as the number of pairings was based on: 1) the inverse relationship which has been found to hold between an animal's position on the phylogenetic scale and number of preconditioning trials required, 2) Sergeyev's successful use of 30 to 50 pairings with birds, and 3) Sergeyev's finding that excessive pairings of S_1 and S_2 could cause S_1 to acquire inhibitory properties (Razran, 1971). Two sessions per day were given with 10 pairings each. During this same period the Control Ss were exposed to the stimuli the same number of times as the Experimental Ss but S_1 and S_2 were never paired. Control Ss received 4 sessions daily, each consisting of 10 5 sec. presentations of one of the two stimuli. S_1 exposure sessions and S_2 exposure sessions were alternated and temporally separated by at least 4 hrs. Feedings were scheduled such that they never coincided with stimulus presentations during this period. Feeding procedures instituted on the fourth day of the experiment were continued.

Beginning the fourteenth day a 5 sec. presentation of S_2 (bubbles) was paired with each of the 4 daily feedings for both groups. Training was conducted for each triad in the home tank, and latency was measured for each fish from offset of S_2 to arrival at the feeding ring. A S that reached the target between onset and offset of the stimulus was assigned a latency of zero. Any S which had not reached the ring after 1 min. was assigned a latency of 60 sec. for that trial. Training continued until all fish had achieved the target within 60 sec. on 4 consecutive trials. When this criterion had been reached (18th day), two tests were performed in which S_2 was not followed by reinforcement but latency was measured to the target. These tests were given at approximately the same times regular trials would have occurred, and each was immediately followed by a reinforced trial.

Twice on the 19th day and once on the 20th day tests were conducted for sensory preconditioning, each one following a feeding by approximately 4 hrs. A test was begun by placing the aquarium light in position, waiting exactly 3 min., and then presenting S_1 for 5 sec. The 3 min. wait was to rule out possible experimenter bias related to differential position of Ss in the two groups at onset of testing and also to diminish any effect the experimenter's presence might have on the Ss. Latency to the feeding ring was measured for each fish. If S did not reach the feeding ring within 60 sec. a latency figure was given for the closest grid entered. However, if a fish's movement was entirely away from the target he was assigned to the last grid he entered. S was considered to be in a particular grid if his front section up to the gills was in that grid. If he had not entered to the level of the gills he was assigned to the grid which included his rear section. Any S that failed to move or to change orientation during 60 sec. was assigned a "no change" classification regardless of his position within the container. Therefore, each fish received either a grid number from 1 (target) to 4 and a latency figure for the nearest grid or a "no change" notation. Ss were then ranked according to grid assignment and latency position within that grid. Any S that came to the surface of the water at the closest point to the target was ranked higher than others with the same grid-latency classification that did not surface. Ss classified as "no change" were all ranked at the bottom of the scale. After ranking was completed, a Mann-Whitney U Test was performed.

Results and Discussion

In Stage II criterion performance was reached after 18 sessions. Mean latencies for the two tests given at the end of Stage II were, respectively, 11 and 9 sec. for the Control Group and 7 and 11 sec. for the Experimental Group. Figure 2 shows the mean learning curves for the two groups.

Figures 3-5 show the results of the three tests for sensory preconditioning. Although the second test indicated a significant difference ($U=15.5$, $n_1=n_2=9$, $p<.05$)* between the Experimental and Control Groups, the first and third tests did not ($U=36$ and $U=29$, respectively). In order to further evaluate the data, Ss were ranked on the basis of their overall performance on the three tests and a Mann-Whitney U Test was performed. (See Table 1 for individual scores and ranks.) This produced a critical value which approached significance ($U=18$, $n_1=n_2=9$, $p<.10$).

A very conspicuous feature of the results which needs some examination is the high incidence of "no change" ratings. In fact, 66% of the Control Ss did not exhibit a single noticeable response to S_1 during

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*All results are reported in terms of two-tailed statistical tests.

the three tests. Two factors may have been responsible for this. First, the activity level of all 18 fish was low from the time they were received. Second, although all Ss responded to both stimuli during the initial exposure sessions, responses to the light were significantly less pronounced than those to the bubbles. This was originally considered to be a favorable event because S_2 should be stronger than S_1 for optimum results in SPC. However, in view of the test results, there is a strong possibility the stimulus chosen for S_1 was too weak.

Although this experiment failed to yield results which were uniformly significant statistically, the data were highly suggestive of some effect of the different treatments received by the two groups. Whether this could be attributed to sensory preconditioning or to some other factor is not clear. By using such a weak stimulus for S_1 it is possible habituation occurred in both groups but that dishabituation occurred to a greater extent in the Experimental Group. Greater dishabituation would be expected for this group because presentation of S_1 alone in the test situation represented a deviation from its former pairing with S_2 in preconditioning sessions. For the Control Group S_1 was always presented alone.

Room lights were inadvertently turned off and on several times during the training period. This could have compounded any habituation effect already present and could have resulted in some experimental extinction. This factor was eliminated in subsequent experiments.

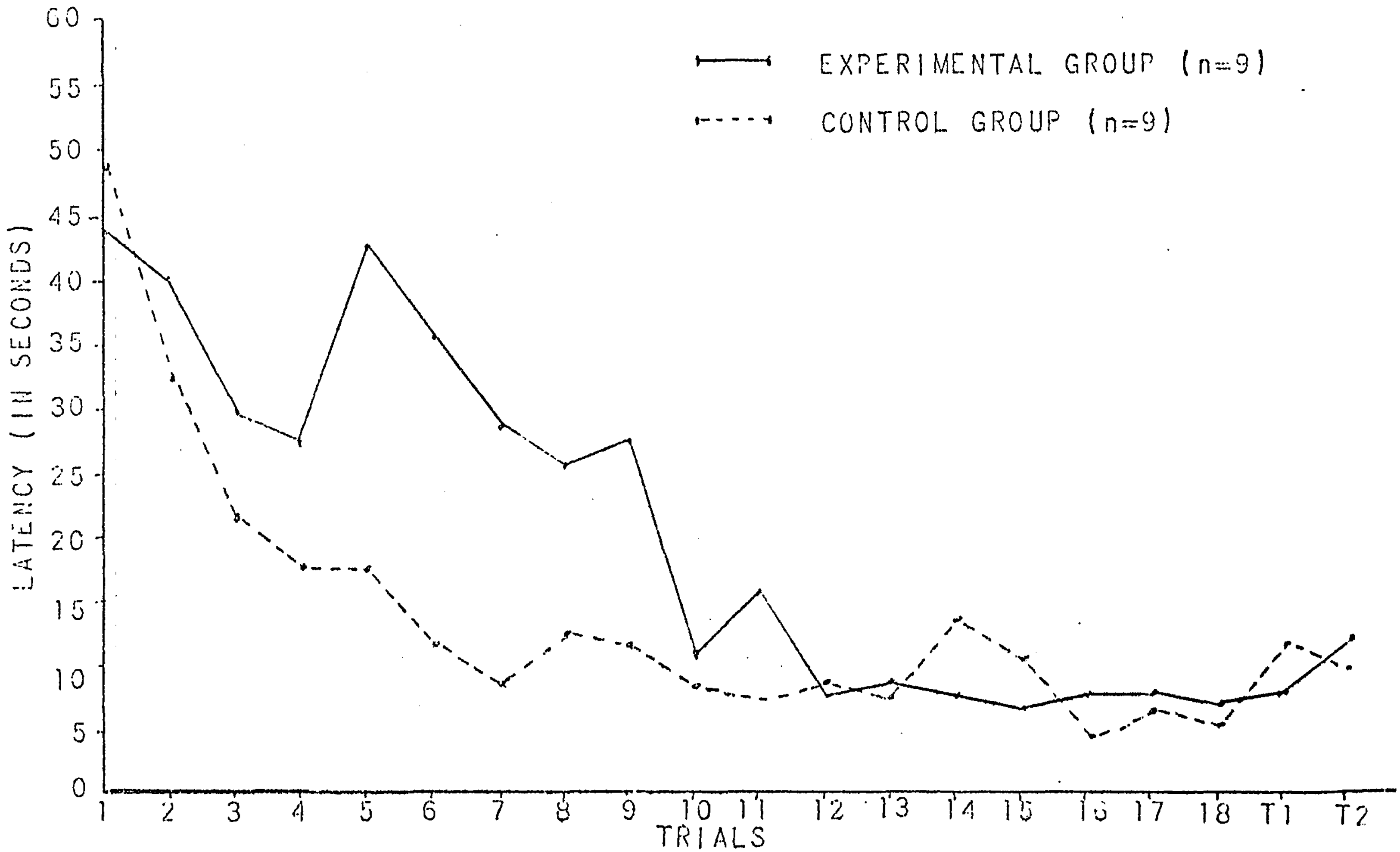


Figure 2. Mean Latency Curves for Stage II, Training with S_2 (Bubbles)

