Name: Andrew Kwang-nieh Chien Date of Degree: July, 1967

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: A TWO-FACTOR DISCRIMINATION AND ASSOCIATION LEARNING IN GOLDFISH

Pages in Study: 25 Candidate for the Degree of Master of Science

Major Field: Natural Science

Scope and Method of Study: This experiment was carried out to test the visual discrimination ability of goldfish and to demonstrate their ability to form associations with various conditioned stimulus through instrumental learning. Three common goldfish were used as subjects. A predetermined positive (blue colored) target released both food odor and food grains when pecked; the negative target (yellow, red, green) offered only food odor but no real reinforcement. The conditioned stimuli were presented as a pairing of blue-yellow, blue-red, and blue-green colored targets in two ten-minute observation periods daily, with each color combination presented for 12 days.

Findings and Conclusions: The subjects were found to be able to discriminate the color blue from colors red, yellow and green. They were able to form positive associations with the positive conditioned stimuli and have achieved mean performances of 70.16 percent, 91.01 percent and 80.59 percent in the blue-yellow, blue-red and blue-green trials.

ADVISER'S APPROVAL L. Herbert Bruneau

A TWO-FACTOR DISCRIMINATION AND ASSOCIATION LEARNING IN GOLDFISH

By

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Bachelor of Science

Southeast Missouri State College

Cape Girardeau, Missouri

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Submitted to the faculty of the Graduate College
of Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
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A TWO-FACTOR DISCRIMINATION AND ASSOCIATION

LEARNING IN GOLDFISH

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PREFACE

The interesting behaviors and occasional demonstrations of high intelligence in animals has fascinated man for ages. The ability of animals to be conditioned or trained has been claimed as far down the phylogenetic scale as the flatworms. However, most of the interest has been centered on the vertebrates.

I have chosen the common goldfish to test and demonstrate two aspects of the overall behavior of fish. These are their ability to discriminate visual cues, and to form associations with them through learning.

This is not an experiment designed to confirm or reject the existence of color vision in goldfish. Without the use of elaborate equipment to control light intensity and wave-length, this would have been quite futile. However, the results I obtained suggest the fact that they can see color per se. This fact has been confirmed by many workers already; in fact most species of teleostean fish seem to possess color vision.

This report could not have been prepared without the valuable guidance and advice of my advisor, Dr. L. Herbert Bruneau. His advice has been of even greater assistance as this report is not written in my native language.

I am also greatly indebted to Dr. Rudolph J. Miller; who as my ethology professor, first introduced me to this field. It is only through Dr. Miller's advice and encouragement that I have chosen to pursue my studies in ethology - the study of animal behavior.

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PART I. INTRODUCTION

This is an attempt to demonstrate the ability of the common goldfish to discriminate between two target objects of different colors and to form associations with each through operant conditioning. The plan is to allow the fish to form positive associations with a predetermined "positive" stimulus and negative associations with a "negative" stimulus.

It is well known that goldfish are voracious feeders. Thus food reward was chosen as the unconditioned stimulus (US). Visual cues of four different colors (red, blue, yellow and green) formed the conditioned stimulus (CS), and the conditioned response (CR) is taken as the motor pattern of a fish pecking at a colored target.

To receive the reward of available food, a fish must utilize its perceptual abilities to discriminate the positive stimulus from the negative stimulus. Learning is involved in the formation of the right association. A response toward the positive target yields food and a response to the negative target fails to yield this reward.

Since the subject's responses are instrumental in bringing about reinforcement (the receiving of food or not), this is a form of instrumental learning. Also since the cues to be discriminated were presented together in a two-choice apparatus situation, this is also referred to as a simultaneous discrimination learning situation.

PART II. MATERIALS

The subjects used were three common goldfish Carassius auratus obtained from a local pet shop. They were 2.8 to 3 inches in length and their sexes were not determined. Code names were given to the three. Subject "A" had a patch of white across it's forehead, "B" had thick blunt caudal fins, and "C" had deeply forked and sharp pointed caudal fins.

