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GOLDMAN, Marjorie, 1942-
CONDITIONAL DISCRIMINATIONS COMPARING
MATCHING-TO-SAMPLE AND ODDITY-FROM-SAMPLE
PARADIGMS IN GOLDFISH.

City University of New York, Ph.D., 1976
Psychology, experimental

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CONDITIONAL DISCRIMINATIONS COMPARING MATCHING-TO-SAMPLE AND ODDITY-FROM-SAMPLE PARADIGMS IN GOLDFISH

by

MARJORIE GOLDMAN

A dissertation submitted to the Graduate
Faculty in Psychology in partial fulfillment of
the requirements for the degree of Doctor of
Philosophy, The City University of New York.

1976

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.

July 6, 1976
date

Chairman of Examining Committee

July 7, 1976
date

Florence L. Denmark
Executive Officer

Supervisory Committee

The City University of New York

Abstract

Conditional discriminations comparing matching-to-sample and oddity-from-sample paradigms in goldfish.

by

Marjorie Goldman

Advisor: Sandra Shapiro

The present study investigated the acquisition of three-alternative simultaneous matching-to-sample and three-alternative simultaneous oddity-from-sample in goldfish, a species which has not yet been shown to solve such complex problems. The data obtained from the goldfish were compared to published data obtained from pigeons, a species which showed strikingly different acquisition functions when performing on the two tasks.

Ten experimentally naive goldfish were tested individually in a three key chamber, five fish on each task. When a red, green or blue colored light was presented behind the transparent center disc, a mouthpress response on that disc resulted in the appearance of stimuli behind the two transparent discs on either side. In the matching problem, a response to the side stimulus that was the same color as the

center was correct. In the oddity problem, a response to the side color which was different from the center was correct. A correct response was always followed by a 10 sec. white reinforcement light, and by the delivery of a brine shrimp on 30% of the trials. An incorrect response was followed by a 10 sec. blackout. The fish had to complete 120 trials daily with no time limit for stimulus presentation. A fixed pseudo-random sequence of stimulus combinations was presented daily without correction. Six of the goldfish were trained on both the matching and oddity tasks. Each fish was trained on one task, three on matching and three on oddity, for 70 days, after which training was immediately begun on the other task and continued for 70 days.

Acquisition curves, measured by percent correct responses over days, for the five fish trained on matching-to-sample as task 1 were similar to the acquisition curves for the five fish trained on oddity-from-sample as task 1. Both groups started at about 50% correct and slowly improved to around 80% correct. On task 2, the three fish trained on oddity reached a higher final level of performance than the three fish trained on matching, even though the rate of increase was the same for both groups. All of the goldfish trained on matching-to-sample showed strong color biases whether it was task 1 or task 2. No color preferences were found for any fish performing oddity-from-sample. Side preferences were characteristic of some individual fish regardless of the task.

The results demonstrate that goldfish are able to perform better than chance on matching-to-sample and oddity-from-sample. In spite of the similarity of the acquisition curves for task 1, the divergence of the task 2 curves may indicate that the oddity problem was easier for the goldfish than the matching problem, a result which is opposite to the differences found in data of pigeons. Data of monkeys, pigeons, and now goldfish, support the conclusion that the contingencies of the matching-to-sample task fosters systematic biases in responding.

Acknowledgements

I would like to thank the Research Foundation of C.U.N.Y. for providing some of the supplies and equipment with which this project was carried out through FRAP grant #RF1721 to Dr. Sandra Shapiro. I would especially like to thank my sponsor, Dr. Shapiro, for her support and assistance throughout. I also appreciate the help obtained on various aspects of the project from Dr. Bruce Brown, Dr. David L. Brown, Dr. Brett K. Cole, Dr. Margarita Garcia, Dr. Robert N. Lanson, and Dr. Jack Orbach. In addition, I would like to acknowledge the contribution of the late Dr. William W. Cumming, who inspired this line of inquiry.

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Introduction

The present study of learning in goldfish, Carassius auratus, a teleost fish, provides conditional discrimination learning data to be compared with those of studies conducted with other vertebrate species. Information can be gained from these data concerning the ability of goldfish to solve complex problems and the types of solutions used. Such information can be applied towards an understanding of the learning processes which have developed among different species. In addition, comparisons can be made between the performances of goldfish on matching-to-sample and oddity-from-sample to find out about the nature of these tasks.

Comparative studies of behavioral similarities and differences of different taxonomic groups provide some insight into the evolution of the nervous system as well as the evolution of behavior. Comparative neuroanatomy provides information about structural differences but only by pursuing behavioral research can the function of the different brain structures of various vertebrates be determined. The complexity of the problems solved by goldfish shows the capability of an organism which does not have a cerebral cortex.

One example of the comparative approach is embodied in the work of Sutherland (1969), who compared visual discrimination of rats, octopi, and goldfish in order to infer the perceptual processing mechanisms characteristic of each group. Another approach, investigating learning mechanisms, is that of "phyletic filtration" (Bitterman, 1965). The intent is to select a series of learning problems (e.g. probability learning, habit reversal), each of which is responded to or mastered by some species and not others. Qualitative differences would be inferred from different patterns of responding during parametric manipulations of variables, such as probability of reinforcement or the number of successive problems in which the stimulus associated with reinforcement is reversed. If qualitative differences could be found between species then differences in mechanisms underlying behavior could be inferred. The end result would be a behavioral taxonomic scale in which a pattern of evolutionary changes in behavior could be discerned.

A discrimination paradigm is often used to investigate behavioral differences in Bitterman's investigations. In a simple two-choice discrimination problem, one stimulus is associated with reinforcement and a second stimulus is not. In the habit reversal experiment the stimulus associated with reinforcement is changed across reversals. Responses to one stimulus are always reinforced, either until a criterional performance level is reached or for a fixed number of trials. Responses to the other stimulus are then reinforced for the same period of time or to the same criterion, then responses to the first stimulus are reinforced again, and so on. As a result of initial studies with selected species, animals that showed successive improvement over a series of habit reversals, e.g. rats and pigeons, were grouped into one behavioral category on Bitterman's phyletic scale; whereas the behavior of animals that did not show demonstrable improvement over problems, e.g. goldfish, was categorized as qualitatively different from those which exhibited improvement.

Serious criticism of Bitterman's approach has been raised by Hodos and Campbell (1969). They consider Bitterman's choice of species selected for comparison to have a poor evolutionary rationale. Goldfish, pigeons, rats do not constitute a phylogenetic progression but represent the result of long independent lines of evolution from a common remote vertebrate ancestor. Evolution can be better characterized as the branching of a tree rather than as a linear progression. To counter Hodos and Campbell's argument it should be pointed out that the usefulness of interspecific comparison is an empirical question rather than a theoretical one. Whether a long line of independent biological evolution is associated with great or little behavioral change can only be determined by observation. In addition, interspecies comparison presents a useful method for the analysis of the properties of learning tasks (Bitterman, 1975). The differences in responding to similar tasks by various species indicates the ways in which a given task may be perceived by an organism.

It is also the case that earlier generalizations about qualitative differences between classes of vertebrates have been modified by later research findings, including those of Bitterman himself. Recently it has been shown that, like the rat and the pigeon, fish are capable of improvement over successive habit reversals (Woodward, Schoel, and Bitterman, 1971; Engelhardt, Woodward, and Bitterman, 1973). These results were obtained under special circumstances, e.g. the color of the correct stimulus remained lit during reinforcement. Thus it has been recognized that more careful attention must be paid to the conditions under which behavioral differences do and do not occur (Bitterman, 1975).

Every area of alleged qualitative differences should be explored. It is possible that other assertions of qualitative differences between species are premature, such as the belief that fish cannot master matching-to-sample or oddity problems (Harlow, 1958).

Another discrimination paradigm which has been used for comparisons across species is the conditional discrimination (Lashley, 1938). In a conditional discrimination the relationship between reinforcement contingencies and stimuli in one set depend upon stimuli in a second set. Matching-to-sample and oddity-from-sample fall into this category in that correct responses are determined by both the sample and the choice stimulus. Typically, in a matching problem reinforcement is contingent upon selection of the stimulus which resembles the sample along some stimulus dimension. In the oddity problem reinforcement is contingent upon a selection of the stimulus which differs from the other stimuli which are presented with it.

Conditional discriminations are more complex than simple discriminations. One way of specifying the complexity of a problem is in terms of the number of stimulus and response alternatives necessary for an accurate performance. In a simultaneous discrimination an animal may perform correctly by responding only to the previously reinforced stimulus. In a successive discrimination, a different correct response is associated with each stimulus. In both simultaneous and successive discrimination situations there is an invariant relationship between each stimulus and a reinforcement schedule. The data on habit reversals indicate that fish learn simple simultaneous and successive discriminations. Tasks like matching-to-sample and oddity-from-sample involve an additional contingency. It has not yet been demonstrated that fish can solve more complex discrimination problems such as matching-to-sample or oddity.

It is generally believed that the cerebral cortex is necessary for the solution of conceptual problems; matching-to-sample and oddity have usually been treated as conceptual problems. However, accurate performance on these problems does not necessarily imply concept formation. Animals can demonstrate better than chance responding through a variety of mechanisms, such as learning to respond to each individual stimulus pattern. Perhaps the assumption that fish are incapable of mastering conceptual matching and oddity has deterred investigators from exploring the acquisition of these problems by fish at a nonconceptual level. If the fish are able to master problems involving several stimulus-response contingencies it would be concluded that their ability to solve these complex problems was not dependent on the presence of a cerebral cortex. Additional tests and controls are necessary to demonstrate that the solutions were based on the principles of matching and oddity. Such controls are beyond the scope of the present study which was only a first step in the understanding of complex problem solving by goldfish.

Even if it were demonstrated that fish could master these problems, further investigation would be required to determine whether the fish solve the problems in the same manner as other organisms. Consider a two-alternative matching-to-sample problem in which there are four possible stimulus combinations. For example, if red and green are the stimuli, either one may be presented on the right or on the left, and either may serve as the sample in the center creating red/red/green; green/red/red; green/green/red; or red/green/green as displays of left, center, right, respectively. If an organism learned truly to "match", then the substitution of new stimuli, such as blue and yellow in place of red and green, would not interfere with correct responding. Children older than two years and monkeys show such transfer to new stimulus combinations (Weinstein, 1941). On the other hand, if the organism does not exhibit transfer but responds at chance when new stimuli are substituted, it is possible that the animal learned the correct response to each individual stimulus combination. A third possibility is that the animal has learned the correct stimulus-response chains for the particular sample stimuli on which it was trained. If only one stimulus is replaced in the above example and the stimulus combinations now consist of red, an old stimulus, and blue, a new stimulus, such an organism would be expected to be correct on both red/red/blue and blue/red/red stimulus combinations but will respond at chance to blue/blue/red and red/blue/blue. An animal which had learned responses to each individual stimulus configuration would respond at chance to all four new combinations. The third alternative was the interpretation given to the performance of pigeons on transfer tests by Farthing and Opuda (1974).

Since matching and oddity are logically reversals of the same problem, the question may be raised as to whether they are acquired with equal ease. This question was not extensively investigated before the work of Cumming and

Berryman (1965) with pigeons. Using a three-alternative stimulus design, one can switch problems by reversing the reinforcement contingencies. In their series of experiments pigeons were trained in a three key chamber. One of the three possible stimulus colors was presented on the center key. A response to this stimulus resulted in the illumination of both side keys, one of which was the same color as the center color and the other was one of the two remaining different colors. In the matching problem, the bird was reinforced for responding to the same color on the side key; for oddity the bird was reinforced for pecking at the different color. Different birds were trained on each problem. If animals were only learning to respond to the correct stimulus in each of the individual stimulus combinations, then matching and oddity results should be indistinguishable. If, on the other hand, an animal were learning more about the situation, e.g. "match the center color", or "when red is on the center choose the red side key regardless of position", then different behaviors might be expected to emerge during performance on the two tasks. Cumming and Berryman pointed out that if the bird were learning to respond to the correct stimulus combinations while ignoring the incorrect stimuli, then it would only be necessary to learn three responses to solve the matching problem, one for each sample stimulus color. Oddity solutions would require the acquisition of six responses, one for each possible pairing of colors. However, if in oddity training the animal was learning not to match, there are only three responses which need be learned.