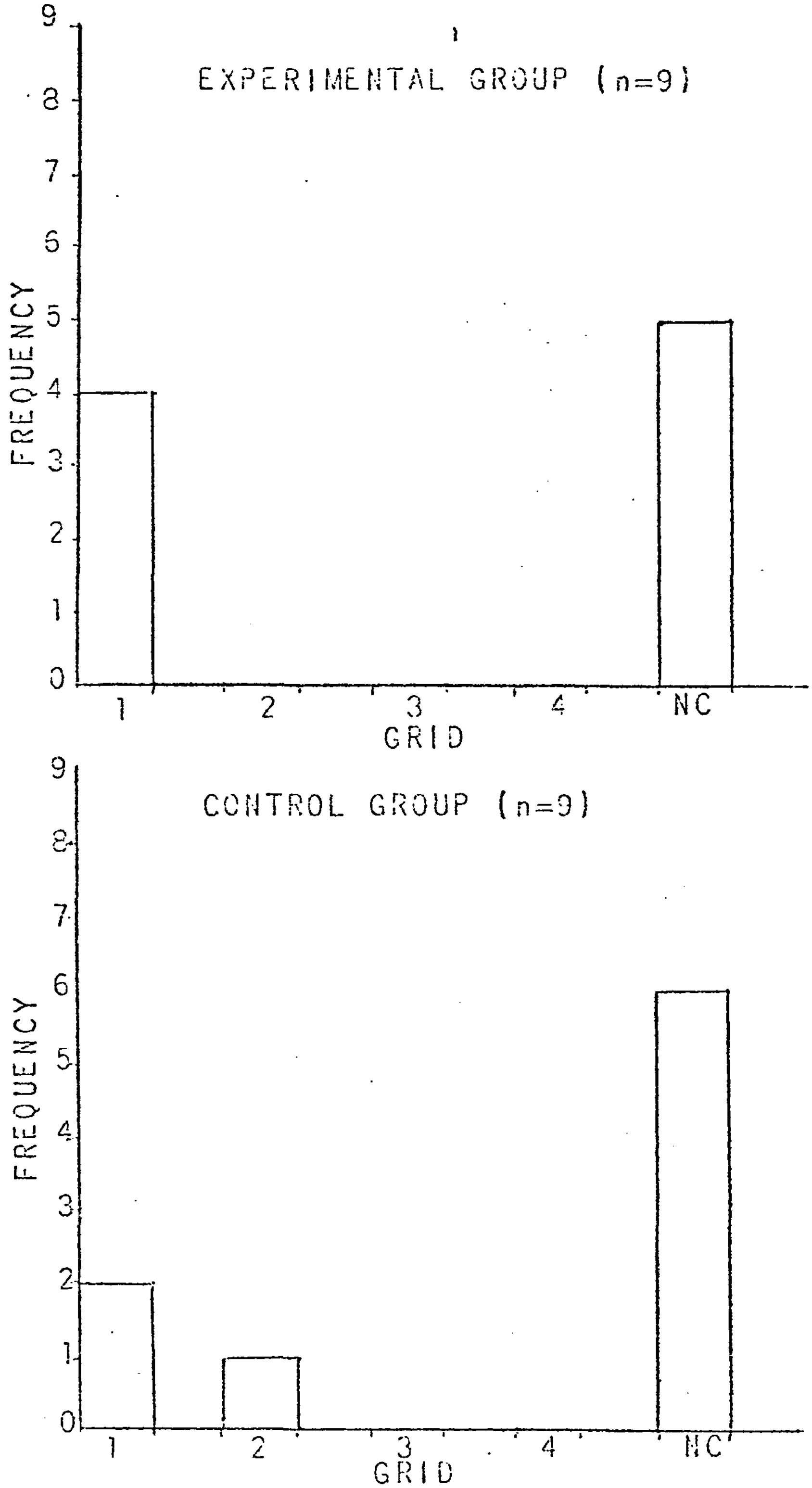


Figure 3. Sensory Preconditioning Test #1, Experiment I.

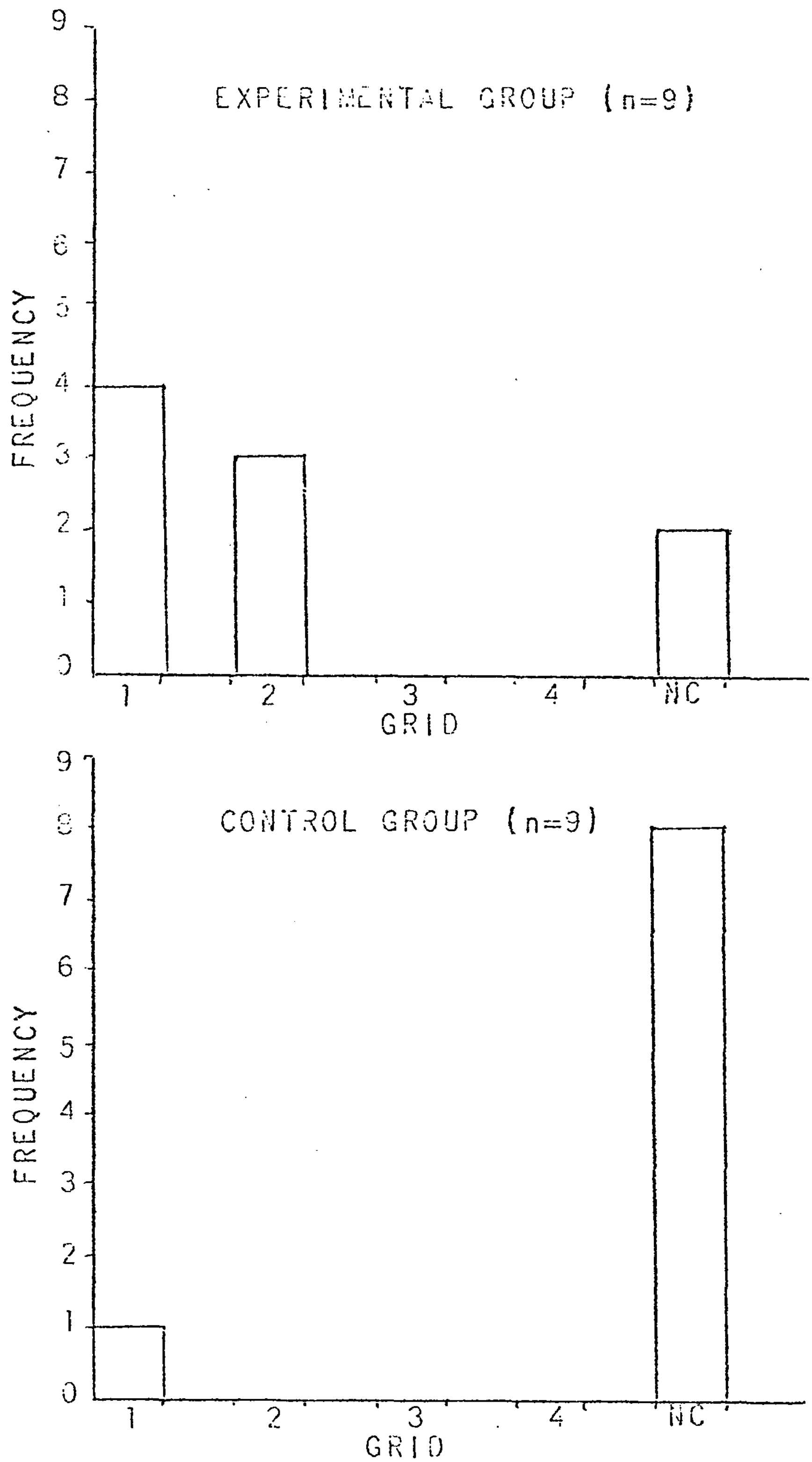
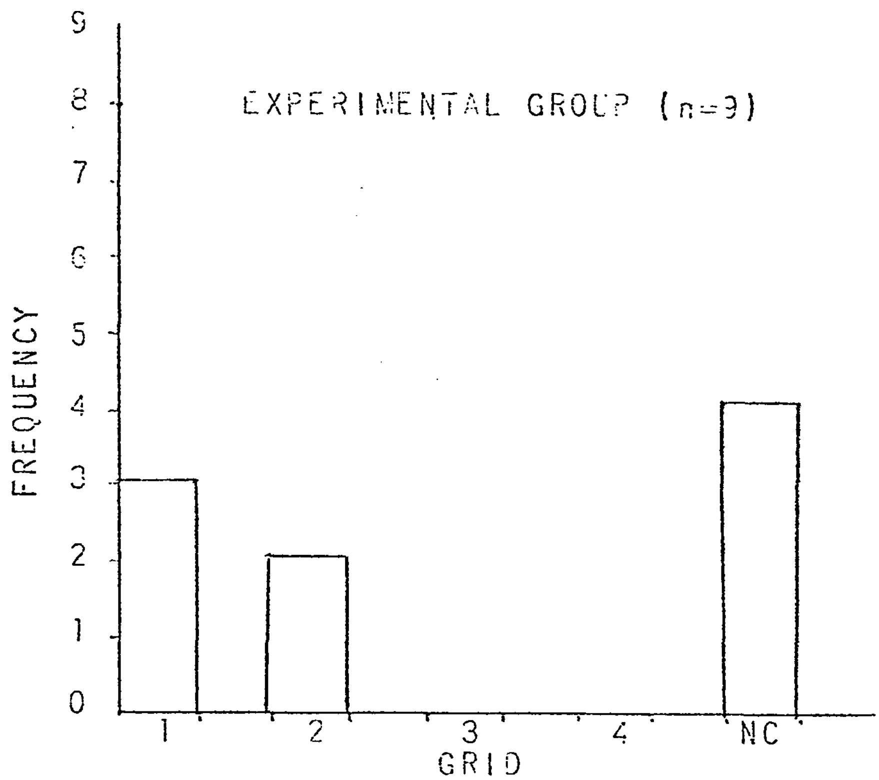


Figure 4. Sensory Preconditioning Test #2, Experiment I.