The object targets were self-made "automatic" feeders. Common medicine eye-droppers were filled with water and commercial dried food, which was allowed to settle to the bottom of the dropper which had the dispensory end polished to a small hole. The hole was slightly larger than a single grain of the soaked food grains. Since the food grains would pack the narrow ends of the dropper and when the whole dropper was emersed into the water, the food would not fall out until a light tap was administered. A few grains would then fall out and be available to the subject.

To prepare the droppers as the CS the eye-droppers were wrapped with brightly colored water-proof Scotch brand tapes. Training droppers were wrapped at only half of their length so the food was visible. The droppers used in the experiment itself had the tapes covered the entire length so the food was not visible to the subjects at any time during the trials.

The "positive" target was as described earlier. The "negative" target also contained food, but it was wrapped in a different color and the dispensory hole was polished to a much smaller hole so the food cannot fall out even with the hardest bump. Thus both droppers were identical as far as olfactory cues were concerned (both releases food odor into the water) but they differed in visual stimulus and only the positive target offers positive reinforcement in the form of available food.

During the whole experimental period the subjects were housed in individual tanks, 9 by $5\frac{1}{2}$ by $6\frac{1}{2}$ inches in dimension. A wire was bent with two loops in it to hold the droppers two inches apart and five inches above the aquarium floor.

Since goldfish food expands too much when wet, Permalife brand tropical fish food with the right grain size for the dropper was used throughout the trials.

PART III. PROCEDURE

Initially the fish were put through a training period of five days during which they were housed together in the same tank. They would scatter when the droppers were first inserted and hide in the far corner. By the second day subject "C" was observed to be pecking at the food through the transparent glass dropper; and before the fourth day all subjects had been observed at some time to be approaching or pecking the target droppers.

The training droppers were wrapped at only the upper ends initially so the lower ends with the food was visible. More tapes were added daily so that by the end of the training period all of the dropper was covered by the tapes. No part of the packed food in the dropper was able to be seen. These droppers all yielded food upon pecking by the subjects.

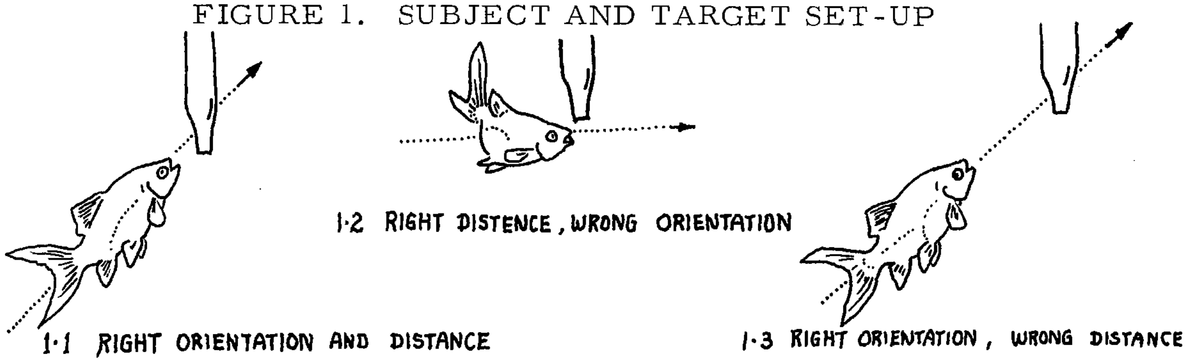
During the five day training period all four colors were presented simultaneously at one end of the communal tank. The target droppers were left in the tank twenty four hours a day and no data was taken.

The experiment itself was started on December 1, 1966. The blue dropper was chosen as the positive CS throughout the experiment. The non-rewarding negative CS were in turn the yellow, red and green target droppers. Positive blue as coupled with negative yellow, negative red and negative green in this sequence.

The subjects were not fed except during the trials when they received food from the positive dropper each time they pecked it. Two observations of ten minutes each (11:30 a.m. and 11:30 p.m.) were made daily for each subject. After six days or twelve observations the droppers were switched around in their relative positions in the tanks.