Pigeons showed strikingly different acquisition functions when confronted with a matching-to-sample task than when performing an oddity discrimination. The matching acquisition curve began at 50% correct, remained at this level for a number of sessions, and then rose steeply over successive sessions to performance levels well above 90% correct. Marked response biases were observed at the beginning of learning to match. A position preference of choosing one side on 100% of the trials was common; but other types of preferences, such as responding to one hue every time it appeared, were also reported. Oddity acquisition performance, on the other hand, began above chance and slowly rose to a maximum of about 90% correct. In oddity discrimination no preferences were apparent. It was not clear whether the differences between oddity and matching learning were peculiar to the pigeon or were engendered by the nature of the tasks. Skinner's (1950) statement that choosing the opposite stimulus would not be any easier or more difficult to acquire than choosing the same stimulus has not been substantiated. Systematic comparisons of oddity and matching learning have not been carried out for species other than the pigeon. There are reports of a tendency for chimpanzees to choose the odd stimulus at higher than chance levels at the beginning of oddity learning (McCulloch and Nissen, 1937). Rhesus monkeys show an initial position bias when solving matching-to-sample tasks using colors as stimuli (Jackson and Pegram, 1970).

In the experiments performed by Cumming and Berryman (1965) pigeons did not show positive transfer to a novel stimulus. In the matching situation, after the birds were responding at over 90% correct to each of three alternative stimuli, red, green and blue, the blue stimulus was replaced by a new color, yellow, to which the birds had not been previously exposed. Percent correct responding when the new stimulus, yellow, was the sample was only 50%, or chance level of performing. This result was interpreted to mean that their animals did not acquire the "concept" of matching. Cumming and Berryman did not train their birds to transfer to new problems as is often done in a learning set experiment. However, Pastore (1955) had previously shown that canaries exhibit progressive improvement over a series of novel oddity problems. Even monkeys do not always show immediate, positive transfer to a new problem. Accuracy of the monkeys in the Jackson and Pegram (1970) study dropped to 50% correct when switched to form stimuli after having been trained to match colors to a criterion of 90% correct or better over five days. Positive transfer is not in itself evidence of concept learning. It may reflect some general improvement such as the elimination of some competing responses. Conversely, an immediate failure to show positive transfer may occur in organisms which subsequently demonstrate conceptual learning.

The question of how different species learn these tasks may not be answered without attention to procedural variations. Both the oddity task and the matching task can be defined by a number of different experimental arrangements. In the first oddity experiment with a cynomologous monkey, two alternative stimuli were used; plain gray boxes and gray boxes with black paper discs pasted to them (Robinson, 1933). These boxes were presented in all six possible combinations. In each combination the odd box was associated with reinforcement. Sometimes reinforcement was associated with the gray box and sometimes with the box with the black discs.

After the demonstration that chimpanzees and monkeys performed the two-alternative tasks very competently (Nissen and McCulloch, 1937; Weinstein, 1941), interest turned to whether or not the animal had learned the concept of oddity and was able to choose the odd stimulus from any array. Matching-to-sample and oddity problems were then used as baselines to study other phenomenon such as: short-term memory, which can be investigated by imposing a delay between the offset of the sample and the onset of the comparison stimuli (Riesen and Nissen, 1942; Etkin and D'Amato, 1969); higher order conditional discriminations, e.g. the identity of the problem (matching or oddity) was determined by an additional stimulus such as the tray color in the WGTA (Spaet and Harlow, 1943); concept formation and abstraction, e.g. Weinstein's (1945) demonstration of symbolic behavior in the monkey; error factor analysis (Moon and Harlow, 1955); information processing (Wilson, 1974); and learning set transfer problems. Evidence of improvement over successive problems occurs in young humans (children older than two years) (Weinstein, 1941), chimpanzees (Nissen, Blum and Blum, 1948) and rhesus monkeys (Weinstein, 1941). Improvement over successive oddity problems has been demonstrated by children between the ages of three and ten years (Martin and Blum, 1960), chimpanzees (Strong and Hedges, 1966), monkeys (Meyer and Harlow, 1949), cats (Warren, 1960), rats (Wodinsky and Bitterman, 1953) and canaries (Pastore, 1955).

Training techniques can have an important influence on the acquisition and transfer of discriminations. It was believed that rats could not perform matching-to-sample and oddity until Wodinsky and Bitterman (1953) trained them using a step-wise training procedure. The procedure of shaping complicated performances by changing the discriminations in small steps starting with a very simple task has been used to train monkeys to solve very complex discriminations (Weinstein, 1945).

With fish as subjects the most obvious example of the influence of procedural variables was the demonstration of progressive improvement in successive habit reversals (Squier, 1969; Engelhardt, Woodward and Bitterman, 1973). In the habit reversal experiment, the stimuli associated with reinforcement change across reversals rather than from trial to trial as in a conditional discrimination. The claim was made, based on a series of studies, that fish do not show progressive improvement (Bitterman, 1965). However, Engelhardt and his colleagues showed that presenting the positive stimulus during the reinforcement period resulted in improvement over successive reversals in fish. Another factor in reducing errors was the requirement that the presentation of the discriminative stimuli be contingent on a center key response.

The present study was an attempt to demonstrate the acquisition of three-alternative matching-to-sample and oddity-from-sample by goldfish using training techniques adapted from those which Cumming and Berryman (1965) used with pigeons. One difference in the present experimental design was that each fish learned both tasks in succession to facilitate a direct comparison between the acquisition of matching-to-sample and oddity-from-sample. Matching and oddity behavior were defined as correct choice between two side colors on the basis of their relation to the center color (same or different). In addition, an analysis of acquisition strategies was carried out. In this paper the terms matching and oddity are employed only in the operational sense and refer solely to performances on the three-alternative procedure of this experiment. Conceptual learning, traditionally inferred from strong positive transfer to novel stimuli, was not tested and should not be inferred from the subsequent presentation.

Method

Subjects

The subjects were 10 experimentally naive goldfish, 7-13 cm in length from tip of the nose to base of the tail, purchased from a local pet store. They were housed individually in 9.5 liter tanks (31 x 16.5 x 20.5 cm) with continuous aeration through plastic filters. The room temperature was maintained at about 21 degrees C. Flourescent room lights were on continuously.

Apparatus

The subjects were trained individually in a three key chamber modified after that of Longo and Bitterman (1959). The fish's hometank, with filter removed and debris siphoned, was placed in a black Plexiglas training chamber, which had a hinged side door and top lid. Attached to the lid were three steel rods at the end of each of which was a clear Plexiglas disc, 3 cm in diameter, with a space of about 1 cm between discs. The rods were suspended from crystal phonocartridges, Turner Model A and Astatic Model 12U. The phonocartridge converted a mechanical displacement into a corresponding electrical signal, which was then converted to compatible voltage pulses for use with relay logic. A sheet of painted black metal, extending 8.5 cm below the lid kept the fish from contacting the rods, and thus insured that the recorded responses were those made to the disc through which the stimuli were presented. Four black metal strips separated the discs and served as barriers thus preventing the fish from hitting more than one disc at a time. When the lid was lowered, the transparent discs moved into place in a row exactly in front of three transparent stimulus windows. Behind the windows, mounted on the wall outside the training chamber, were three Grason Stadler pattern #E4580-156 multiple stimulus projectors. Thus each projector was aligned with one of the discs when the lid was down. The stimuli used in the present experiment were white, red (Wratten filter #25A), green (Wratten filter #61), and blue (Wratten filter #47) lights. By illumination of a G.E. #44 bulb with 6.3 volts AC, the stimuli were projected onto the discs, coloring the entire disc. At the end of the training chamber opposite the stimuli was a translucent white Plexiglas panel behind which two G.E. #44 lightbulbs were mounted. These lights were turned on following the occurrence of a correct response. Food reinforcement was delivered through a hole in the lid 5 cm from the lighted end of the tank. A bank of eye droppers, arranged on a rotating platform above the box, held the reinforcer, a tubifex worm or a brine shrimp. On reinforced trials one dropper was squeezed by a solenoid-actuated clamp to deliver a single reinforcer.

All phases of the stimulus presentation and response recording were programmed using electromechanical equipment.

Procedure

Pretraining. After each fish was observed to have returned approximately to its usual hometank level of activity on daily sessions in the training situation, the center disc was transilluminated with white light. When the fish was near the disc, the reinforcement light was turned on and simultaneously a brine shrimp was dropped into the tank. When the fish no longer appeared to be startled at the onset of either the stimulus or reinforcement light, and was readily eating the shrimp, the fish was shaped to press the center disc with its mouth. Once the fish was responding rapidly on the center disc, a new contingency was added. The center disc response led to the illumination of both side discs with white light and a response to either side disc was reinforced. Since the fish distributed their responses between the two discs, no attempt was made to control the number or order of responses to the side discs. A partial reinforcement procedure was formally introduced during pretraining because about 10% of the reinforcers remained in the dropper or missed the hole, such that a continuous reinforcement schedule was impossible to maintain. Daily pretraining trials continued until the fish appeared satiated. Additional feeding was dependent upon the progress of the fish and was withheld from those who seemed to be responding slowly. When the fish was responding rapidly, with short latencies to both center and side discs, conditional discrimination training was begun. Preliminary training required from 5 to 12 days per fish.

Conditional discrimination training. The fish were trained on one of two separate problems: three-alternative simultaneous matching-to-sample and three-alternative simultaneous oddity-from-sample. When either a red, green, or blue light appeared behind the center disc, a mouthpress on the center disc resulted in the appearance of stimuli behind the two side discs, with the center stimulus remaining on. One side stimulus was the same color as the center, and the other side stimulus was one of the two remaining different colors. In the matching problem, the side stimulus which was the same as the center color was designated correct. In the oddity problem, the side stimulus which was different from the center color was designated correct. There are twelve possible combinations of the three colors, given the restriction that one side must be the same color as the center. The stimulus order was derived from a random permutation of twelve which was then repeated in reverse to provide a sequence of twenty-four trials. This sequence was repeated five times per session, 120 trials in all. The same stimulus order was maintained throughout discrimination training. The stimulus order is presented in Table 1 in the Appendix.

A noncorrection procedure was employed. A response to the correct side was always followed by a 10 sec. reinforcement light. The delivery of a brine shrimp for correct responding was on a random schedule of either approximately 30% or 90%. Thus the light, which was presumed to be a secondary reinforcer, followed each correct response; but primary reinforcement was delivered on a partial reinforcement basis. While the exact level of partial reinforcement varied throughout the experiment, on the first day of discrimination training a schedule approximating continuous reinforcement was in effect for all animals. An incorrect response was followed by 10 sec. in darkness, which ended the trial. Both correct and incorrect trials were followed by a 4 sec. intertrial interval in darkness, after which the center disc was illuminated for the next trial. There was no time limit for stimulus presentation; the center and/or side stimuli remained lit until a response was made. The fish were fed to satiation immediately after they completed a session. By the fifth day of conditional discrimination training a daily session was completed in about 50 min. In rare instances, when no response occurred for an hour or more, the fish was removed from the apparatus and not fed. Each fish was exposed to daily discrimination training sessions except for a few omissions.

Each fish was trained on one task, either matching-to-sample or oddity-from-sample, for 70 days, after which training was immediately started on the other task and continued for 70 days. Matching discrimination was the first-learned problem for five fish, three of which were subsequently trained on oddity discrimination. Oddity discrimination was the first-learned task for five other fish, three of which were subsequently trained on matching discrimination. In addition to these ten fish, six fish became ill or died during shaping and four more died after conditional discrimination training had begun.

The training conditions for each subject are given in

Table 1. Reinforcement schedules shown in the table are nominal values. Procedural variations were introduced during the training of the first three fish to increase the efficiency of the experiment. The initial plan was to train the first three fish (2,3, and 6) until they responded at a steady level; i.e. no further increases in accuracy over a 10-day period. They were, therefore, trained on task 1 only, for variable amounts of time. Fish 2 and 6 were trained on the matching problem and fish 3 was trained on the oddity problem. The schedule of reinforcement for all three animals was a variable ratio 3 (range 1-5) in which only correct side disc responses across trials were counted in fulfilling the ratio. On approximately the 35th day of training, a probability gate (LVE model #235-11), set at 30% for correct responses, was substituted and employed thereafter. After fish 3 and fish 6 had reached approximately 80% correct responding during a session, the probability of reinforcement was systematically reduced by 5% for 10 days at each probability. The lowest probability used was 10% with fish 3. Fish 2 was maintained on a 30% reinforcement schedule because accuracy was increasing very slowly and erratically. The fish were fed to satiation immediately after training. Since the

Table 1

Reinforcement schedule for each subject during each experimental condition

	Task 1			Task 2	
Day:	1	2-35	36-70	1-35	35-70
Subjects					
Matching				Oddity	
2	100%	VR3	30%	continued on task 1 at 30%	
6	100%	VR3	30%-15%	ill	
4	95%	90%	30%	30%	90%
30	90%	30%	30%	30%	30%
35	90%	30%	30%	30%	30%
Oddity				Matching	
3	100%	VR3	30%-10%	continued on task 1 at 20%	
21	95%	90%	30%	30%	90%
33	90%	30%	30%	30%	30%
34	90%	30%	30%	30%	30%
32	90%	90%	90%	ill	

session took about an hour, they were approximately 23 hours food deprived at the beginning of each session. The reinforcer was changed from tubifex worms to freshly killed brine shrimp after about 90 days of training because the death of fish 6, at that time, was suspected to be caused by contaminated tubifex worms.