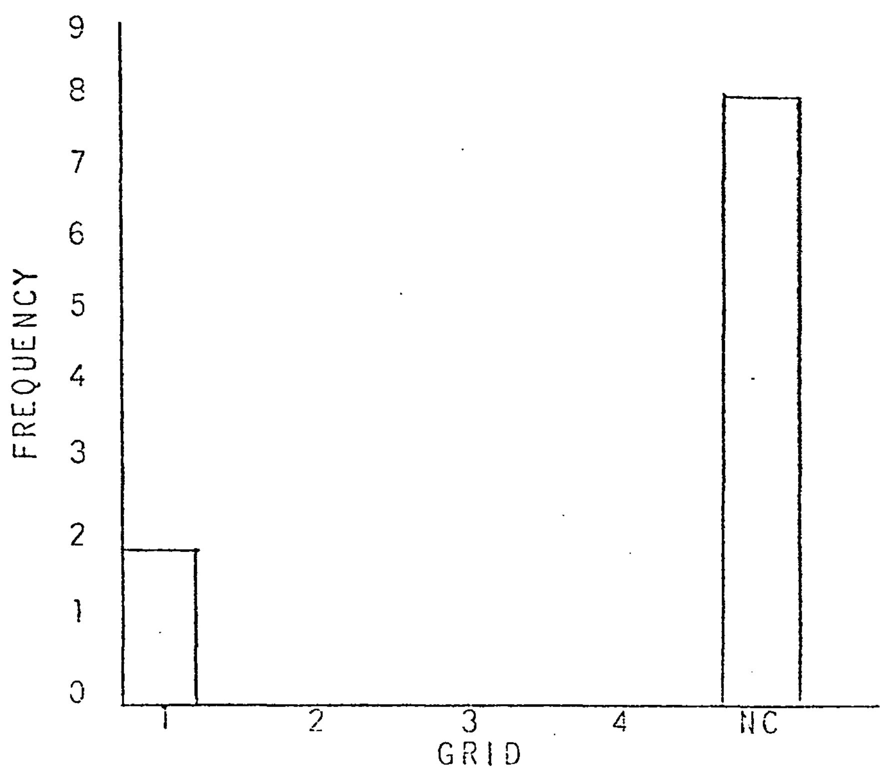


Figure 5. Sensory Preconditioning Test #3, Experiment I.

Subject	Test #1 Grid/ Latency	Test #1 Rank	Test #2 Grid/ Latency	Test #2 Rank	Test #3 Grid/ Latency	Test #3 Rank	Combined Rank
EXPERIMENTAL GROUP							
IA	1/5	16.5	1/5	16.5	1/10*	14.0	16.0
IB	1/15	13.5	NC**	5.5	2/5	13.0	13.0
IC	1/15	13.5	NC	5.5	2/10	12.0	12.0
IIA	1/5	16.5	1/5	16.5	1/0	18.0	18.0
IIB	NC	6.0	1/5	16.5	1/5	16.0	15.0
IIC	NC	6.0	2/5	11.0	NC	6.0	9.0
IIIA	NC	6.0	1/10	14.0	NC	6.0	10.0
IIIB	NC	6.0	2/10	12.0	NC	6.0	8.0
IIIC	NC	6.0	2/20	13.0	NC	6.0	7.0
CONTROL GROUP							
IA	NC	6.0	NC	5.5	NC	6.0	3.5
IB	NC	6.0	NC	5.5	NC	6.0	3.5
IC	NC	6.0	NC	5.5	NC	6.0	3.5
IIA	1/5	16.5	1/5	16.5	1/5	16.0	17.0
IIB	2/5	12.0	NC	5.5	1/5	16.0	14.0
IIC	1/5	16.5	NC	5.5	NC	6.0	11.0
IIIA	NC	6.0	NC	5.5	NC	6.0	3.5
IIIB	NC	6.0	NC	5.5	NC	6.0	3.5
IIIC	NC	6.0	NC	5.5	NC	6.0	3.5

*Fish surfaced in food ring.
**No change notation.

Table 1. Grid/Latency Ratings and Ranks of the Individual Fish During Stage III Testing, Experiment I.

III. EXPERIMENT II

Method

A second experiment was performed using basically the same methods with the following modifications.

1) For greater ease in tracking the Ss, the fish were housed, trained and tested in dyads. Four control dyads and four experimental dyads were used for a total of 8 fish per group.

2) A stronger stimulus was chosen for S_1 in an attempt to minimize the amount of habituation and consequently habituation-dishabituation effects. The new S_1 was a flashing red light which was created by using two 100 watt white bulbs in the Metaframe aquarium light apparatus and covering the apparatus with six thicknesses of red cellophane. The light was turned on and off five times during a 5 sec. interval. Reactions to this stimulus were much more vigorous than had been the reactions to the white light. However, Ss did not appear to respond as actively to this as they did to S_2, which was again the bubbles.

3) Total number of preconditioning pairings was cut from 60 to 50 for the Experimental Group

with a corresponding cut to 50 pre-exposure presentations of each stimulus for the Control Group. Sessions were conducted in the same manner as before except only one session was given the Experimental Group the first day of preconditioning and only two pre-exposure sessions (one for S_1 and one for S_2) were given the Control Group that day. Sessions on the second and third day of preconditioning were the same as in Experiment I.

4) During the tests for SPC no latency measure was taken for any grid except the first (target). In cases where Ss failed to reach the target a grid notation only was made. Therefore, each S was classified either in grid 1 with a latency, or in grids 2, 3, or 4 with no latency, or with "no change."

Results and Discussion

During Stage II training the number of trials required to reach criterion performance was 26. This is eight more trials than were required in Experiment I, and many Ss demonstrated great instability in their Stage II performance during this experiment. Mean number of trials to criterion was 6.7 in the first study as opposed to 13.4 in this one.

This is in line with the results of an early goldfish experiment by Welty (1934) in which he found an inverse relationship between group size and number of trials required to learn an appetitive task. A further discussion of the effects of group size on the Stage II performance of the fish in this study will be presented in a later section.

Mean latencies on the two Stage II post-training tests were, respectively, 9 and 19 sec. for the Controls and 18 and 14 sec. for the Experimentals. Figure 6 shows the mean learning curves for the two groups.

Figures 7-9 show the results of the three tests for sensory preconditioning. No significant difference between the two groups was found on any of the tests (Tests 1 and 3: $U=16.5$, $n_1=n_2=8$, $p<.13$; Test 2: $U=41$). Ss were also ranked on the basis of their overall performance on the three tests, and a Mann-Whitney U Test on this data revealed no significant difference ($U=16.6$, $n_1=n_2=8$, $p<.13$). (See Table 2 for individual scores and ranks.)

This experiment was less suggestive of a difference between the two groups than was Experiment I. Several factors may have contributed to this.

1) As a result of longer time required to reach criterion performance during Stage II, 7 days lapsed between initial preconditioning and testing in this experiment as opposed to 5 days in Experiment I. It is impossible to assess how important this difference is. It is likely, however, that if fish can be preconditioned, the maximum length of time between Stages I and III would be less than the 14 day limit for birds. This assumption is based on the inverse relationship which has been found between position on phylogenetic scale and maximum length of retention of preconditioning (Razran, 1971).

2) An unpublished experiment performed at the University of Houston (Laird, Braud, and Richards, 1972) has indicated a distinct preference for green light in goldfish when the choice is between red and green. Although this does not prove red light to be aversive to goldfish, green light might have been a better stimulus choice in a situation involving feeding.