Data was recorded the following ways. The time elapsed in seconds before the first response. The target chosen (positive or negative target) for the first response bout. A "bout" is defined as a response continuing from the time the first peck touches the target through the time when the fish's body axis is directed toward the target and when not more than one inch from the target. Every time it turned its head so the body axis would miss the target or when it backed off more than one inch a new bout was indicated. Any further pecks would be that of a new bout.

FIGURE 1. SUBJECT AND TARGET SET-UP



Thus a bout may contain from one peck to as many as fourteen. The total number of pecks, regardless of bouts, were also recorded. Throughout the observations a response was recorded as a peck only when physical contact between the fish jaws and eye-dropper was detected.

The order of the trials administered was always A, B, C in this order. Thus for subject C, trial time was always around noon and midnight.

PART IV. RESULT AND DATA

The observations were carried out daily from December 1, 1966 to January 5, 1967. Tabulated data is presented in Tables 1 through IX.

Successful association was assumed when the subjects achieved 70 percent correct response. A correct response is a motor response that brings about positive reinforcement; in this case, a peck at the blue dropper target.

Three kinds of data were used in considering the performance of the subjects. These indexes included the total number of bouts directed at the blue (positive) target, the total number of pecks within all the positive bouts and the number of observation trials when the initial response was directed at the positive target.

Performance of the degrees of associations were expressed as the percentage of positive responses -- the number of positive response over the combined responses in each experimental situation (each bi-colored combination). These results are tabulated and presented in Tables X through XII.

TABLE I. SUBJECT A IN BLUE-YELLOW TRIAL

Date-time	Sec. elapsed before first peck-	initially at..	(Blue) bouts	(Blue) pecks	(Yellow) bouts	(Yellow) pecks
12. 1 a. m.	(no response)		0	0	0	0
12. 1 p. m.	360 sec.	Blue	1	3	1	1
12. 2 a. m.	(no response)		0	0	0	0
12. 2 p. m.	60	Yellow	2	8	1	2
12. 3 a. m.	50	Blue	3	7	1	2
12. 3 p. m.	45	Blue	6	14	0	0
12. 4 a. m.	120	Blue	5	19	0	0
12. 4 p. m.	15	Blue	1	6	0	0
12. 5 a. m.	64	Blue	4	7	0	0
12. 5 p. m.	22	Blue	6	11	2	2
12. 6 a. m.	10	Yellow	3	5	10	27
12. 6 p. m.	4	Blue	1	3	2	3
12. 7 a. m.	178	Blue	4	7	1	3
12. 7 p. m.	130	Blue	5	17	2	8
12. 8 a. m.	5	Yellow	3	6	4	7
12. 8 p. m.	39	Blue	12	24	0	0
12. 9 a. m.	6	Yellow	2	3	2	7
12. 9 p. m.	5	Yellow	16	23	15	40
12. 10 a. m.	2	Blue	6	12	0	0
12. 10 p. m.	26	Blue	3	10	0	0
12. 11 a. m.	17	Blue	24	26	3	3
12. 11 p. m.	(no response)		0	0	0	0
12. 12 a. m.	7	Blue	9	13	2	2
12. 12 p. m.	70	Blue	3	6	0	0