The two fish trained next (4 and 21) performed on matching discrimination and oddity discrimination respectively for 70 days, a time period chosen because the previously trained fish had reached stable levels of accuracy within that time. For the first 35 days a 90% reinforcement schedule was in effect; reinforcement probability was reduced to 30% during the second half of training. After 70 days the tasks were reversed; the animal originally learning matching discrimination was then trained on the oddity task and the animal originally learning oddity discrimination was then trained on the matching task. Probability of reinforcement remained at 30% for the first 35 days and at 90% for the second half of the training period. These fish were fed twice after their daily session and were therefore about 22 hours deprived each day.

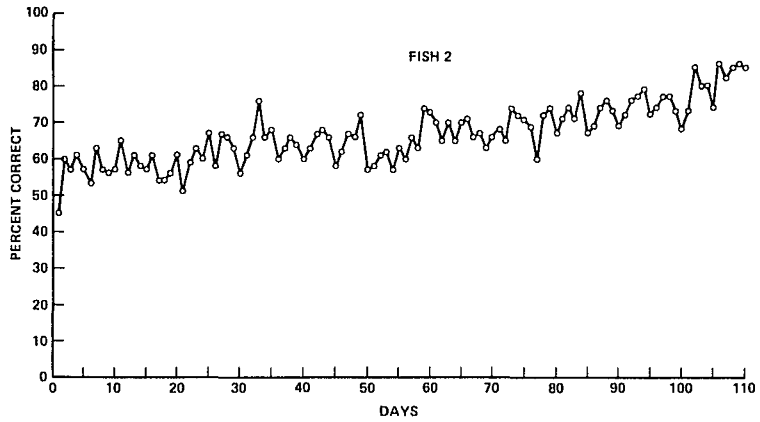
For the next six animals, the following conditions prevailed: two (30 and 35) were trained on matching-to-sample at 30% reinforcement probability, two (33 and 34) were trained on oddity-from-sample at 30% reinforcement probability, one (31) was trained on matching-to-sample at 90%, and one (32) was trained on oddity-from-sample at 90%. The fish performed on one task for 70 days and then on the reverse task for another 70 days at the same probability of reinforcement. Fish 31 on 90% matching discrimination stopped responding on day 15, and was dropped from the experiment. Since fish 32 (on 90% oddity discrimination) became ill in the middle of the second 70 day task, only the first task data are presented for this subject. After each daily session, these fish were fed additional food over the course of three hours such that they were 21 hours deprived before the next day's training. If an animal did not complete the 120 trials on any given day, it was removed from the apparatus and not fed. On the following day, it was given its daily ration in the home tank but not trained until the next day.

Results

Five fish learned matching-to-sample as the first task. Individual acquisition curves, showing the percent correct response over training days, and an averaged group acquisition curve are shown in Figure 1. In all, a total of six daily data points are missing from the figures as a result of failure of data recording apparatus or incomplete sessions. Average percent correct performance increased from an initial level of about 50% correct to a maximal level of about 77% during the last 10 days of training. Individual maxima ranged from 68% (fish 35) to 93% (fish 6). Acquisition of matching appears generally to have occurred at a slow, continuous rate, but there were some individual differences in response patterns. Early acquisition was most rapid in the case of fish 4, where performance reached 80% by day 22, and remained at about that level during further training. On the other hand, the performance level of fish 6, which reached 80% by day 30, continued to increase during subsequent training. Performance continued to improve throughout training of one fish (2) given a prolonged period of training over 110 days.

Comparable individual and group acquisition curves for five fish that learned oddity-from-sample as task 1 are shown

Figure 1. Percent correct response as a function of days for first task matching-to-sample acquisition. Only the first 70 days of acquisition for fish 2 are included in the average.


FISH 2
PERCENT CORRECT
0
10
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DAYS
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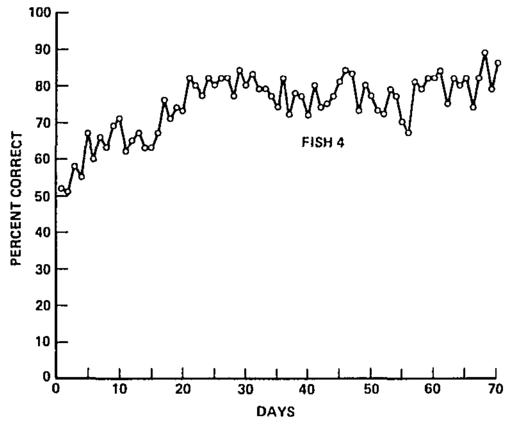
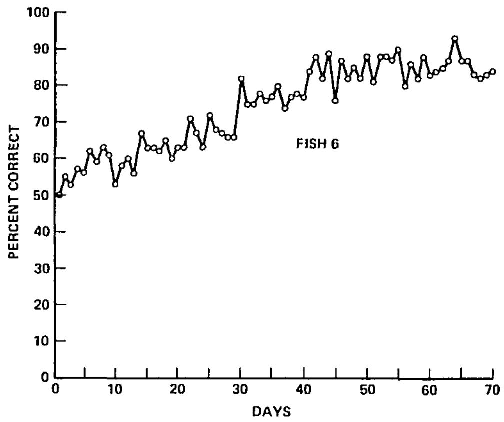
100
110


FISH 4
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 6
PERCENT CORRECT
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40
50
60
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DAYS
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30
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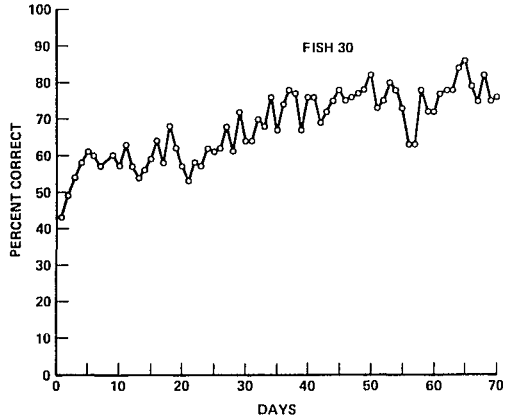
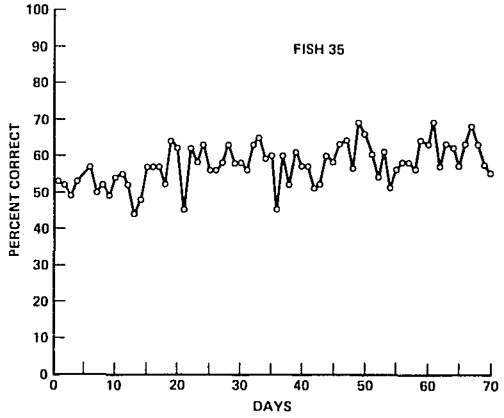
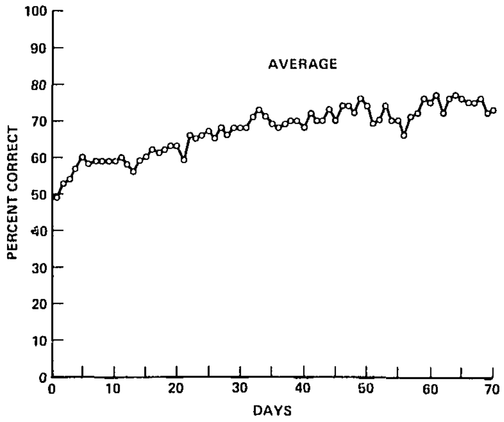
70


FISH 30
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 35
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

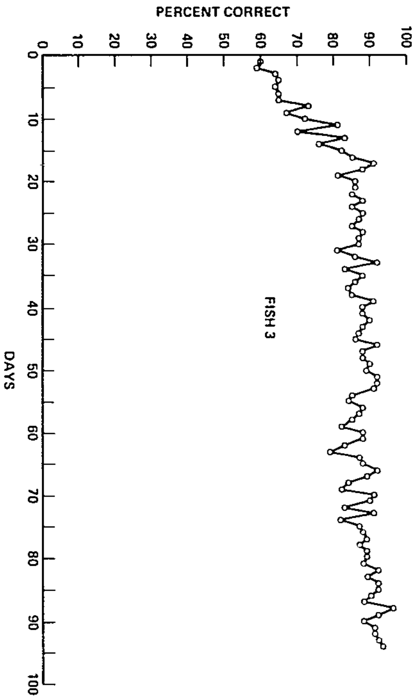

AVERAGE
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

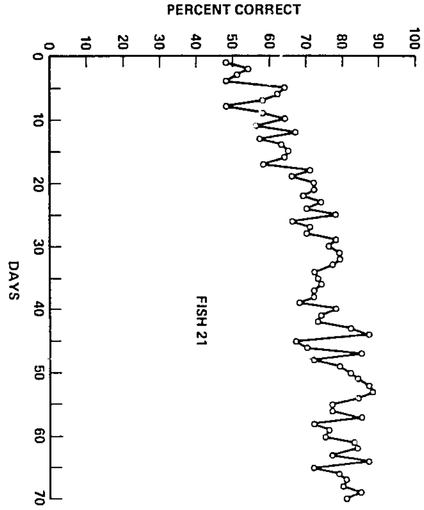
in Figure 2. The averaged acquisition curve is quite comparable to that of matching. Performance started at about the 50% level and increased slowly to 77% at the end of training. Individual maxima ranged from 65% (fish 34) to over 90% (fish 3). Acquisition was most rapid in the case of fish 3, where performance reached 90% correct by day 20. Acquisition was minimal in the case of fish 34. Performance level was 60% by day 15 after which no further improvement occurred. One fish received prolonged training (fish 3, 94 days) during which the highest obtained level of performance (96%) was observed.

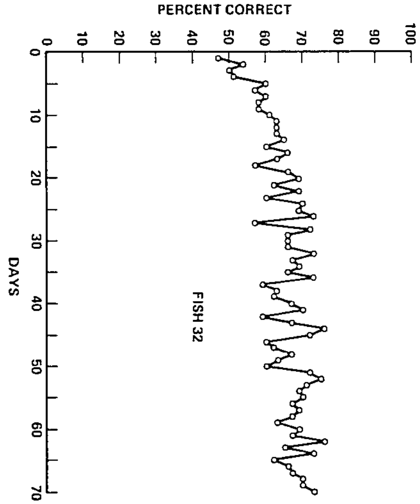
Figure 3 illustrates the acquisition curves for the three fish that were trained on matching after having completed 70 days of oddity training. All fish began the second task below chance, which reflects negative transfer from training on the previous task. The shapes of the acquisition curves are similar to those for the other three conditions, all showing the slow steady increase in percent correct responses.

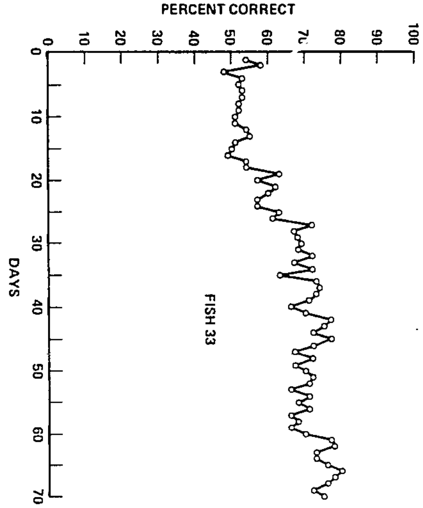
The average task 2 matching performance started at 30% and leveled off in the 60% range, reaching a high of 69% by the end of 70 days. Individual maxima were 73%, 68% and 67%. This average curve was typical of the three individual graphs,

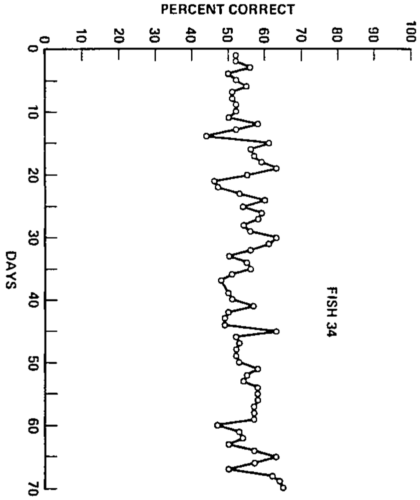
Figure 2. Percent correct response as a function of days for first task oddity-from sample acquisition. Only the first 70 days of acquisition for fish 3 are included in the average.


PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
FISH 3


PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
FISH 21


PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
FISH 32


PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
FISH 33


PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
FISH 34

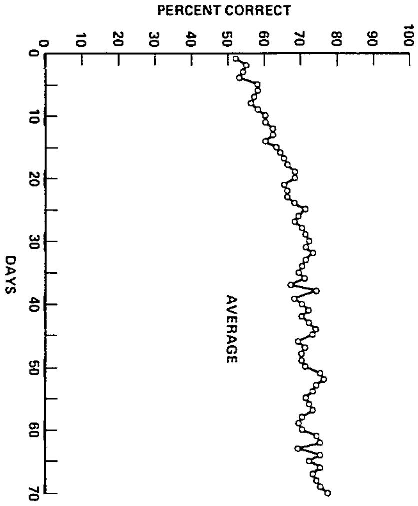
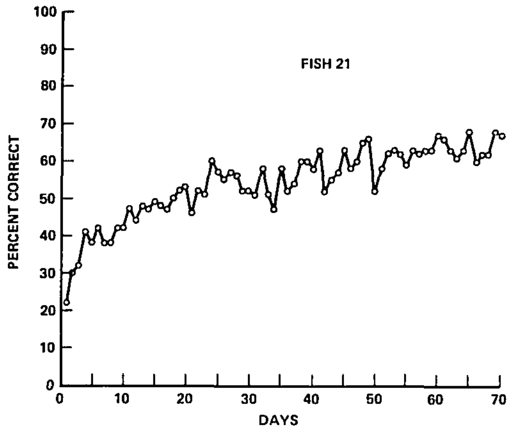
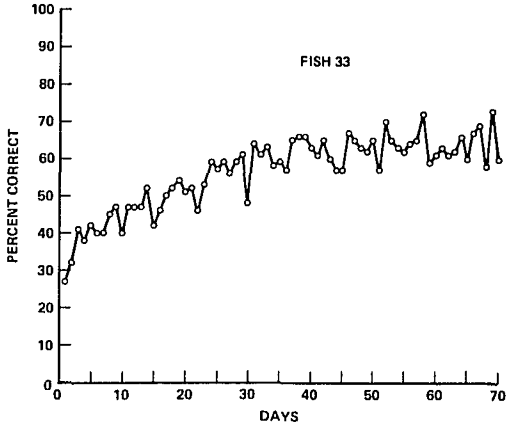
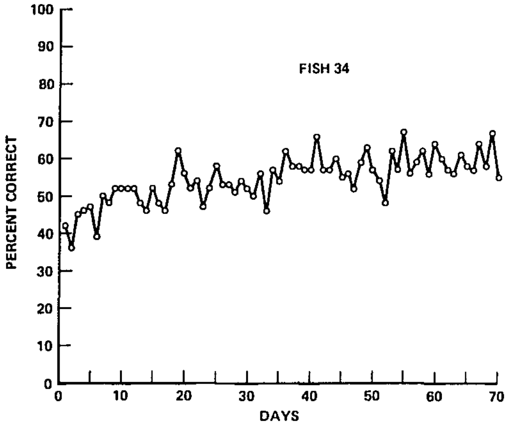
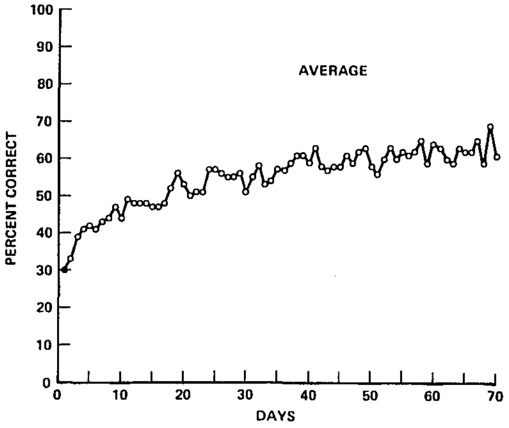

PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
AVERAGE

Figure 3. Percent correct response as a function of days for second task matching-to-sample acquisition.


FISH 21
PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
DAYS


FISH 33
PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
DAYS


FISH 34
PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
DAYS

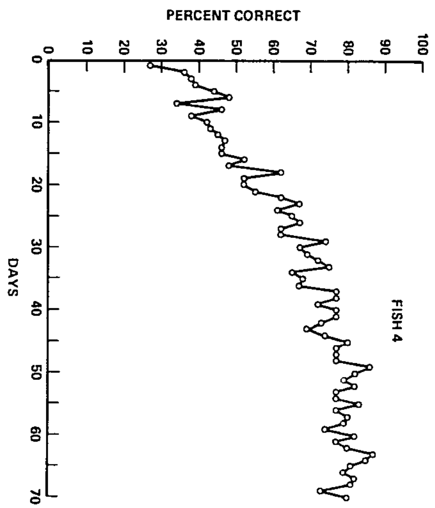

AVERAGE
PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
DAYS

unlike the average curves for task 1. The absolute change in performance level from day 1 to day 70 was greater for task 2 than for task 1 for the fish that learned both tasks. The larger change occurred even though two out of three fish ended matching training at a level which was lower than the level at which their oddity training had terminated.

Individual and group averaged oddity acquisition curves for the three fish previously trained in matching are presented in Figure 4. The average level of performance started at 36% and following a steady rate of increase reached 78% correct. Individual maxima were 87%, 81% and 78%. The final performance levels were equal to the levels attained by each of the fish after 70 days of matching training on task 1. In each case the initial level of performance was lower on second task oddity learning than on first task matching for the fish which learned both tasks, again providing evidence for negative transfer from the first learned task. As in the case of task 2 matching (Figure 3), the average oddity curve was representative of the acquisition curves for the individual animals. The individual performances were more similar to each other during task 2 training than during task 1 training.

A greater absolute change in performance level from day 1 to day 70 occurred in task 2 learning, regardless of the

Figure 4. Percent correct response as a function of days for second task oddity-from-sample acquisition.


FISH 4
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
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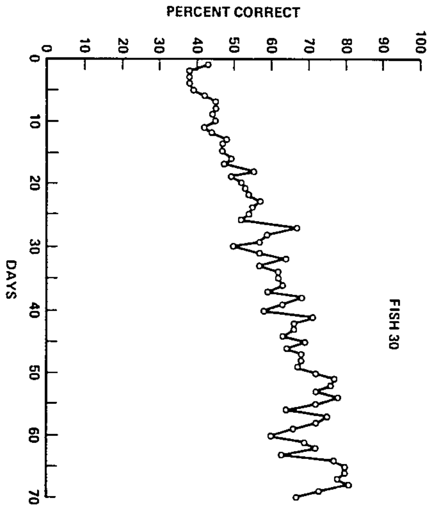
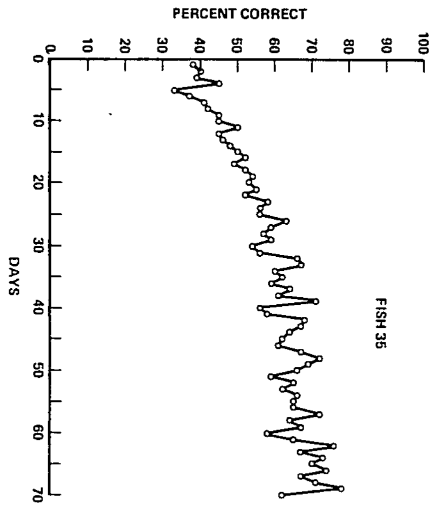
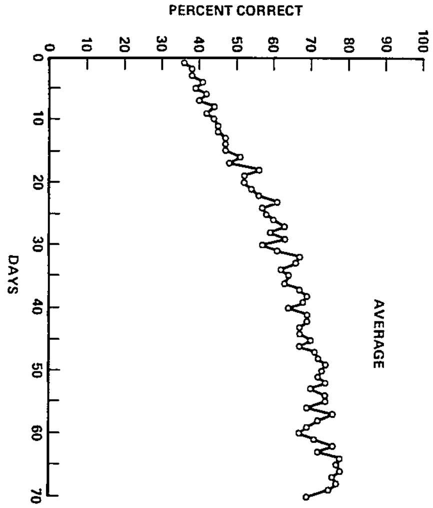
30
40
50
60
70


FISH 30
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

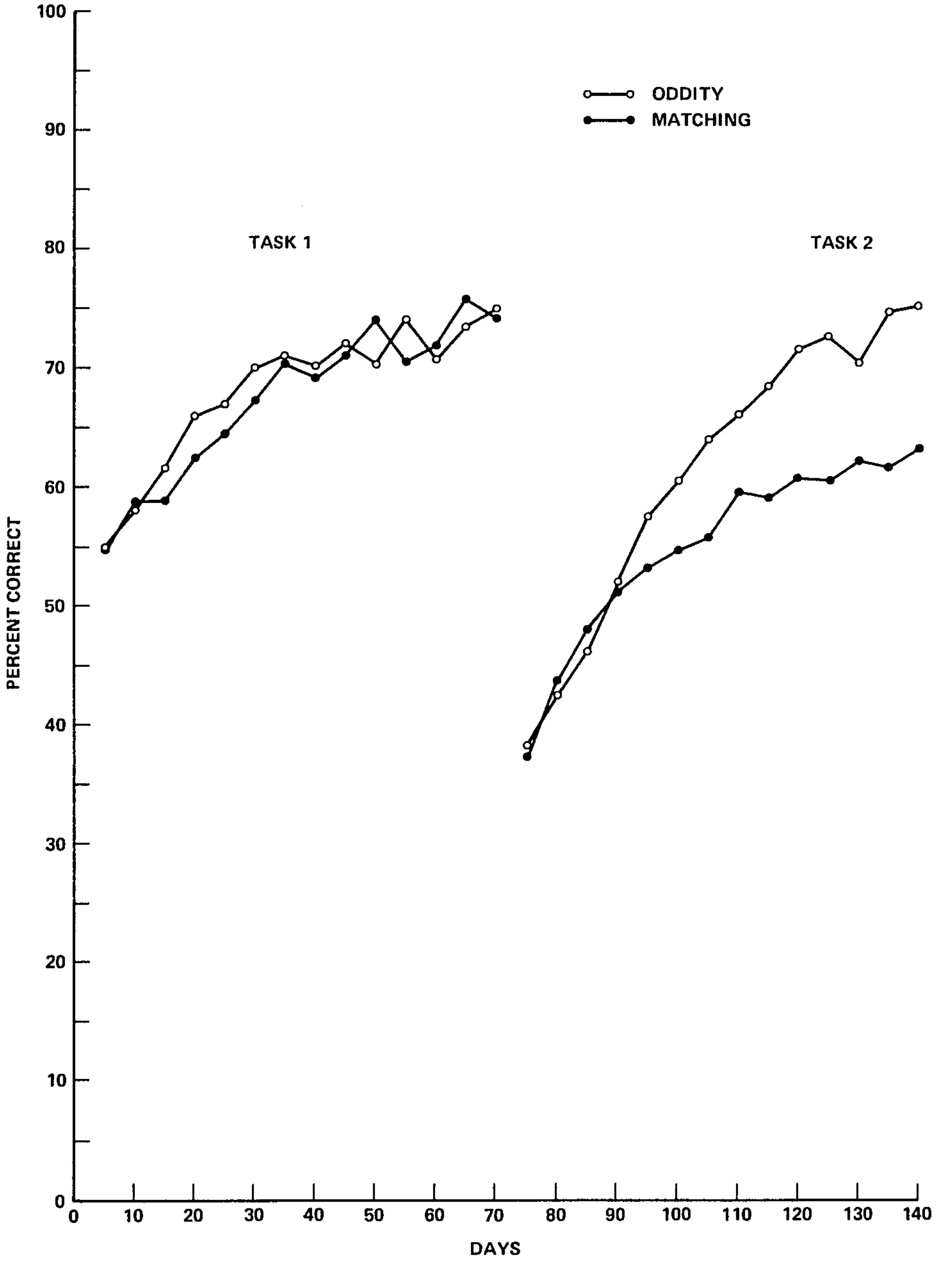

FISH 35
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


AVERAGE
PERCENT CORRECT
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

identity of task 2. However, this effect was greater when oddity was the second task. The difference is illustrated in Figure 5, in which mean percent correct performance per five-day testing block is plotted for each group and each task. It is evident that the average acquisition of oddity and matching were quite similar when they were the first-learned tasks (left half of figure). The results on the left hand side of Figure 5 (task 1) are based on five animals per group. The results were the same for the averaged first task data of only those fish observed on both tasks (three animals per group). When oddity and matching were learned as the second task (right side of figure), the initial level of performance was lower than that of average task 1 acquisition, but it was the same for oddity and matching groups. The average acquisition curve for task 2 oddity rose to a final level comparable to both task 1 oddity and matching levels. However, average task 2 matching performance did not reach the level of task 1 matching and oddity performance during the 70 days of training. As indicated earlier, these two results were consistent with individual functions of five out of six animals trained on both tasks.

To analyze the increasing portion of the acquisition

Figure 5. Percent correct responses for matching-to-sample and oddity-from-sample as first (left) and second (right) tasks. The data are group means presented in five day blocks which were derived from the data already shown in Figures 1-4. On the first task N=5 per group, on the second task N=3 per group.