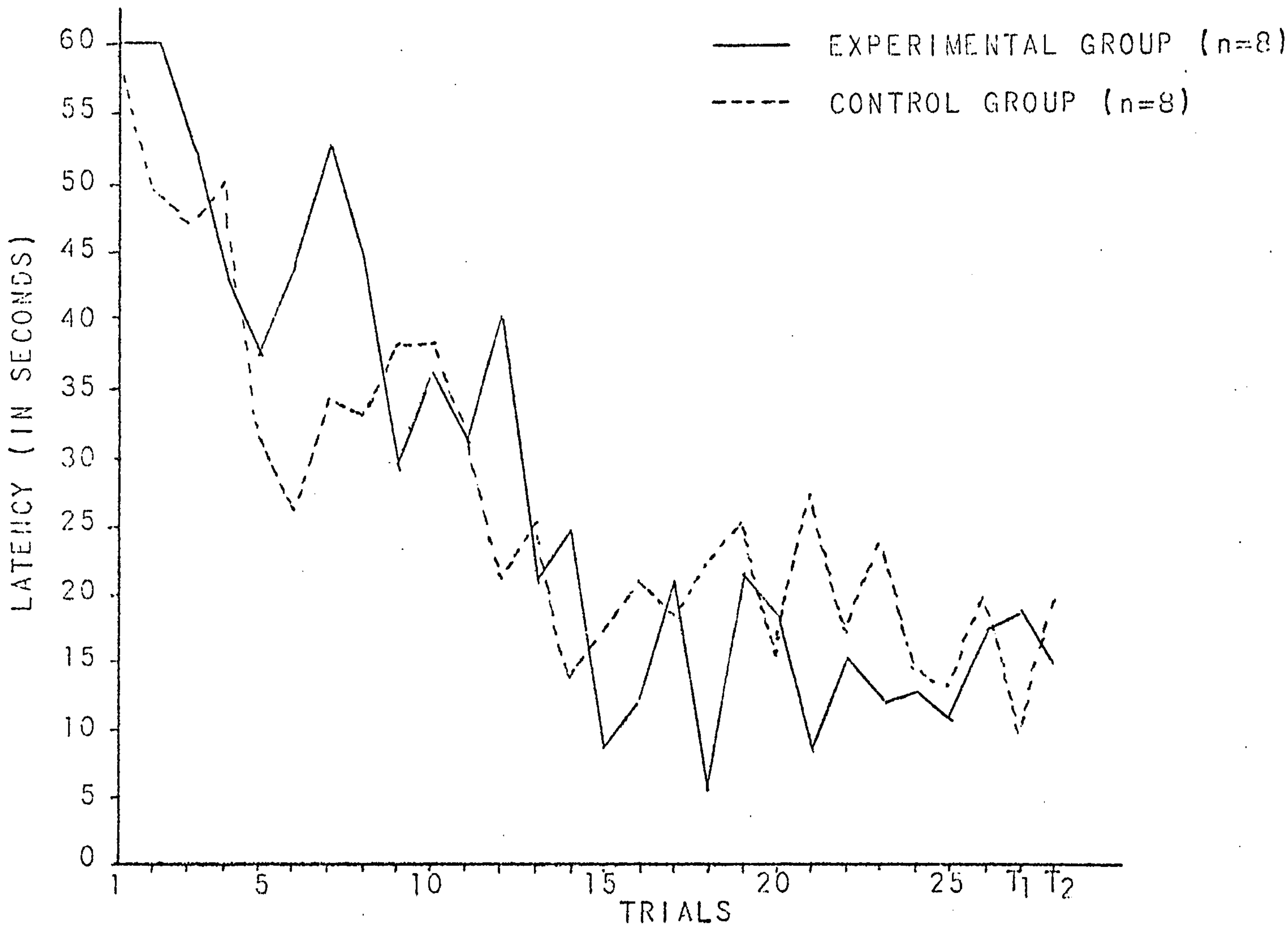


Figure 6. Mean Latency Curves for Stage II, Training with S_2 (Bubbles)

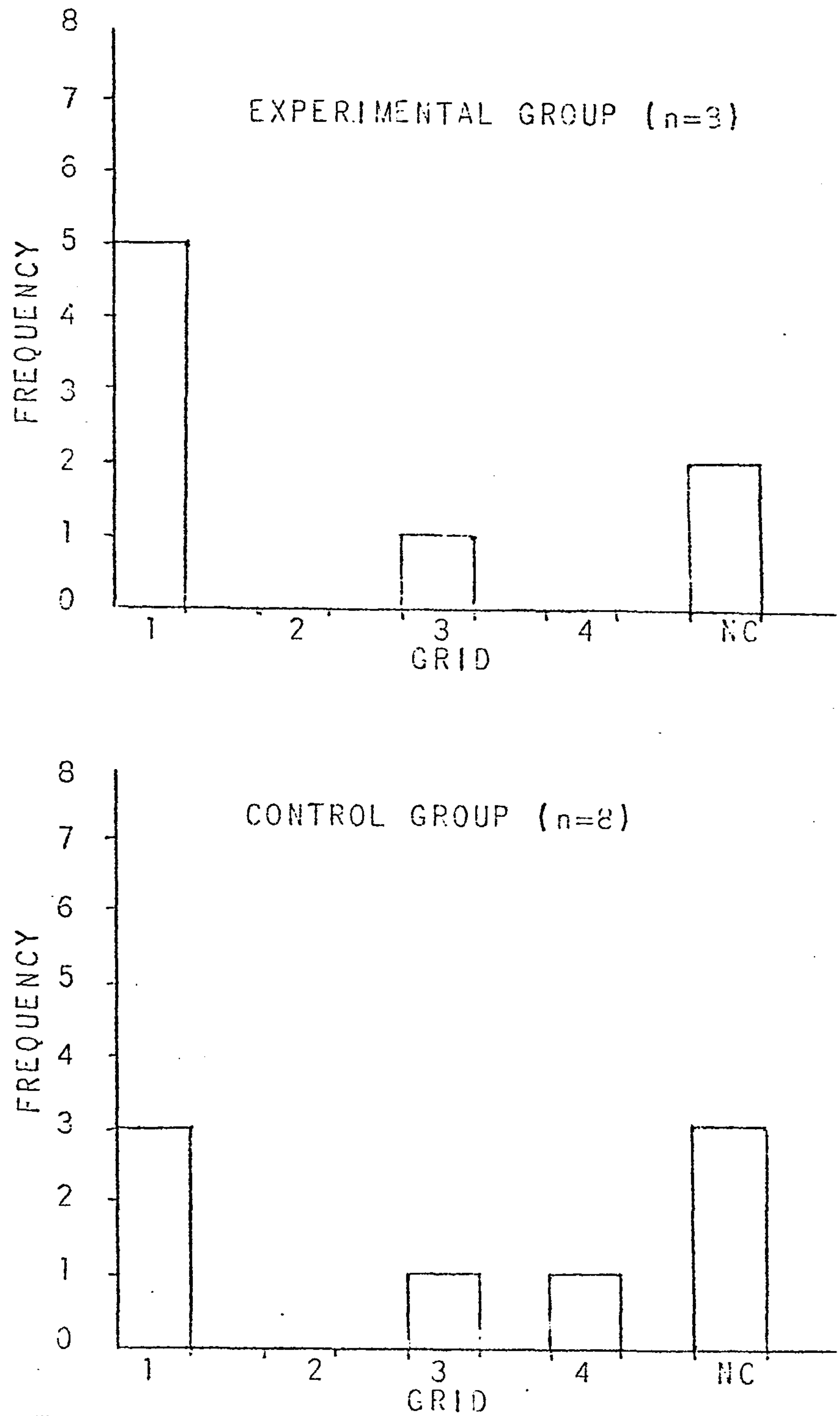


Figure 7. Sensory Preconditioning Test #1, Experiment II.

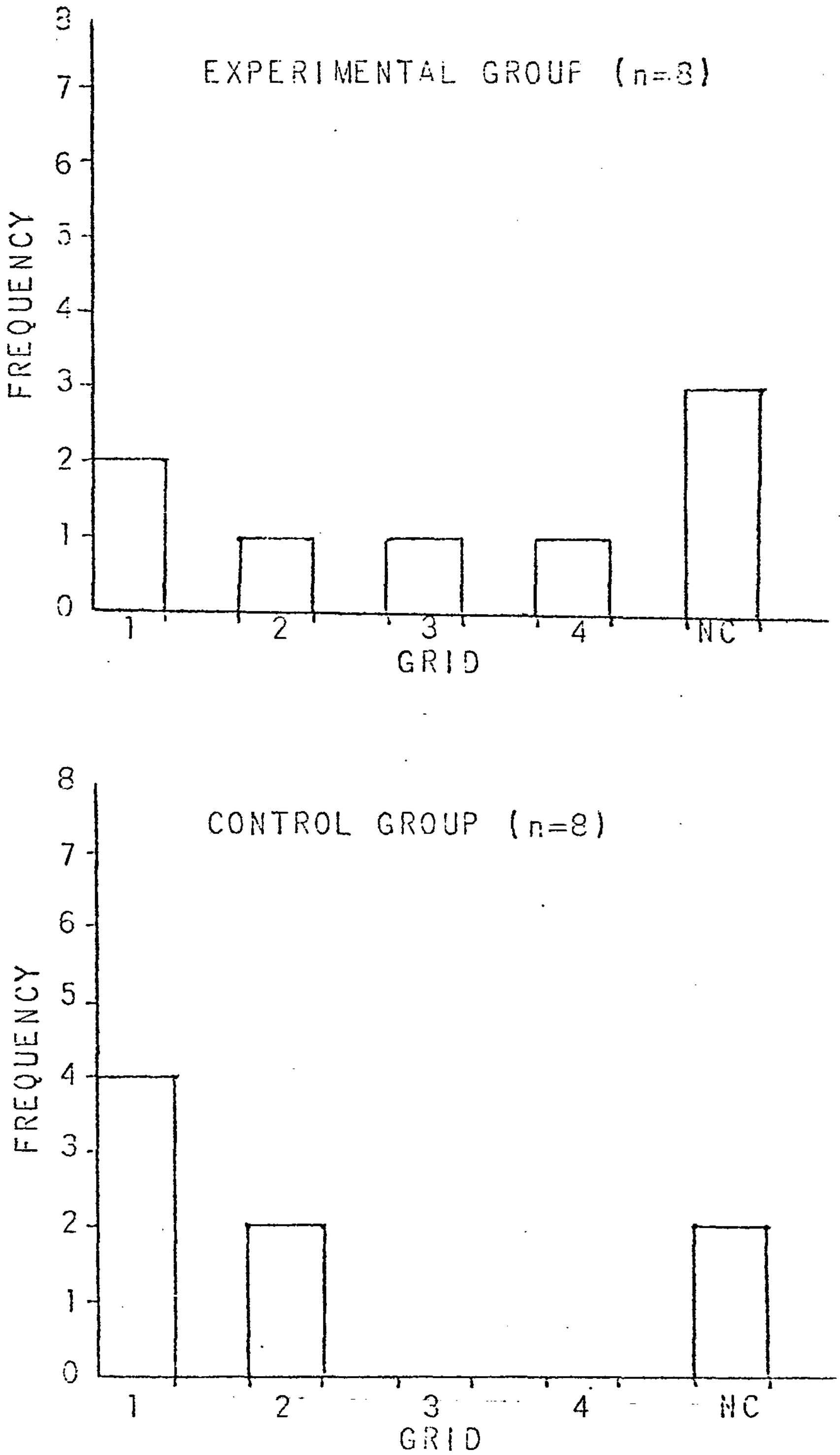


Figure 8. Sensory Preconditioning Test #2, Experiment II.