TABLE II. SUBJECT B IN BLUE-YELLOW TRIAL

Date-time	Sec. elapsed before first peck-	initially at..	(Blue) bouts	pecks	(Yellow) bouts	pecks
12. 1 a.m.	180 sec.	Blue	3	8	0	0
12. 1 p.m.	100	Yellow	3	16	4	12
12. 2 a.m.	80	Yellow	2	12	6	27
12. 2 p.m.	60	Yellow	3	14	1	1
12. 3 a.m.	120	Blue	3	5	8	30
12. 3 p.m.	20	Yellow	5	13	4	10
12. 4 a.m.	70	Blue	1	1	1	2
12. 4 p.m.	10	Blue	3	6	13	26
12. 5 a.m.	85	Yellow	2	2	2	2
12. 5 p.m.	95	Yellow	3	4	2	4
12. 6 a.m.	4	Yellow	4	12	2	8
12. 6 p.m.	7	Blue	3	4	0	0
12. 7 a.m.	8	Blue	2	5	0	0
12. 7 p.m.	12	Blue	3	4	5	13
12. 8 a.m.	18	Blue	8	10	3	3
12. 8 p.m.	4	Blue	16	32	0	0
12. 9 a.m.	75	Blue	3	5	0	0
12. 9 p.m.	13	Blue	5	8	3	6
12. 10 a.m.	5	Blue	3	4	1	2
12. 10 p.m.	14	Yellow	17	32	1	1
12. 11 a.m.	24	Blue	10	13	2	4
12. 11 p.m.	5	Blue	8	12	3	6
12. 12 a.m.	2	Blue	2	3	0	0
12. 12 p.m.	10	Blue	5	6	0	0

TABLE III. SUBJECT C IN BLUE-YELLOW TRIAL

Date-time	Sec. elapsed before first peck-	initially at..	(Blue) bouts	pecks	(Yellow) bouts	pecks
12.1 a.m.	200 sec.	Blue	3	4	0	0
12.1 p.m.	180	Yellow	2	8	1	6
12.2 a.m.	60	Blue	6	14	3	4
12.2 p.m.	30	Blue	1	3	0	0
12.3 a.m.	90	Yellow	3	10	10	38
12.3 p.m.	5	Blue	7	25	14	27
12.4 a.m.	3	Blue	3	7	0	0
12.4 p.m.	160	Blue	11	23	9	16
12.5 a.m.	5	Blue	8	20	2	3
12.5 p.m.	4	Blue	10	16	3	5
12.6 a.m.	55	Blue	22	77	3	4
12.6 p.m.	3	Blue	13	27	0	0
12.7 a.m.	14	Blue	5	13	0	0
12.7 p.m.	2	Yellow	24	45	14	24
12.8 a.m.	3	Yellow	5	10	6	8
12.8 p.m.	2	Blue	15	23	9	17
12.9 a.m.	5	Blue	9	18	0	0
12.9 p.m.	1	Blue	6	14	0	0
12.10 a.m.	7	Yellow	2	7	4	6
12.10 p.m.	6	Blue	3	12	0	0
12.11 a.m.	1	Blue	7	22	1	3
12.11 p.m.	2	Blue	6	16	0	0
12.12 a.m.	1	Blue	14	28	0	0
12.12 p.m.	1	Blue	6	16	1	1

TABLE IV. SUBJECT A IN BLUE-RED TRIAL

Date-time	Sec. elapsed before first peck	-initially at..	(Blue) bouts	(Blue) pecks	(Red) bouts	(Red) pecks
12.13 a.m.	2	Blue	11	36	3	3
12.13 p.m.	7	Blue	9	22	0	0
12.14 a.m.	12	Blue	19	46	0	0
12.14 p.m.	25	Blue	15	24	0	0
12.15 a.m.	9.5	Blue	7	14	0	0
12.15 p.m.	2	Red	3	3	2	4
12.16 a.m.	28	Blue	9	12	0	0
12.16 p.m.	108	Blue	8	12	0	0
12.17 a.m.	26	Blue	4	8	0	0
12.17 p.m.	81	Red	6	19	2	3
12.18 a.m.	16	Blue	4	7	0	0
12.18 p.m.	17	Blue	5	7	0	0
12.19 a.m.	53	Blue	3	4	0	0
12.19 p.m.	2	Red	7	13	1	3
12.20 a.m.	1	Blue	4	6	0	0
12.20 p.m.	105	Blue	5	9	0	0
12.21 a.m.	16	Blue	9	21	0	0
12.21 p.m.	25	Blue	3	5	0	0
12.22 a.m.	10	Blue	7	18	0	0
12.22 p.m.	13	Blue	4	13	0	0
12.23 a.m.	10	Blue	11	30	3	11
12.23 p.m.	300	Blue	1	1	0	0
12.24 a.m.	32	Blue	1	4	0	0
12.24 p.m.	51	Red	4	5	2	4