ODDITY
MATCHING
TASK 1
TASK 2
PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
DAYS

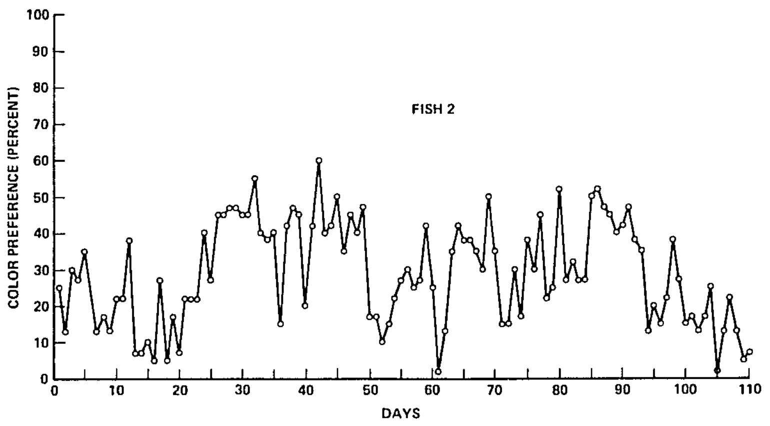
curves, covering the first 25 days, the learning rate was estimated by regression coefficients. The regression coefficients are presented in Table 2 of the Appendix. The first 25 days were chosen by inspection of the individual acquisition curves as the portion in which percent correct responding was still increasing for a majority of the animals. For each fish, it was possible to calculate the sum of squares (one degree of freedom) due to its linear regression (Hayes, 1963). In order to make group comparisons the regression sums of squares were pooled. The null hypothesis was that all groups were sampled from populations with the same regression coefficient (learning rate). Groups were compared by dividing the pooled regression mean squares for one group by the corresponding quantity for the other group and referring the result to the *F*-distribution. Regression coefficients were not significantly different in any comparison of oddity vs. matching groups: task 1, oddity vs. matching, $F\ (5,5)=1.75$, $p>.05$; task 2, oddity vs. matching, $F\ (3,3)=1.27$, $p>.05$. These results indicate that there was no reason to suspect a difference between the rate of acquisition on the two tasks.

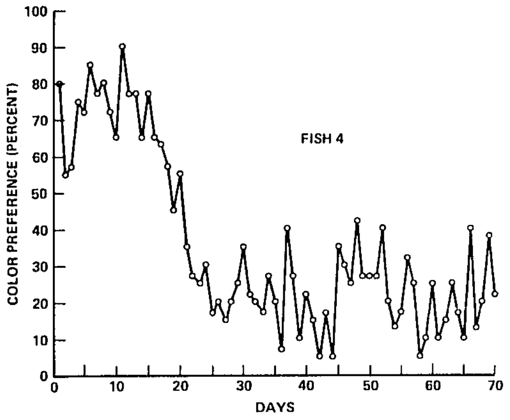
In order to evaluate further the differences and similarities between the groups *t*-tests were performed. All *t*-tests reported in this paper are two-tailed tests and utilized a mean of the 70 data points for each fish in the group. These fish means were summed and a mean and variance for the group were calculated and used in the test. The means are given in Table 3 in the Appendix. Overall mean scores did not differ significantly, either in comparison of percent correct scores for the first task oddity group vs. the first task matching group, $t(8)=0.12$, $p>.05$, or in comparison of percent correct scores for the second task oddity group vs. the second task matching group, $t(4)=2.73$, $p>.05$. However, when early and late phases of acquisition were compared separately, differences emerge. The last 25 days was chosen by inspection of the individual functions as the time during which the percent correct responding had stopped increasing for a majority of animals. A *t*-test between the percent correct for the oddity and matching groups on task 2 for the last 25 days of training, where acquisition had leveled off, was significant, $t(4)=2.83$, $p<.05$. Thus the oddity group reached a significantly higher level of performance than the matching group on task 2.

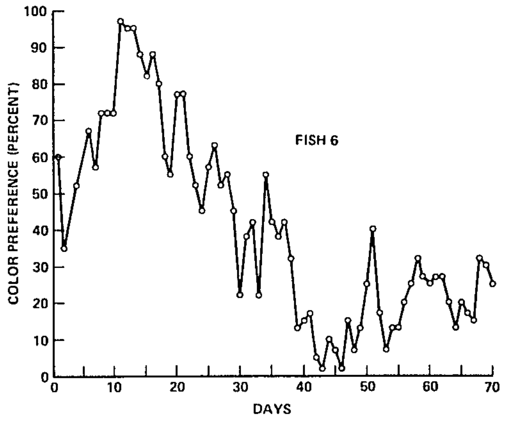
Even though performance levels on the oddity and matching tasks did not differ in general, systematic biases were present. Twenty-six specific hypotheses were looked at for each fish which included all possible preferences for a specific color or side stimulus and combinations of these preferences. These analyses revealed patterns which could be accounted for by the overall side and color preference measures so only the data from these two measures are presented. A color preference was calculated for each day of training by adding the absolute deviations from chance responding for each color and dividing the sum by the number of possible alternatives. Each color appeared on both sides on a total of 80 trials, for half of which the color was the correct alternative and for the other half of which it was incorrect. Thus, if an animal were performing perfectly it would choose each color 40 times. Also, if it were performing randomly it should pick each color 40 times, 50% of the total of 80. Therefore, a color preference would be indicated by deviations from choosing each color 40 times. Since the total number of times any single color could be chosen was 80, the sum of the absolute value of the deviations from 40 for each color was divided by 80. For example, if an animal had a preference for red and an aversion to blue and was neutral to green, it would choose red 80 times, blue 0 times, and green 40 times. Green would be chosen on all the trials in which it appeared with blue, but not on any of the trials in which it were paired with red. The color preference index would therefore be computed as follows: 80 - 40 = 40, 0 - 40 = 40, 40 - 40 = 0; 40 + 40 + 0 = 80; 80/80 = 1 or 100% color preference.

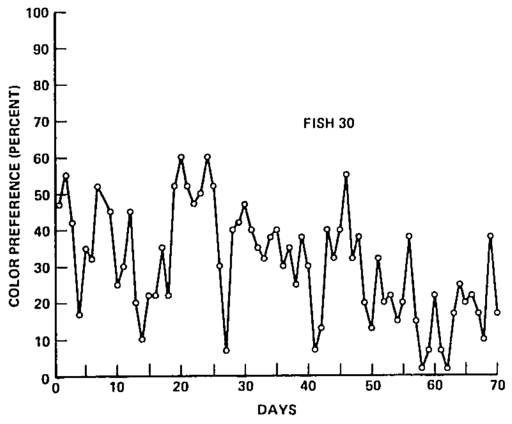
Figure 6 shows the color preference data for the five fish that learned matching as task 1 and a curve of color preference results averaged over the group. Every fish in the group showed some color preference. For fish 6 and 4 there was an increase in bias to 90 or 100%, and then a drop off at the point at which percent correct began to level off. Fish 2 and 30, that acquired more slowly, showed fluctuating color biases which were as high as 50 or 60% on given days. Fish 35, that showed the least improvement of the group in percent correct responding, showed an increasing bias which was still over 80% after 70 days of testing. Contrasting results are present in the color preference data from the five fish that learned oddity as task 1, shown in Figure 7. No animal in this group had a color preference over 40%; and most of the time the points were well below that level, fluctuating more or less between 10 and 20%. Although the average curve for the matching group is not representative of individual functions, the average does emphasize the greater deviations from baseline shown

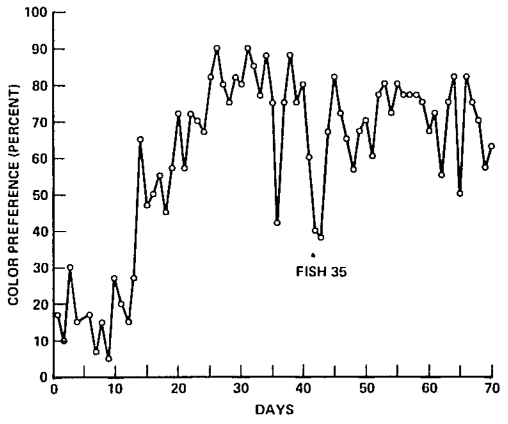
Figure 6. Color preference index expressed in percent for first task matching-to-sample acquisition as a function of days of training. Only the first 70 days of acquisition for fish 2 are included in the average.


FISH 2


FISH 4


FISH 6


FISH 30


FISH 35

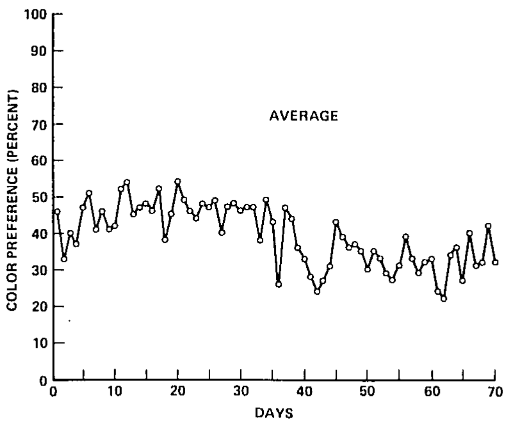
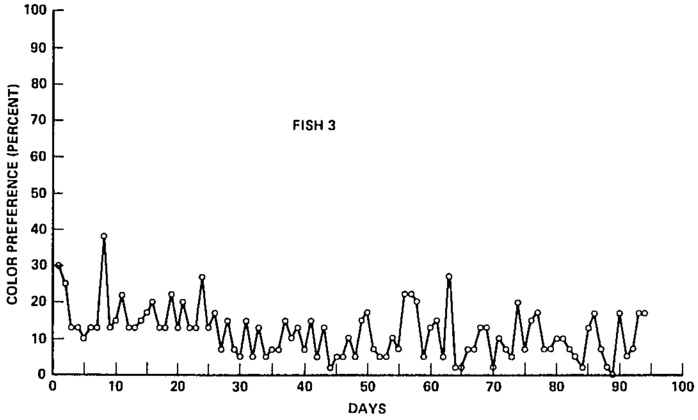
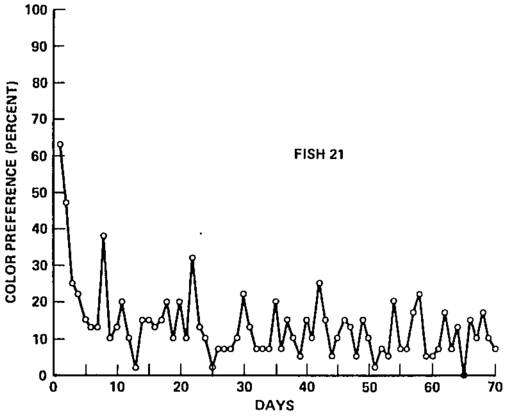
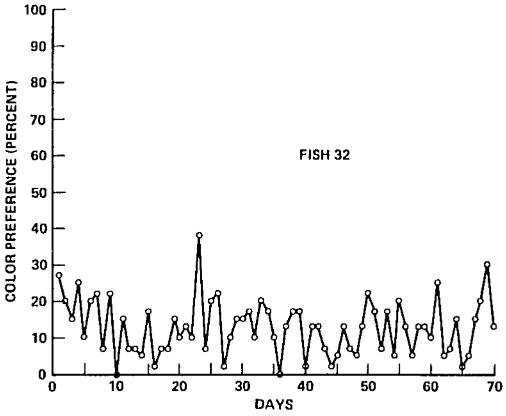
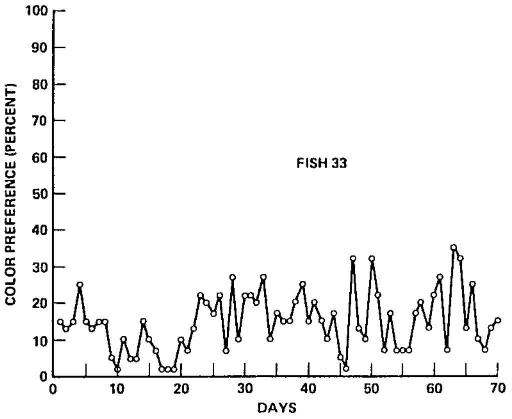

AVERAGE

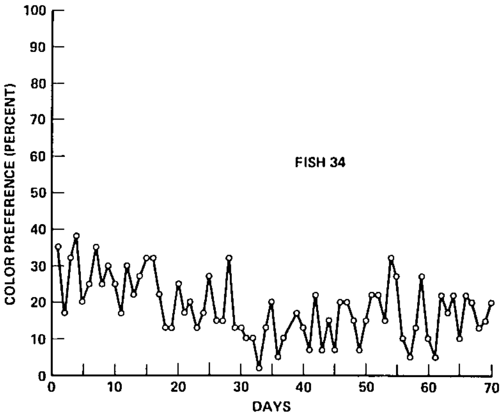
Figure 7. Color preference index expressed in percent for first task oddity-from-sample acquisition as a function of days of training. Only the first 70 days of acquisition for fish 3 are included in the average.