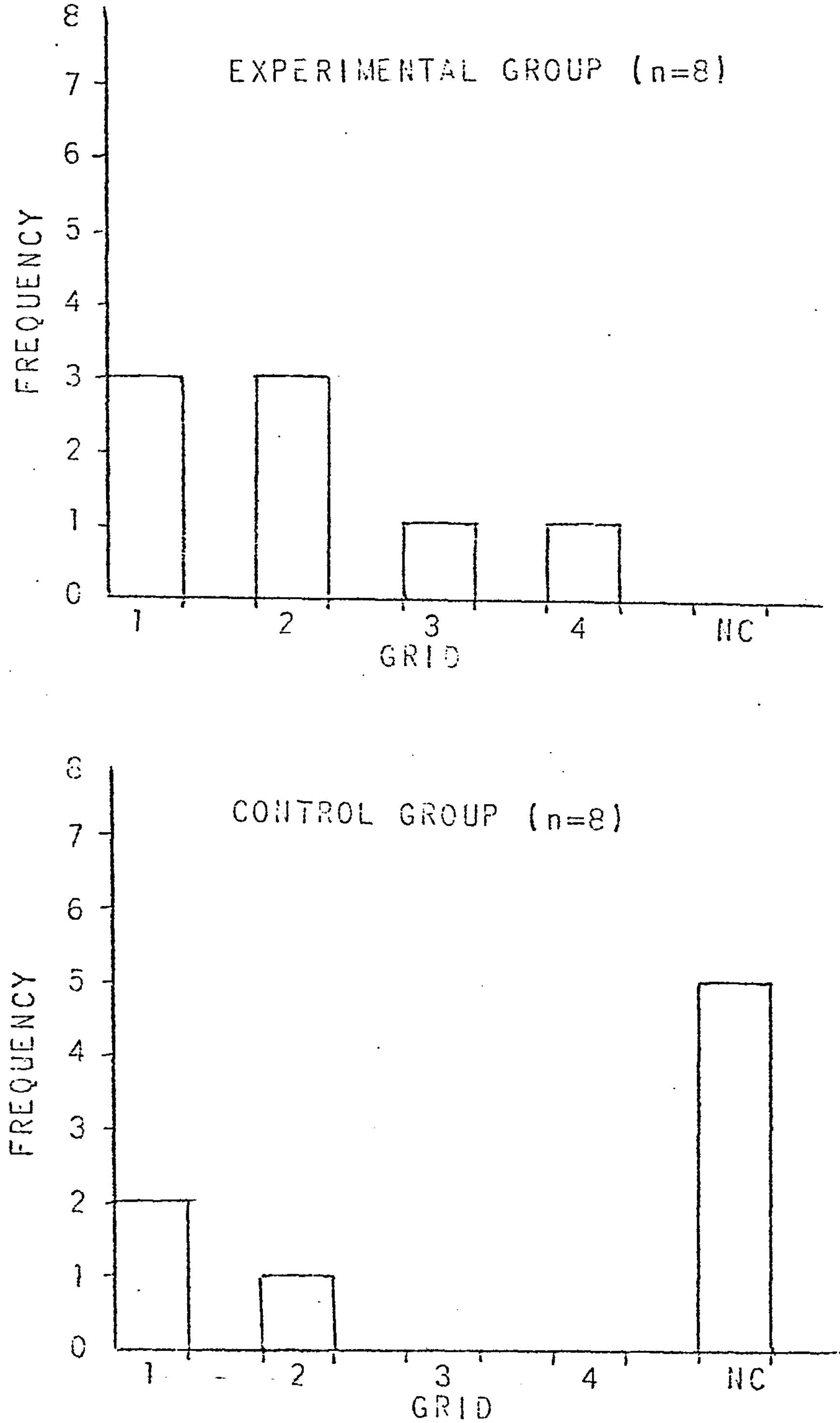


Figure 9. Sensory Preconditioning Test #3, Experiment II.

Subject	Test #1 Grid/ Latency	Test #1 Rank	Test #2 Grid/ Latency	Test #2 Rank	Test #3 Grid/ Latency	Test #3 Rank	Combined Rank
EXPERIMENTAL GROUP							
IA	1/0	15.0	2	9.0	1/0	15.0	16.0
IB	1/5	12.5	3	7.0	2	9.5	13.0
IIA	1/5	12.5	1/5	14.5	2	9.5	15.0
IIB	NC*	3.0	NC	3.0	1/0	15.0	4.0
IIIA	1/0	15.0	NC	3.0	1/40	12.0	10.5
IIIB	1/0	15.0	NC	3.0	2	9.5	8.0
IVA	3	7.5	1/5	14.5	3	7.0	12.0
IVB	NC	3.0	4	6.0	4	6.0	5.0
CONTROL GROUP							
IA	1/20	11.0	2	9.0	NC	3.0	6.0
IB	1/35	9.0	1/5	14.5	NC	3.0	10.5
IIA	NC	3.0	1/5	14.5	NC	3.0	3.0
IIB	NC	3.0	2	9.0	1/5	13.0	7.0
IIIA	3	7.5	1/55	11.5	1/0	15.0	14.0
IIIB	4	6.0	1/55	11.5	2	9.5	9.0
IVA	1/25	10.0	NC	3.0	NC	3.0	2.0
IVB	NC	3.0	NC	3.0	NC	3.0	1.0

*No change notation.

Table 2. Grid/Latency Ratings and Ranks of the Individual Fish During Stage III Testing, Experiment II.

IV. EXPERIMENT III

Method

A third experiment was performed with several modifications to the basic methods.

1) Because of the possibility that group size might affect rate of learning in this experimental situation, 4 Ss were assigned to each home tank. A total of 16 Experimental Ss and 16 Control Ss were used.

2) For greater ease in tracking, the grids were redrawn dividing the tanks into only three sections. Figure 10 shows the new dimensions of the grids.

3) Feedings were reduced from 4 to 3 per day. Training sessions with S_2 were also cut to three per day.

4) A green non-flashing light of 5 sec. duration was used for S_1. The same Metaframe light apparatus with two 100 watt bulbs was covered with six thicknesses of green cellophane paper to create this stimulus. All Ss responded vigorously to this light, but the response did not seem as vigorous as that to S_2, which was again bubbles.

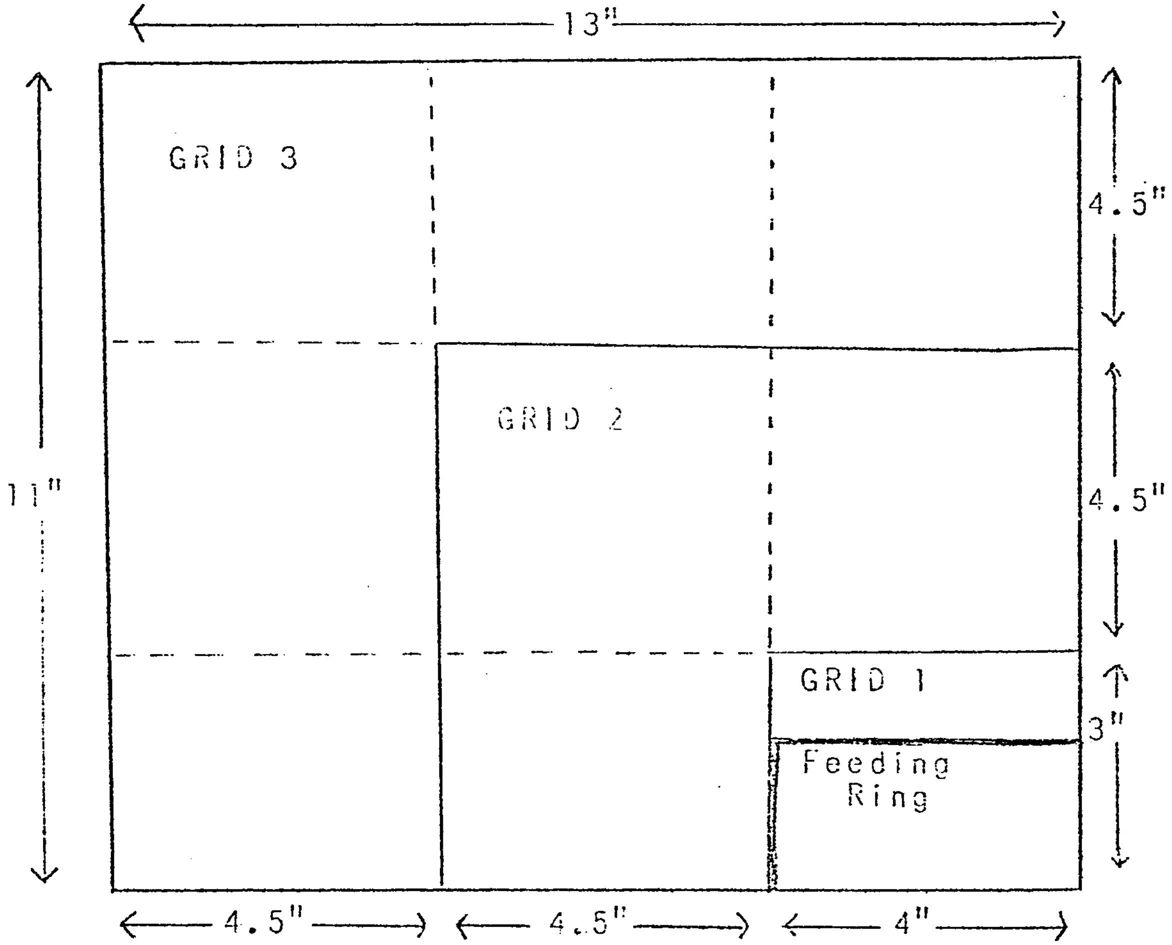


Figure 10. Diagram of tank used for housing, preconditioning, training, and testing of fish in Experiment III. The containers were the same used in the previous two experiments, but grid placement was changed.