TABLE V. SUBJECT B IN BLUE-RED TRIAL

Date-time	Sec. elapsed before first peck-initially at..		(Blue) bouts	pecks	(Red) bouts	pecks
12.13 a.m.	11	Blue	14	17	0	0
12.13 p.m.	2	Blue	8	12	0	0
12.14 a.m.	4	Blue	4	6	0	0
12.14 p.m.	6	Blue	6	8	0	0
12.15 a.m.	14	Blue	5	12	0	0
12.15 p.m.	2	Blue	14	16	0	0
12.16 a.m.	4	Blue	7	7	0	0
12.16 p.m.	10	Blue	7	7	1	1
12.17 a.m.	96	Blue	1	2	0	0
12.17 p.m.	13	Blue	6	11	0	0
12.18 a.m.	5	Blue	8	12	0	0
12.18 p.m.	28	Blue	3	4	0	0
12.19 a.m.	6	Blue	3	4	0	0
12.19 p.m.	4	Blue	7	8	0	0
12.20 a.m.	14 Blue		4	5	0	0
12.20 p.m.	46	Blue	9	13	0	0
12.21 a.m.	20	Blue	5	7	2	2
12.21 p.m.	1	Red	11	15	3	5
12.22 a.m.	23	Blue	3	6	0	0
12.22 p.m.	7	Blue	9	12	0	0
12.23 a.m.	27	Blue	3	8	0	0
12.23 p.m.	188	Blue	3	5	0	0
12.24 a.m.	90	Blue	6	7	1	1
12.24 p.m.	2	Blue	9	9	0	0

TABLE VI. SUBJECT C IN BLUE-RED TRIAL

Date-time	Sec. elapsed before first peck-initially at..		(Blue) bouts	(Blue) pecks	(Red) bouts	(Red) pecks
12.13 a.m.	1	Blue	3	9	0	0
12.13 p.m.	1	Blue	9	25	0	0
12.14 a.m.	1	Blue	8	16	0	0
12.14 p.m.	4	Blue	14	27	0	0
12.15 a.m.	2	Blue	6	12	0	0
12.15 p.m.	2.5	Red	5	8	1	3
12.16 a.m.	1	Blue	6	9	1	3
12.16 p.m.	6	Blue	5	8	3	5
12.17 a.m.	3	Red	4	7	1	5
12.17 p.m.	2	Red	9	14	1	1
12.18 a.m.	5	Red	7	16	1	3
12.18 p.m.	1	Blue	12	22	0	0
12.19 a.m.	2	Blue	4	9	0	0
12.19 p.m.	5	Blue	7	8	1	3
12.20 a.m.	1	Blue	3	7	0	0
12.20 p.m.	2	Blue	8	15	0	0
12.21 a.m.	3	Blue	11	16	0	0
12.21 p.m.	1	Red	10	21	1	2
12.22 a.m.	9	Blue	8	13	0	0
12.22 p.m.	19	Blue	6	20	0	0
12.23 a.m.	8	Blue	10	24	0	0
12.23 p.m.	28	Blue	6	22	0	0
12.24 a.m.	4	Blue	2	10	0	0
12.24 p.m.	11	Blue	7	12	0	0