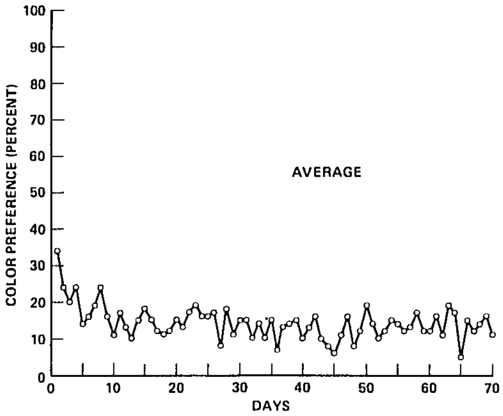

FISH 3
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70
80
90
100


FISH 21
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 32
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 33
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

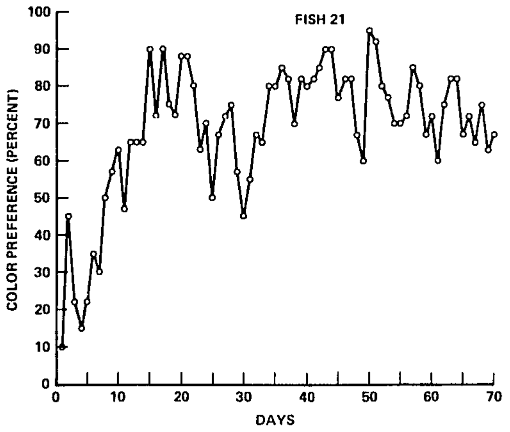

FISH 34
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

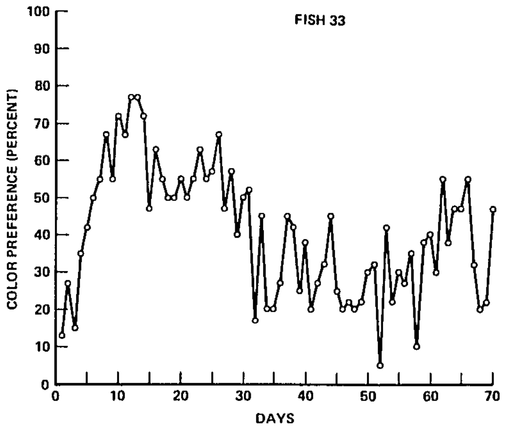

AVERAGE
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

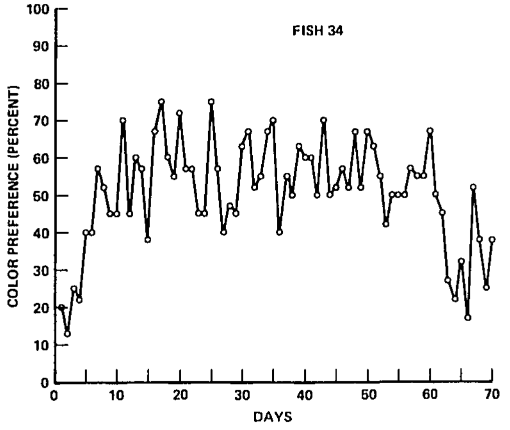
by the matching fish as compared to similar data of oddity fish. There was no overlap between the points of the average curves for the task 1 oddity group and the previously shown matching group. The greater incidence of color preference in first task matching vs. first task oddity was significant, $\underline{t}(8)=4.36$, $\underline{p}<.01$.

The same result was evident from the task 2 data, as seen in Figures 8 and 9. In Figure 8 showing the group that learned matching, the color preference rose for all three fish, from the low level demonstrated during oddity, to over 70% within the first 10 or 15 days. The levels remained rather high, again paralleling the poor performances indicated by the percent correct measure. Similarly, in Figure 9, all three oddity animals demonstrated low levels of color preference. Fish 35, for which color bias was strong at the end of matching, showed an abrupt decrease in bias when oddity was introduced. Again there was no overlap in color bias scores between the average curves, except for the first few days. A $\underline{t}$-test between the groups was significant, $\underline{t}(4)=4.67$, $\underline{p}<.01$, reflecting the greater amount of color bias in task 2 matching when compared to task 2 oddity. The analyses of specific hypotheses revealed that all five goldfish trained on matching as

Figure 8. Color preference index expressed in percent for second task matching-to-sample acquisition as a function of days.


FISH 21
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 33
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 34
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

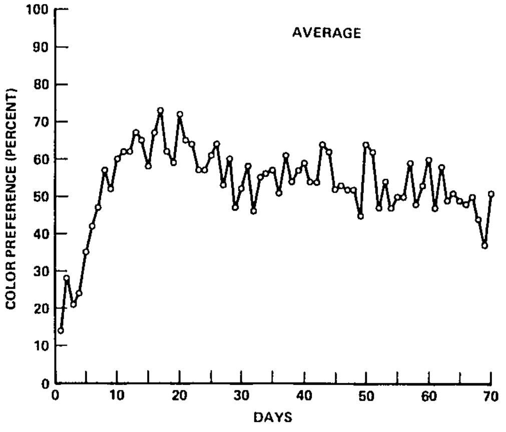
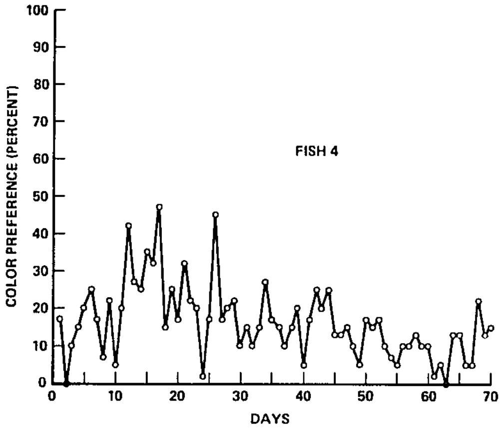
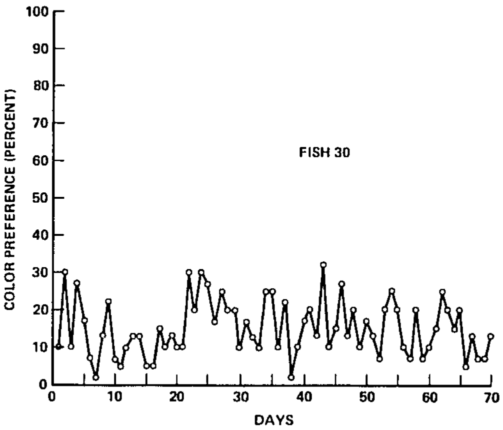
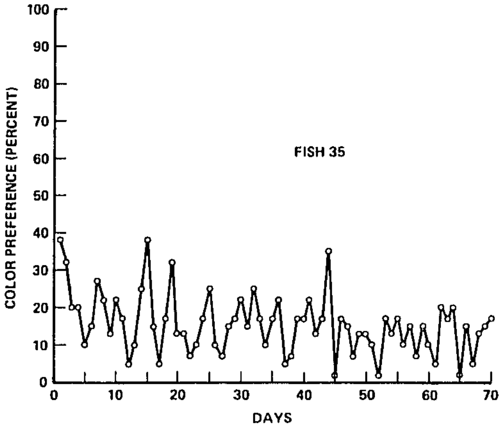
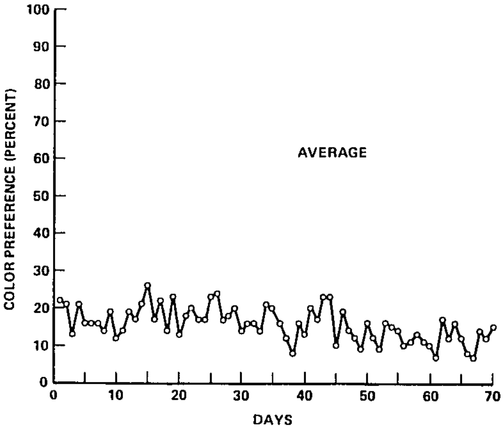

AVERAGE
COLOR PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

Figure 9. Color preference index expressed in percent for second task oddity-from-sample acquisition as a function of days.


FISH 4
COLOR PREFERENCE (PERCENT)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
DAYS


FISH 30
COLOR PREFERENCE (PERCENT)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
DAYS

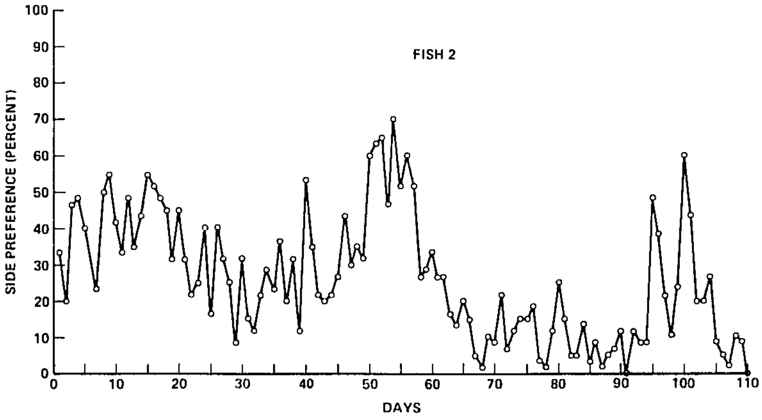

FISH 35
COLOR PREFERENCE (PERCENT)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
DAYS

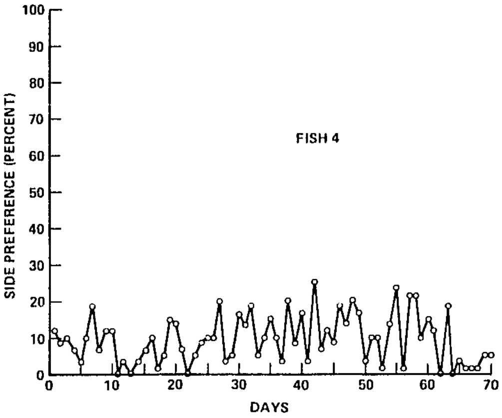

AVERAGE
COLOR PREFERENCE (PERCENT)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
DAYS

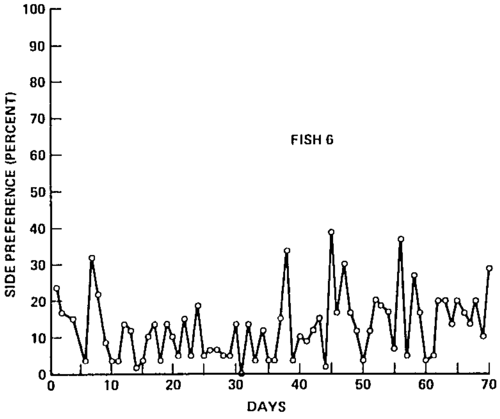
task 1 and one goldfish trained on matching as task 2 avoided the blue stimulus when it was presented on the sides. The other two matching fish (task 2) had a preference for choosing the blue side stimulus during the first half of training.

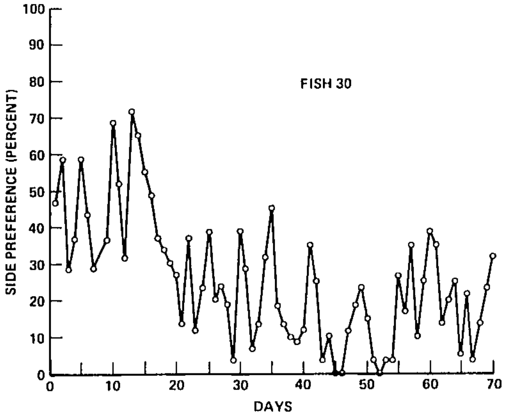
A position preference measure was calculated by subtracting the percent left responses from chance, 50%, and doubling the absolute value. This calculation provided a side bias index on a scale from 0 to 100%. Regardless of whether the bias was to the left or right, a higher number indicated a stronger bias. Figure 10 presents the side preferences for the five fish that learned matching as task 1, and the average curve. No consistent pattern can be discerned here since three fish had moderate position preferences and two fish did not. It should be pointed out that accurate performance in the task leads to neither a position nor a color preference. Also, in the extremes the two preference measures are mutually exclusive, i.e. a 100% position preference would lead to a 0% color preference and a 100% color preference would result in a 0% side preference. As can be seen from the data in Figure 10 and Figure 6, fish can maintain intermediate levels of both color and side biases simultaneously. It is apparent, however, that these

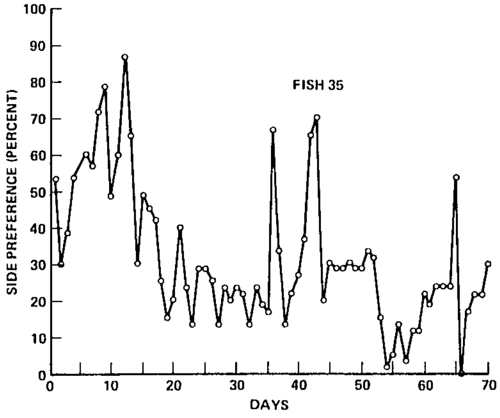
Figure 10. Side preference index expressed in percent for first task matching-to-sample acquisition as a function of days of training. Only the first 70 days of acquisition for fish 2 are included in the average.