5) Preconditioning was conducted exactly as in Experiment I with total number of pairings again set at 60. Correspondingly, the Control Group also received 60 pre-exposure presentations of each stimulus.

6) Four tests were conducted for SPC instead of three, and latency figures were again assigned for all grid levels. Therefore, each S had a grid rating with latency or a "no change" notation.

7) The first test for SPC was conducted 4 hrs. after feeding, but subsequent tests were conducted after 12 hrs. food deprivation.

Results and Discussion

In Stage II all the Ss reached the previously defined performance criterion on the second day of training, i.e., after 5 trials. To assure adequate conditioning, however, training was continued for a total of 4 days or 11 trials. Only one post-training test was conducted. Mean latency on this test was 4 sec. for the Control Group and 2 sec. for the Experimental Group. Figure 11 shows the mean learning curves for the two groups.

Figures 12-15 show the results of the four tests for sensory preconditioning. The first test, which was conducted after 4 hrs. food deprivation, was not even suggestive of SPC ($U=134$, $n_1=n_2=16$). Of the other three tests, which were conducted after 12 hrs. food deprivation, only Test 2 revealed a significant difference between the two groups ($U=65.5$, $n_1=n_2=16$, $p<.02$). During the third test ($U=101.5$) one whole group of fish in the Experimental Group failed to move at all. On each of the other three tests all four of these Ss had reached the target area. The fourth test for SPC was highly suggestive of some effect since the critical value for significance at $p<.05$ was only exceeded by 2 points ($U=77$, $n_1=n_2=16$, $p<.10$).

Ranking Ss on the basis of their performance on all four tests resulted in non-significant values on a Mann-Whitney U Test ($U=104$). However, dropping the lowest score for each fish and ranking them on their best three scores yielded values which were significant ($U=70.5$, $n_1=n_2=16$, $p<.05$) using a Mann-Whitney U Test. Dropping the lowest score for each fish controlled for the cases in which entire groups did not respond at all. (See Table 3 for individual scores and ranks.)

Although this experiment failed to produce unequivocal evidence of SPC, the results were highly suggestive of some differential effect of the treatments given the two groups.

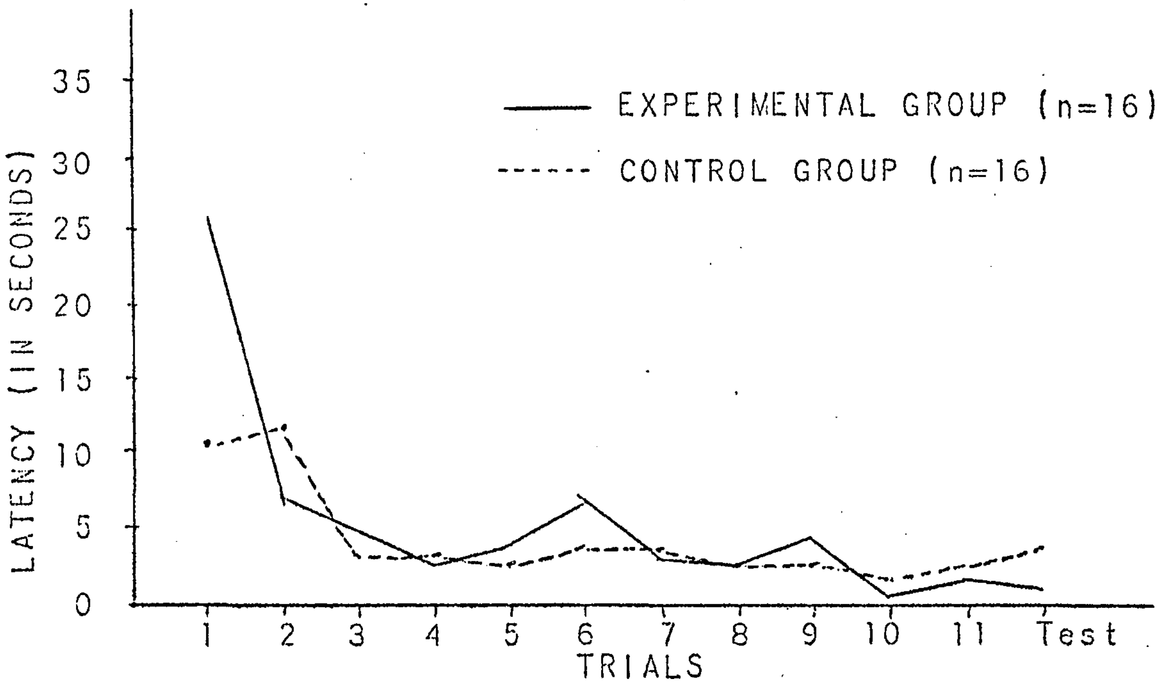


Figure 11. Mean Latency Curves for Stage II, Training with S_2 (Bubbles.

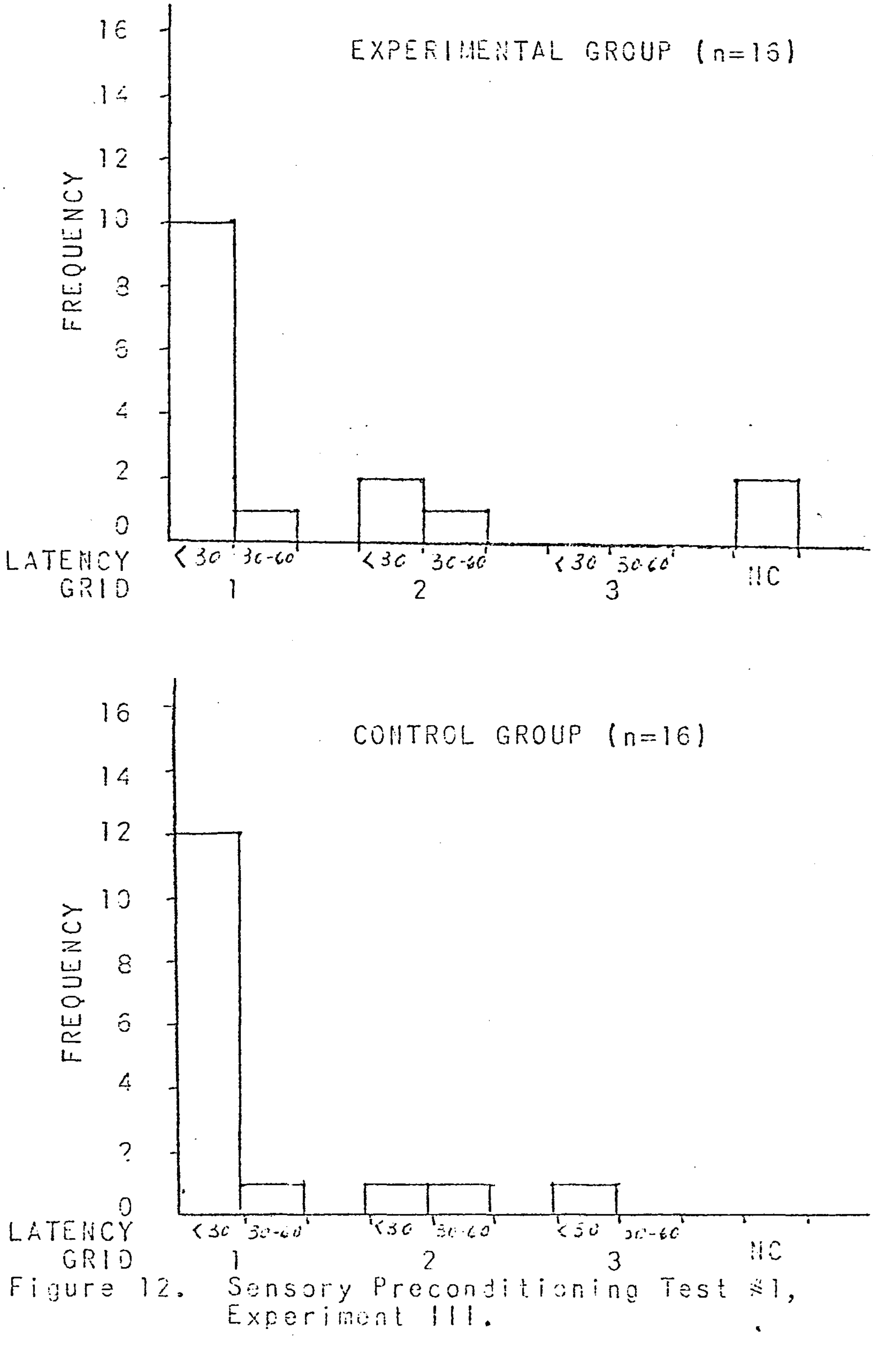


Figure 12. Sensory Preconditioning Test #1, Experiment III.