TABLE VII. SUBJECT A IN BLUE-GREEN TRIAL

Date-time	Sec. elapsed before first peck	-initially at..	(Blue) bouts	(Blue) pecks	(Green) bouts	(Green) pecks
12.25 a.m.	(no response)		0	0	0	0
12.25 p.m.	3	Green	3	7	5	11
12.26 a.m.	5	Blue	4	11	0	0
12.26 p.m.	9.5	Blue	2	7	0	0
12.27 a.m.	5	Blue	4	5	0	0
12.27 p.m.	6	Green	6	8	2	7
12.28 a.m.	2	Blue	10	20	0	0
12.28 p.m.	6	Blue	12	18	0	0
12.29 a.m.	1	Blue	11	20	0	0
12.29 p.m.	9	Blue	5	11	0	0
12.30 a.m.	25	Blue	7	7	0	0
12.30 p.m.	1	Green	7	10	4	18
12.31 a.m.	1	Green	12	30	4	6
12.31 p.m.	1	Blue	13	28	5	11
1.1 a.m.	121	Blue	1	2	0	0
1.1 p.m.	1	Blue	13	22	2	5
1.2 a.m.	1.5	Blue	5	11	2	5
1.2 p.m.	1	Blue	18	45	6	11
1.3 a.m.	1	Blue	5	9	0	0
1.3 p.m.	1	Blue	6	15	2	4
1.4 a.m.	1	Green	17	43	3	8
1.4 p.m.	.5	Blue	7	16	2	2
1.5 a.m.	2	Blue	13	28	0	0
1.5 p.m.	1	Blue	7	10	1	1

TABLE VIII. SUBJECT B BLUE-GREEN TRIAL

Date-time	Sec. elapsed before first peck-	initially at..	(Blue) bouts	pecks	(Green) bouts	pecks
12.25 a.m.	3	Blue	4	5	3	4
12.25 p.m.	56	Green	2	8	4	4
12.26 a.m.	20	Blue	3	7	1	1
12.26 p.m.	17	Blue	2	4	2	4
12.27 a.m.	14	Blue	2	5	0	0
12.27 p.m.	26.5	Blue	2	2	0	0
12.28 a.m.	50	Blue	11	24	0	0
12.28 p.m.	35	Blue	2	3	0	0
12.29 a.m.	53	Blue	4	8	2	6
12.29 p.m.	185	Blue	3	6	2	4
12.30 a.m.	22	Blue	4	11	1	1
12.30 p.m.	171	Green	1	2	3	4
12.31 a.m.	13	Blue	4	8	0	0
12.31 p.m.	43	Green	6	6	2	2
1.1 a.m.	29.5	Blue	4	7	0	0
1.1 p.m.	1	Green	3	4	1	1
1.2 a.m.	12	Blue	3	5	0	0
1.2 p.m.	11	Green	1	1	1	1
1.3 a.m.	1	Blue	3	10	1	1
1.3 p.m.	3	Blue	3	5	1	1
1.4 a.m.	4.5	Blue	11	12	0	0
1.4 p.m.	22	Blue	5	6	2	2
1.5 a.m.	5	Blue	13	18	0	0
1.5 p.m.	10	Blue	9	10	1	1

TABLE IX. SUBJECT C IN BLUE-GREEN TRIAL

Date-time	Sec. elapsed before first peck	-initially at..	(Blue) bouts	(Blue) pecks	(Green) bouts	(Green) pecks
12.25 a.m.	2.5	Blue	12	20	3	3
12.25 p.m.	1	Blue	15	23	6	10
12.26 a.m.	3	Blue	8	15	0	0
12.26 p.m.	3	Green	13	19	3	10
12.27 a.m.	2.5	Blue	9	24	4	8
12.27 p.m.	1	Blue	7	15	5	8
12.28 a.m.	3	Green	15	20	4	6
12.28 p.m.	1	Blue	11	17	0	0
12.29 a.m.	1	Blue	18	35	0	0
12.29 p.m.	1	Blue	20	33	4	7
12.30 a.m.	1	Blue	10	16	0	0
12.30 p.m.	1	Blue	9	12	5	5
12.31 a.m.	2	Blue	15	31	0	0
12.31 p.m.	1	Blue	10	14	3	4
1.1 a.m.	1	Blue	9	15	3	4
1.1 p.m.	1	Blue	5	15	3	6
1.2 a.m.	1	Blue	11	19	1	1
1.2 p.m.	1	Green	20	26	2	4
1.3 a.m.	6	Green	10	15	2	2
1.3 p.m.	1	Green	10	14	4	5
1.4 a.m.	6	Green	14	21	4	6
1.4 p.m.	1	Blue	18	21	0	0
1.5 a.m.	1	Green	23	39	2	3
1.5 p.m.	4	Blue	18	34	1	2