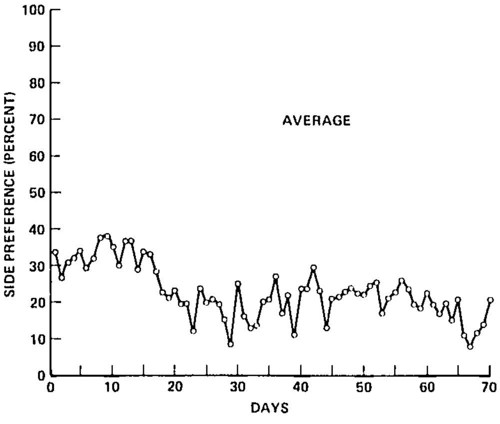

FISH 2
SIDE PREFERENCE (PERCENT)
DAYS
0
10
20
30
40
50
60
70
80
90
100
110


FISH 4
SIDE PREFERENCE (PERCENT)
DAYS
0
10
20
30
40
50
60
70
80
90
100


FISH 6
SIDE PREFERENCE (PERCENT)
DAYS
0
10
20
30
40
50
60
70
80
90
100


FISH 30
SIDE PREFERENCE (PERCENT)
DAYS
0
10
20
30
40
50
60
70
80
90
100


FISH 35
SIDE PREFERENCE (PERCENT)
DAYS
0
10
20
30
40
50
60
70
80
90
100

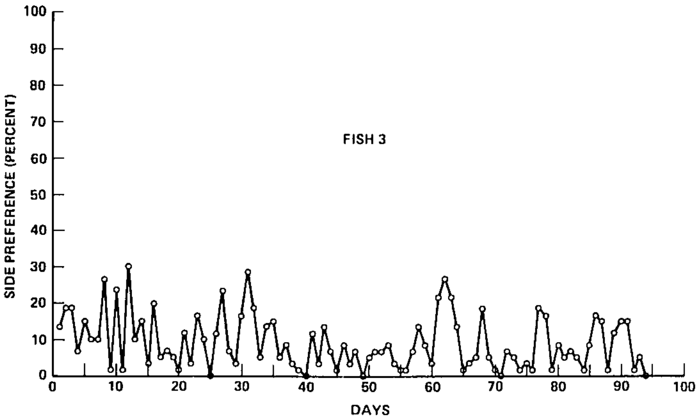

AVERAGE
SIDE PREFERENCE (PERCENT)
DAYS
0
10
20
30
40
50
60
70
80
90
100

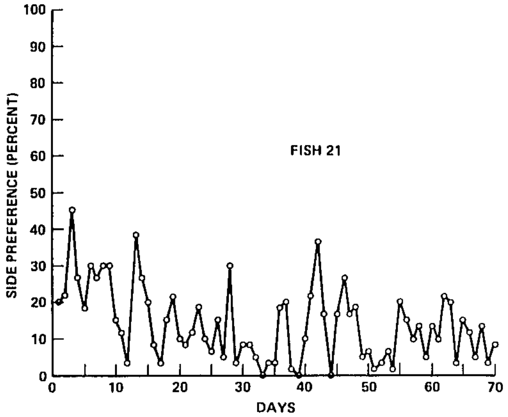
two events are independent to the extent that on the same task some fish showed one bias without the other, and other fish showed neither bias.

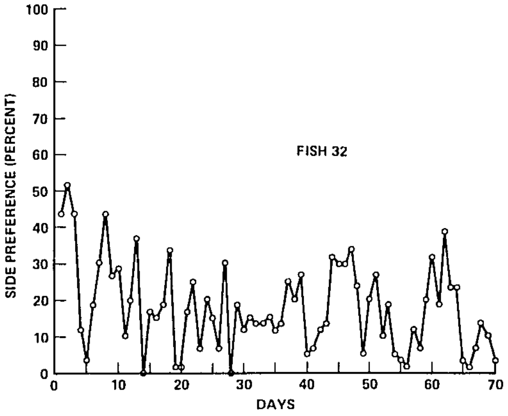
The side preferences for the fish that learned oddity as task 1, and the average curve are illustrated in Figure 11. These animals showed a pattern similar to the matching group in that some fish, fish 33 and 34, had a position bias and some fish did not. It should be recalled that these animals did not show any color bias. The average curves for the matching and oddity groups overlap considerably, both vary mainly around 20% and are slightly higher in the beginning. There was no significant difference in side preference of task 1 matching and oddity groups, $\underline{t}(8)=0.15$, $\underline{p}>.05$.

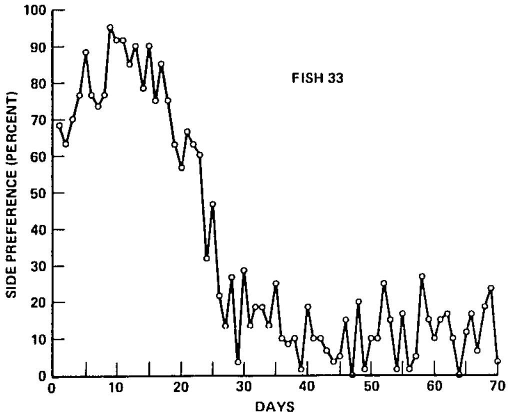
As can be seen in Figure 12, there was no evidence of any position preference in the data of the three goldfish that learned matching after having had 70 days of oddity training. It is possible that the strong color biases of these fish (see Figure 8) precluded the appearance of a position bias. Figure 13 presents the side preferences for those fish that learned oddity after 70 days of matching training. Here there is evidence of moderate position biases in the results from two out of three fish. These

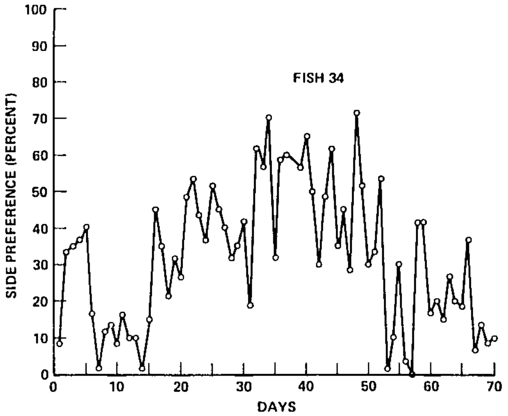
Figure 11. Side preference index expressed in percent for first task oddity-from-sample acquisition as a function of days of training. Only the first 70 days of acquisition for fish 3 are included in the average.


FISH 3
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS


FISH 21
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS


FISH 32
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS


FISH 33
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS


FISH 34
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS

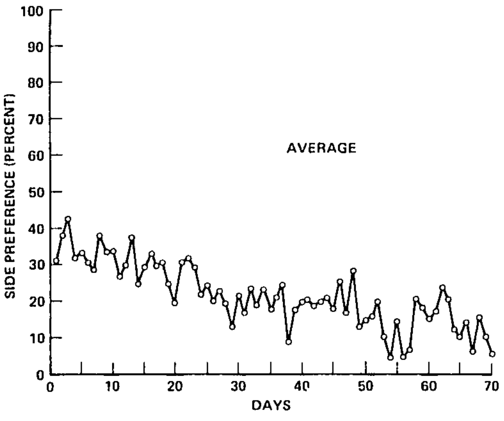
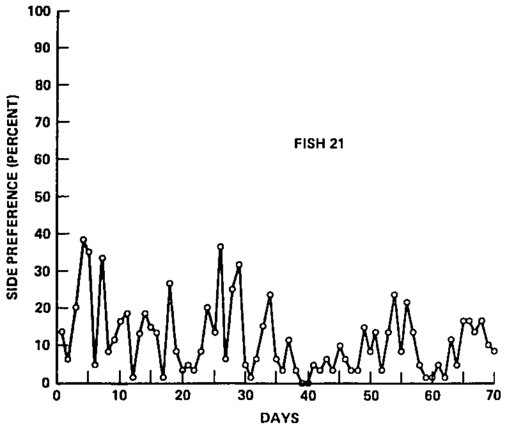
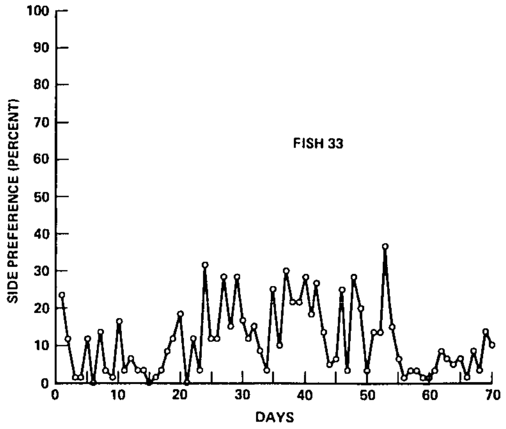
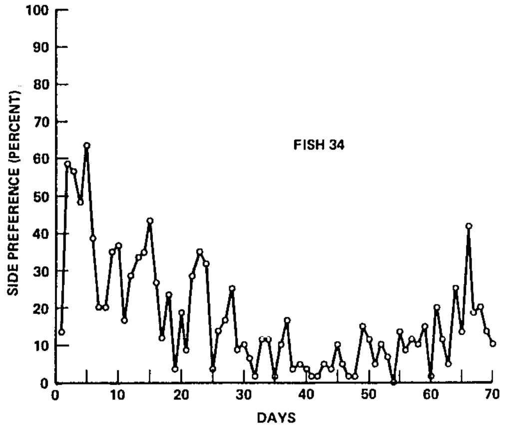

AVERAGE
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS

Figure 12. Side preference index expressed in percent for second task matching-to-sample acquisition as a function of days.


FISH 21
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 33
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 34
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

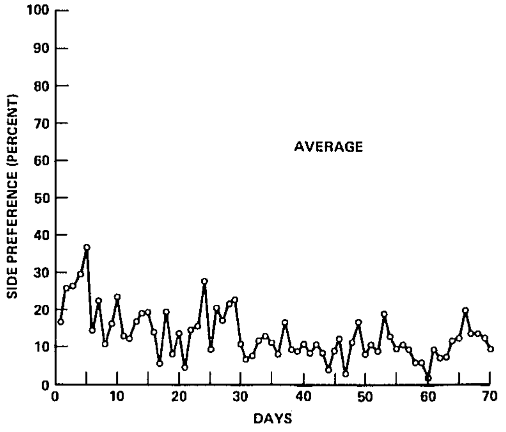
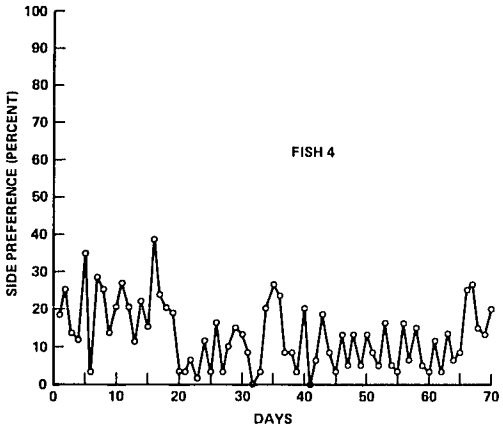
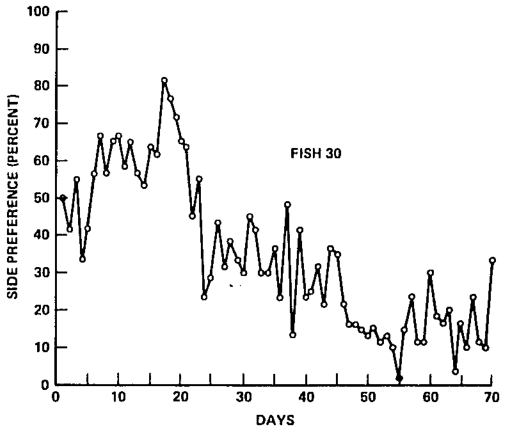
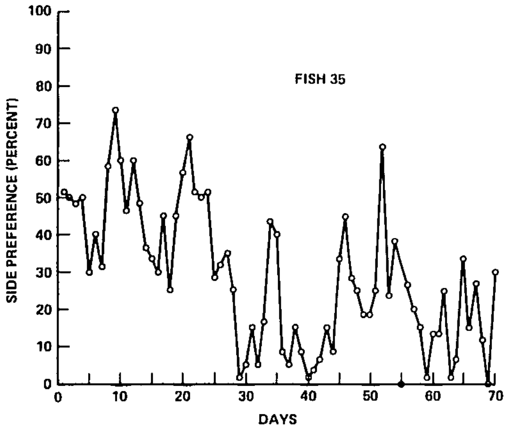
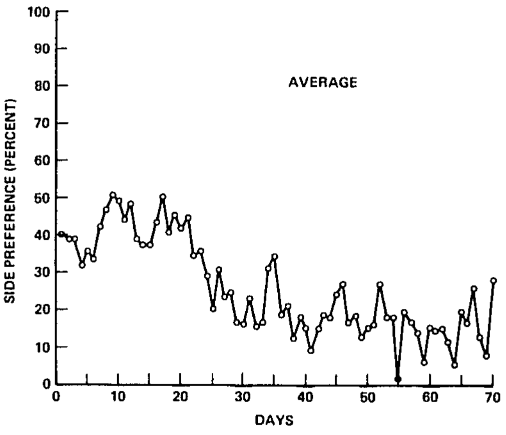

AVERAGE
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

Figure 13. Side preference index expressed in percent for second task oddity-from-sample acquisition as a function of days.