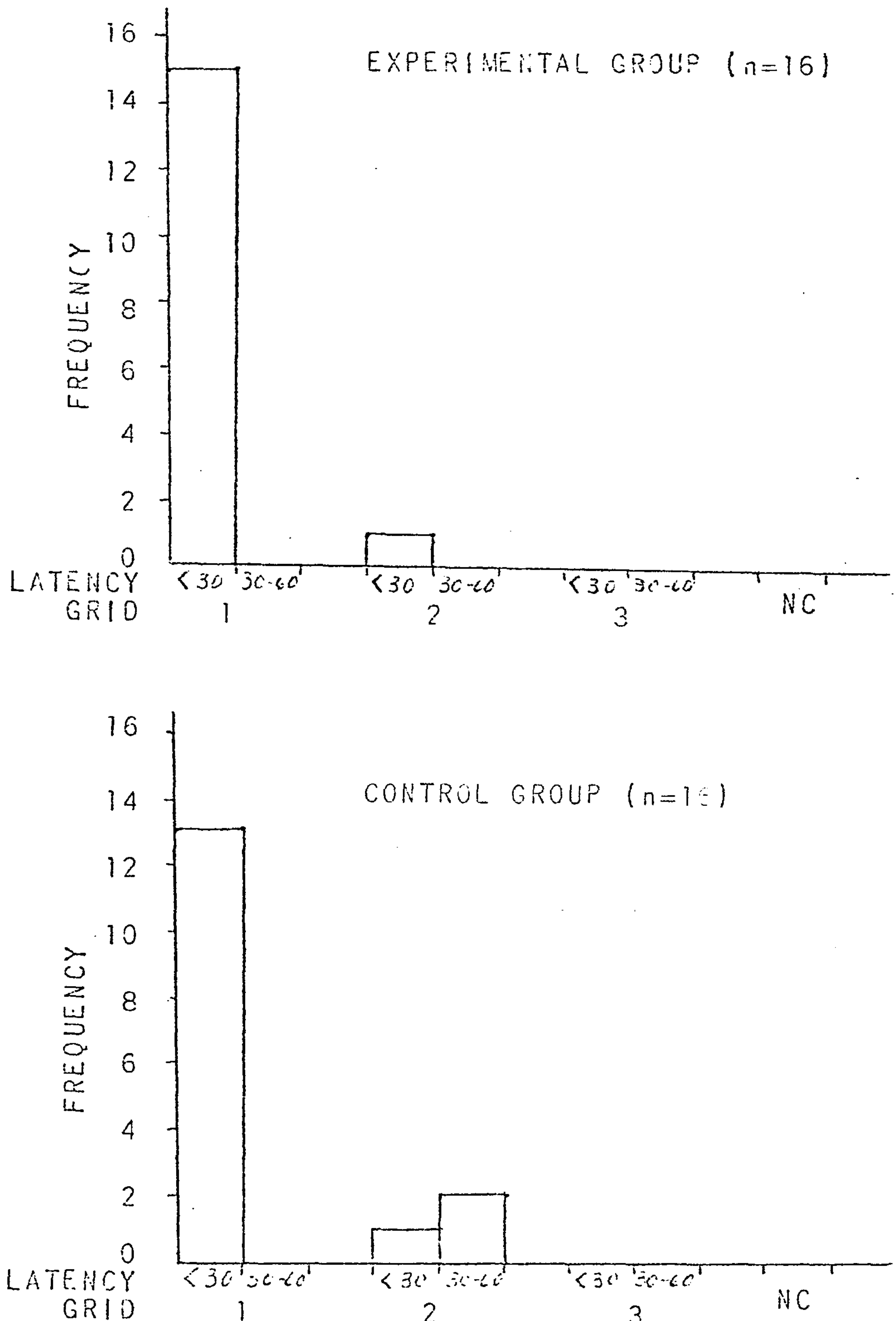
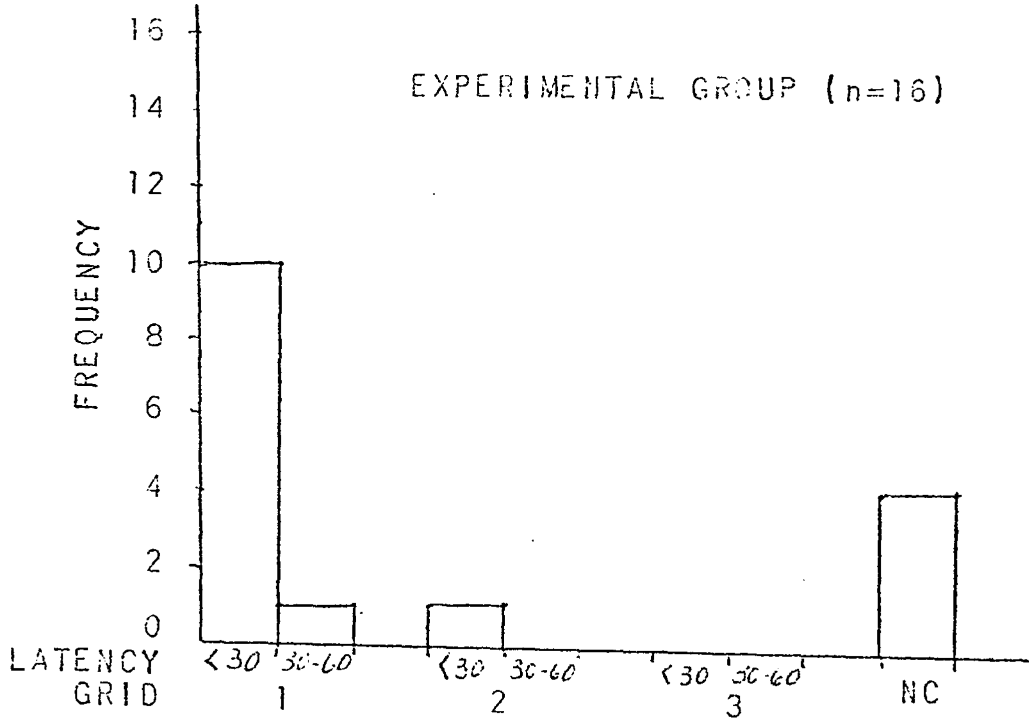


Figure 13. Sensory Preconditioning Test #2, Experiment III.



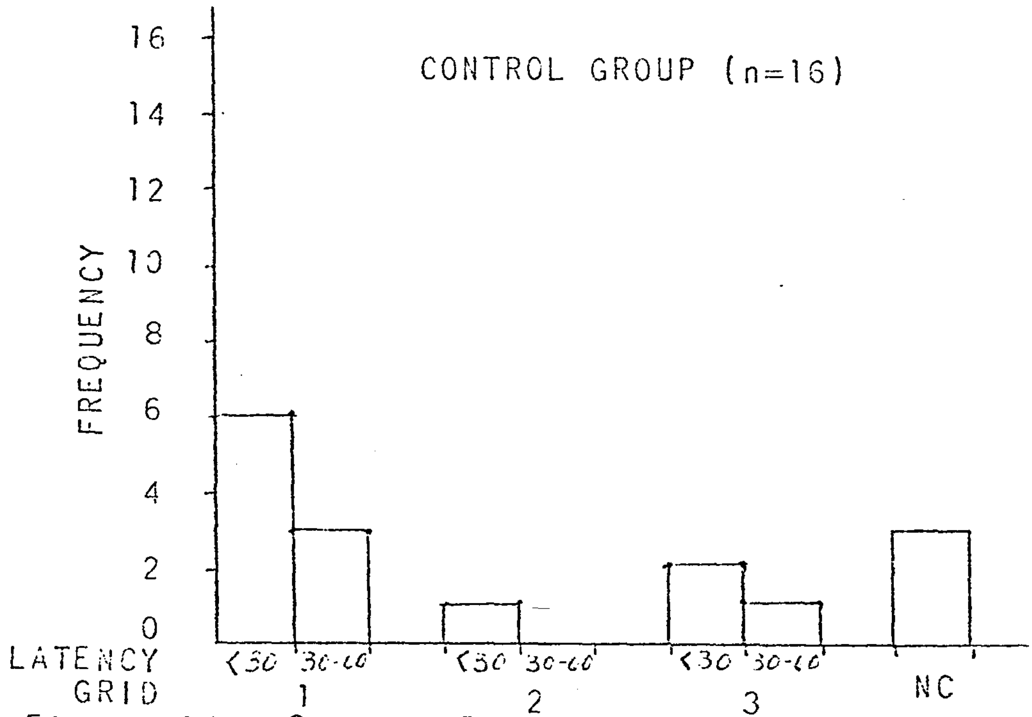
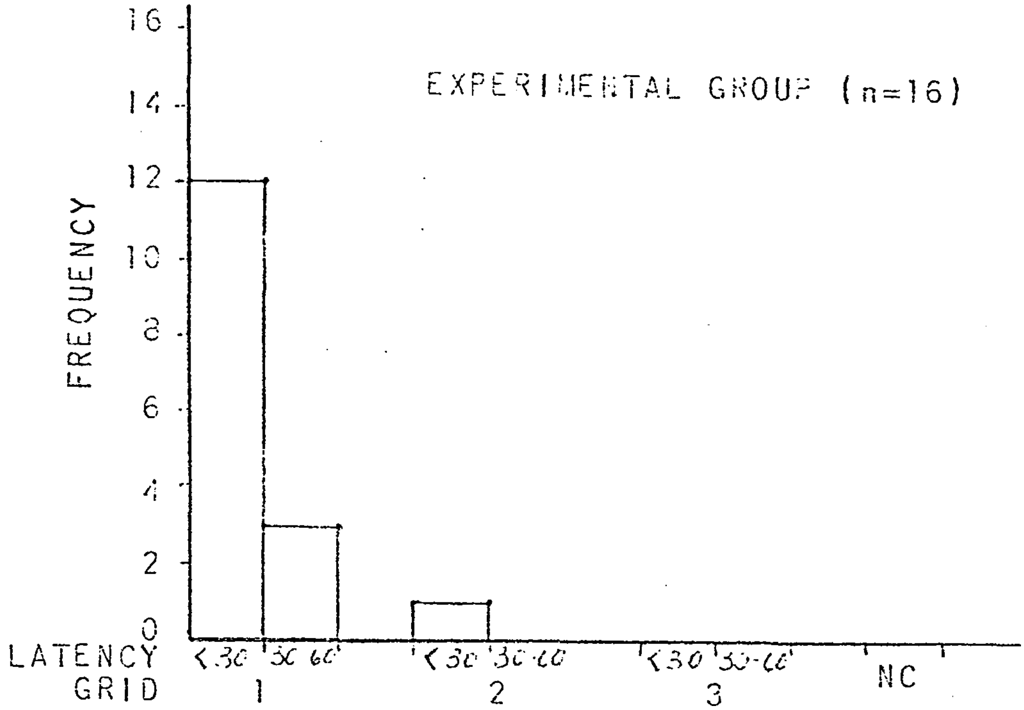


Figure 14. Sensory Preconditioning Test #3, Experiment III.



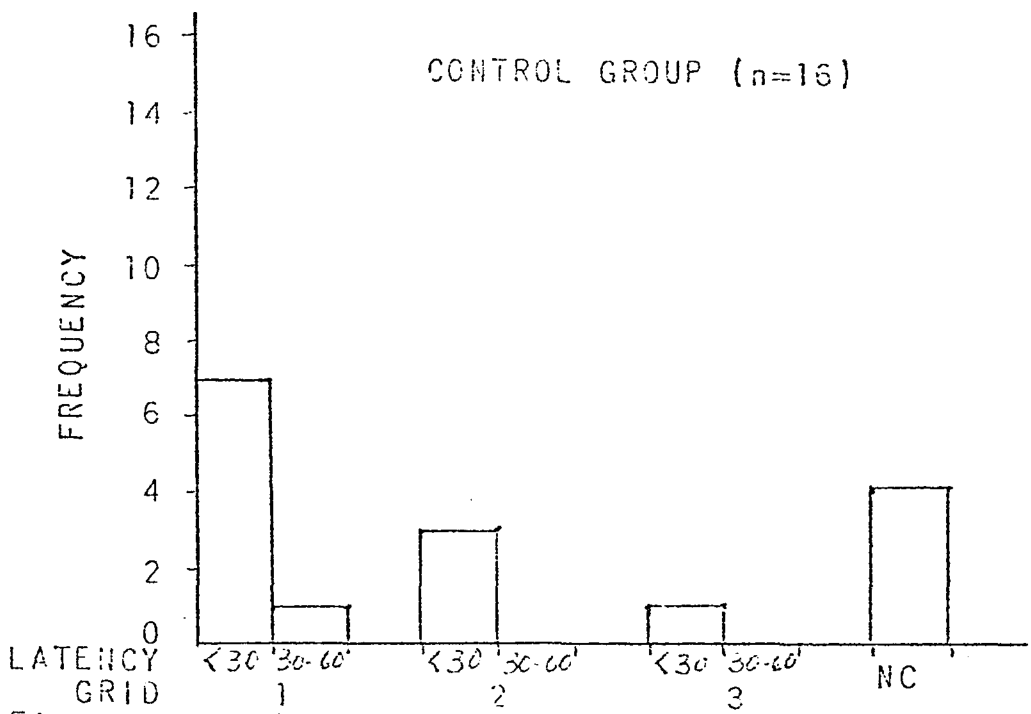


Figure 15. Sensory Preconditioning Test #4, Experiment III.

Subject	Test #1 Grid/ Latency	Rank	Test #2 Grid/ Latency	Rank	Test #3 Grid/ Latency	Rank	Test #4 Grid/ Latency	Rank	Best 3 of 4 Rank
EIA	1/0	25.0	1/0	21.5	NC	3.5	1/10	15.5	16.0
EIB	1/0	25.0	1/0	21.5	NC	3.5	1/40	12.0	11.0
EIC	1/0	25.0	1/0	21.5	NC	3.5	1/5	17.0	20.0
EID	1/50	9.0	1/0	21.5	NC	3.5	1/10	15.5	8.5
EIIA	2/5	7.0	1/0	21.5	1/0	27.5	1/0	25.0	27.0
EIIB	1/10	15.5	1/0	21.5	1/30	15.0	1/45	11.0	11.0
EIIC	2/30	5.0	1/0	21.5	1/0	27.5	1/0	25.0	27.0
EIID	NC	1.5	1/0	21.5	1/0	27.5	1/0	25.0	27.0
EIIIA	1/0	25.0	1/0	21.5	1/0	27.5	2/0	9.0	27.0
EIIIB	1/0	25.0	1/0	21.5	1/0	27.5	1/0	25.0	27.0
EIIIC	1/25	11.0	1/0	21.5	2/0	12.0	1/50	10.0	7.0
EIIID	1/0	25.0	1/0	21.5	1/5	21.0	1/0	25.0	27.0
EIVA	2/0	8.0	1/0	21.5	1/0	27.5	1/0	25.0	27.0
EIVB	1/0	25.0	1/0	21.5	1/0	27.5	1/0	25.0	27.0
EIVC	NC	1.5	1/0	21.5	1/10	18.0	1/0	25.0	16.0
EIVD	1/0	25.0	2/15	4.0	1/10	18.0	1/0	25.0	16.0
CIA	1/15	13.0	1/20	5.0	1/0	27.5	1/0	25.0	13.0
CIB	1/15	13.0	1/0	21.5	1/0	27.5	1/0	25.0	27.0
CIC	1/30	8.0	1/10	7.0	1/30	15.0	1/0	25.0	11.0
CID	1/15	13.0	1/0	21.5	1/45	13.0	2/10	6.0	8.5
CIIA	1/0	25.0	1/0	21.5	1/5	21.0	1/20	14.0	20.0
CIIB	1/10	15.5	1/0	21.5	NC	3.5	1/0	25.0	16.0
CIIC	1/0	25.0	1/0	21.5	NC	3.5	1/0	25.0	27.0
CIID	1/0	25.0	2/25	3.0	1/0	27.5	1/0	25.0	27.0
CIIIA	1/5	17.0	2/30	1.5	NC	3.5	2/5	7.5	3.0
CIIIB	1/0	25.0	2/30	1.5	3/0	10.0	2/5	7.5	4.0
CIIIC	2/25	6.0	1/5	9.5	1/30	15.0	3/0	5.0	5.0
CIIID	1/0	25.0	1/0	21.5	1/5	21.0	1/35	13.0	20.0
CIVA	1/0	25.0	1/0	21.5	1/10	18.0	NC	2.5	16.0
CIVB	1/0	25.0	1/5	9.5	2/5	11.0	NC	2.5	6.0
CIVC	3/15	3.0	1/10	7.0	3/40	8.0	NC	2.5	1.0
CIVD	2/35	4.0	1/10	7.0	3/20	9.0	NC	2.5	2.0

Table 3. Grid/Latency Ratings and Ranks of the Individual Fish During Stage III Testing, Experiment III.

V. DISCUSSION

All three experiments, but particularly the last one, yielded data that suggested some effect of sensory preconditioning in the goldfish. In the first two experiments differences between the two groups were due almost entirely to a "change- no change" dichotomy. However, in the third study there were only 13 "no change" notations throughout the four tests, and these were evenly distributed between the two treatment groups (7 for Control Group and 6 for Experimental Group). This last experiment, then, provides a more valid test of goal directed movement based on SPC rather than on general differences in activity.

An evaluation of the methods used here should furnish information which will be of value in the design of future SPC experiments with goldfish. The basic design of the study has merit. Conducting the entire experiment in the home tank minimizes traumatic handling of the fish, which could interfere with formation or retention of SPC. The task used provides a very sensitive test for preconditioning, which is appropriate for early work with a species. It is also a task which can be learned within the interval constraints for this species. The stimuli used in Experiment III appear to be good choices. They are dissimilar enough to minimize stimulus generalization, and their relative intensities seem satisfactory.

The results of Experiment III indicate that deprivation level at the time of testing may be a factor in eliciting an SPC response in an appetitive task. The obvious explanation for greater SPC response at higher hunger levels is that in this state the animal will be more sensitive to any stimulus which might indicate food. Adamec and Melzack (1970) found that in cats high hunger drive during Stage I led to better preconditioning than low drive when an appetitive task was used for testing. They hypothesize an arousal or attentional process in SPC which is facilitated by hunger in a food-getting task.

Group size appears to have been an important factor in rate of learning during this study. The mean number of trials to criterion for the three experiments were as follows: Experiment I, 3 Ss per group - 6.7; Experiment II, 2 Ss per group - 13.4; and Experiment III, 4 Ss per group - 4.1. An analysis of variance performed on this data revealed a significant difference among the three groups ($F=44.3$, $df=2/63$, $p<.01$). (It is realized that a statistical test on this measure is not strictly legitimate because of the differences in methods over the three studies: pre-treatment differences and a change from 4 training sessions per day in Experiments I and II to 3 per day in Experiment III.) This finding is supportive of Zajonc's (1965) view that the presence of conspecifics raises the probability of dominant responses (food getting, nest building, etc.). He hypothesizes that the presence of others increases the individual's general arousal, which has been shown to enhance the emission of dominant responses. In cases such as the present study, the larger group size should be beneficial to performance because no new, non-dominant response has to be learned; all that is learned is a connection between a stimulus and a response which is already dominant.

In summary, the results of the present study suggest that failure to demonstrate SPC in goldfish may be a function of previous experimental methods used rather than a deficiency in the fish. Further work in the area is, therefore, indicated.

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