FISH 4
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 30
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


FISH 35
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70


AVERAGE
SIDE PREFERENCE (PERCENT)
0
10
20
30
40
50
60
70
80
90
100
DAYS
0
10
20
30
40
50
60
70

fish did not show any color preference. A *t*-test between the side preferences for the task 2 oddity and matching groups was not significant, $t(4)=1.81$, $p>.05$. Comparison between Figures 10 and 13 indicates that position preferences were characteristic of individual animals rather than the task. Fish 30 and fish 35 had side preferences under both the matching and oddity conditions, whereas fish 4 did not show a side preference under either condition. The analyses of specific hypotheses revealed that most of the position preferences were for the left side, which was closest to the door of the training chamber.

Discussion

The aim of the present experiment was to determine whether or not goldfish were able to solve a matching-to-sample problem and an oddity-from-sample problem. The results were interpreted in terms of performances on conditional discrimination tasks. Since transfer to novel stimulus configurations was not tested in the present experiment, matching and oddity do not refer to conceptual tasks. The tasks were defined in terms of the same three alternative stimuli which were repeated throughout the experiment and the terms "matching-to-sample" and "oddity-from-sample" refer only to this procedure in the following discussion. The results of this experiment demonstrate that goldfish are able to perform better than chance on matching-to-sample and oddity-from-sample. The majority of animals attained an accuracy level of 75%, several fish performed at over 85% correct, and one fish performed at a level of over 95%. All of the fish that improved did so at a slow but steady pace, showing no sharp increases or decreases, under all four conditions (task 1 matching, task 1 oddity, task 2 matching,and task 2 oddity). This type of performance is characteristic of the acquisition curves of pigeons learning oddity, but not matching. Even the goldfish that improved most rapidly showed a steady increase, i.e. there was no sharp break in the function which is characteristic of pigeons learning matching-to-sample. If Farthing and Opuda (1974) are correct in the statement that pigeons learn the correct stimulus-response chains while ignoring the incorrect stimulus, then the differences in the pigeons' acquisition curves for the two tasks may reflect the difference in learning three vs. six sequences, as Cumming and Berryman (1965) had hypothesized. If the same analysis is applied to the fish data, the animals in the present study may have been learning the correct response for each set of stimuli, where the incorrect stimulus would have had some influence. This interpretation seems unlikely in view of the overall response strategies displayed by these fish.

The overall course of acquisition, measured in terms of percent correct, appears to be essentially similar for matching and oddity when they were the first learned tasks. The fish began around 50% correct regardless of the task being learned. The animals did not show an initial preference for the odd stimulus as is found in the data of pigeons and monkeys. It is possible that this result was not due to a species difference but was due to the differences in shaping procedures. Pigeons, such as those studied by Cumming and Berryman (1965), were usually shaped to peck at a white center key and then given equal numbers of reinforcements for responding to each of the three colors presented individually on each of the three keys. The goldfish were shaped to respond to a white light only, but were trained to perform the center-side response sequence. Thus the fish may have been biased in favor of matching.

One unique feature of the present experiment was that the animals were trained on both the matching and the oddity tasks, which allows for the comparison of oddity and matching performance from the same animal. All six fish trained on both tasks began task 2 below chance which indicates negative transfer from 70 days of training on task 1. All six animals also showed a greater absolute change in performance level on task 2 than on task 1. However, while the initial rate of improvement was the same for both task 2 groups, the goldfish trained on oddity attained a higher percent correct than those trained on the matching problem. It can be seen from Figure 5 that the final level of acquisition was lower for task 2 matching than for the other three training conditions which all end at the same point. These average differences are representative of the individual functions from the animals that were trained on both tasks. No simple conclusion regarding the relative difficulty of matching and oddity is possible.

All three fish trained on oddity as their second task reached the same level of accuracy at the end of the 70 days that they had attained on matching during task 1 training, in spite of the lower starting point. The performance of two out of the three animals trained on matching as task 2 leveled off at a lower percentage correct than they had achieved on oddity training. The third fish, 34, had the flatest acquisition curve for task 1 of any fish trained on any task in the study, so the fact that more improvement was shown during matching training is not surprising. Thus the data from five out of six individual's task comparisons agree with the group data in showing greater increases in percent correct responding during 70 days of oddity training than during 70 days on matching.

The similarity of the individual acquisition curves within each group on task 2 reflects the influence of the common experience of training on task 1 for 70 days. Task 2 performance may provide a more sensitive index of task difficulty than task 1 performance. The differences found in task 2 performance may indicate that the goldfish do have a natural preference for the odd stimulus that could have been obscured by the variability in the data from task 1 or the shaping procedure. Alternatively the difference may indicate that the oddity problem is actually easier for goldfish, a result which could only emerge when the animal's prior learning was controlled. In either case, the pigeon behaves differently by choosing the odd stimulus initially and reaching lower asymptotic levels when trained on oddity as compared to matching. It is possible that the oddity performance of the goldfish was similar to that of the pigeon, and that the differences reported here reflected the greater difficulty of the matching-to-sample problem for goldfish than for pigeons.

The influence of task 1 in the form of negative transfer is apparent from the below chance starting points for task 2 acquisition curves. It is not clear what types of influences were affecting the rest of task 2 acquisition. The greater absolute change in performance levels in both task 2 groups could merely reflect the amount needed to recover from the negative transfer effect. On the other hand, the task 2 oddity function rose to the same final performance level as the task 1 functions in the same amount of time, 70 days, which may be reflecting some positive transfer effect. Positive transfer could be in the form of general adaptation to the apparatus, or specific learning effects from performance on the tasks, or the formation of a conceptual solution to the problem. The present experiment was not designed to test for transfer effects so these questions cannot be answered here. No attempt was made to test for concept formation nor learning sets. Such questions would have been premature in the light of the available evidence which shows that fish improve in habit reversals under a more limited range of conditions than is true for pigeons or mammals (Engelhardt, Woodward, and Bitterman, 1973). If transfer tests were performed on goldfish using the three alternative problems there would be some difficulty in interpreting the results because of the moderate levels of performance which the goldfish achieved after 70 days, 75%-85% correct. If an animal has not completely mastered the original task it would not be clear what was being transferred to a new problem.

All of the goldfish studied showed marked color preferences when responding on matching-to-sample and no color preference when responding on oddity-from-sample. Side preferences, on the other hand, were characteristic of some individual animals regardless of task. These observations are true whether the comparison is made between groups or within subjects. The most frequent finding was one of avoidance of blue as the choice stimulus, which occurred in all five cases of color preferences on task 1 and in one case on task 2. The other two animals on task 2 had a preference in favor of choosing blue when they began matching training. There may have been a prior aversion to blue or a reluctance to respond to the blue stimulus in this situation. (The blue color appeared to be the darkest stimulus to human observers.) It is also possible that these preferences and aversions were determined by the programmed fixed sequence of reinforcement contingencies.

Present results from goldfish support previous conclusions from pigeons (Cumming and Berryman, 1965) that the matching-to-sample task fosters response biases and that the oddity-from-sample task does not. The emergence of the color preference in the data from all three goldfish trained on matching as task 2 is a clear indication of this effect. There must be something about the nature of the task that makes biases more prevalent. The similarity of the results from all of the fish lend credence to the speculations concerning possible influences from the contingencies of the matching and oddity tasks resulting in the different behaviors obtained on each, as discussed by

Berryman, Cumming, Cohen,and Johnson (1965). Speculations of this type concern the aspects of the reinforcement contingencies in the matching-to-sample situation that foster such biases, and may be elaborated upon in view of the results from the present study. The center key response in the matching and oddity problems is required but not directly followed by primary reinforcement. This unreinforced response may be viewed as an extinction trial associated with the particular color which was present at the time of the response. When an animal is then presented with the side key stimuli it may be more likely to respond to the odd hue. Under the matching contingency such responses are punished with a blackout. This repetition of nonreinforcement may reduce the animal's attention to the relevant stimulus dimensions and lead it to respond according to characteristic biases. Under the oddity contingency a response to the side color which is different from the center color is correct and followed by reinforcement. This property of the two tasks may be responsible for the initial advantage in oddity in pigeons and the higher final levels achieved in task 2 oddity by the goldfish. However, if an animal always chose the odd side key it would immediately be responding at 100% correct. Such a result does not occur and may be due to the fact that a single trial is not an isolated event. The side key color associated with reinforcement on one trial may be associated with extinction on the very next trial, both as the sample and the side color. This interaction may foster other systematic modes of responding. Sequential analysis of oddity data from the present study revealed no consistent pattern of a number of possible response strategies, i.e., position biases, color preferences, win-stay-lose shift, and similar patterns. Further examination of response biases might be carried out on simpler tasks using various fixed stimulus sequences.

Cumming and Berryman (1965) also speculated on the possibility that the position preference of the pigeon was an aid in the acquisition of matching-to-sample and led to the better performance of the birds on the matching problem as compared to oddity. This does not seem to be the case in the present results with the color bias of the fish. Although the decline of the color preference was correlated with improvement on the matching task in some cases, e.g. fish 4, the learning curves for the two tasks were so similar that it would be hard to conclude that the color preference had been effective. While there was no difference between matching and oddity acquisition on task 1, a reliable difference was found on task 2, in spite of the fact that during both tasks fish showed color biases while performing on matching. Thus, there is no evidence for a relationship between color bias and the differences in acquisition on matching and oddity shown by goldfish, although the color bias may be a preliminary solution to the matching contingencies.

Another feature of the present study was the use of intermittent primary reinforcement, accompanied by continuous secondary reinforcement, during the entire training period. Studies have shown increased accuracy when pigeons that had already been trained to match to sample were placed on a variable ratio schedule (e.g. Nevin, Cumming and Berryman, 1963). However, it is not known whether the same effect would occur during acquisition, or with fish as subjects. It would be difficult to predict whether intermittent reinforcement would slow down acquisition, or speed it up, or change the shape of the function. An attempt was made to compare the 30% reinforcement schedule with a denser one. Because a continuous reinforcement schedule was impossible to implement, a 90% schedule was used instead. The three fish trained at 90%

(fish 4, fish 21 and fish 32) did not appear to have behaved differently from the other goldfish trained at 30%. However, since 90% is still an intermittent schedule, comparisons to continuous reinforcement should be made when the delivery of primary reinforcement can be better controlled for fish.

Appendix

Table 1

Order of presentation of the twelve stimulus combinations for the 24 trials which were repeated throughout a session.

Left	Center	Right
blue	green	green
green	green	red
blue	blue	green
red	red	green
blue	red	red
green	green	blue
red	blue	blue
red	red	blue
green	red	red
red	green	green
blue	blue	red
green	blue	blue
green	blue	blue
blue	blue	red
red	green	green
green	red	red
red	red	blue
red	blue	blue
green	green	blue
blue	red	red
red	red	green
blue	blue	green
green	green	red
blue	green	green

Table 2

Regression coefficients for the first 25 days of acquisition

	Task 1	Task 2
Subjects	Matching	Oddity
2	.22	
6	.68	
4	1.30	1.47
30	.42	.89
35	.46	1.03
	Oddity	Matching
3	1.55	
32	.79	
21	1.17	1.27
33	.38	1.07
34	.15	.64

Table 3

Means for 70 days of training

	Task 1			Task 2		
	Matching			Oddity		
	% correct	% preferences		% correct	% preferences	
		side	color		side	color
Subjects						
2	62	33	30			
6	74	13	40			
4	75	10	36	66	13	16
30	68	26	31	60	35	15
35	57	31	61	59	29	16
	Oddity			Matching		
	% correct	% preferences		% correct	% preferences	
		side	color		side	color
3	83	10	13			
32	65	18	13			
21	72	14	14	54	12	68
33	65	34	15	56	11	41
34	55	32	19	55	17	51

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