TABLE X. PERFORMANCE IN BLUE-YELLOW TRIAL

Subject	Total "+" bouts	Total "+" pecks	First response
A	119--72.5%	230--68.6%	16--76.2%
B	117--66.1%	230--59.6%	16--66.6%
C	190--70.1%	462--72.2%	19--79.5%
Mean	69.57%	66.8%	74.1%

TABLE XI. PERFORMANCE IN BLUE-RED TRIAL

Subject	Total "+" bouts	Total "+" pecks	First response
A	161--92.5%	332--92.2%	20--83.3%
B	158--95.8%	213--95.5%	23--95.8%
C	170--94.4%	354--93.4%	19--79.2%
Mean	94.23%	93.7%	86.1%

TABLE XII. PERFORMANCE IN BLUE-GREEN TRIAL

Subject	Total "+" bouts	Total "+" pecks	First response
A	190--83.3%	377--81.8%	18--78.3%
B	104--80.0%	177--83.5%	19--79.2%
C	308--83.9%	514--84.5%	17--70.8%
Mean	82.4%	83.27%	76.1%

FIGURE 2. MEAN PERFORMANCE IN BLUE VS YELLOW

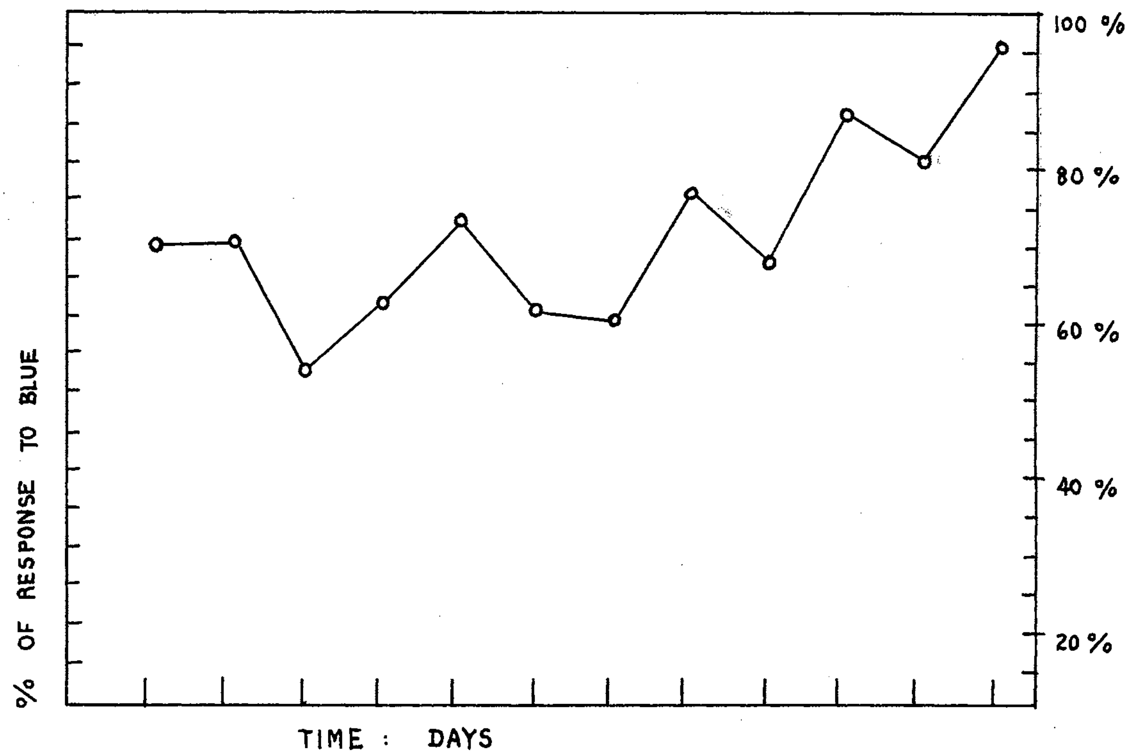


FIGURE 3. MEAN PERFORMANCE IN BLUE VS RED

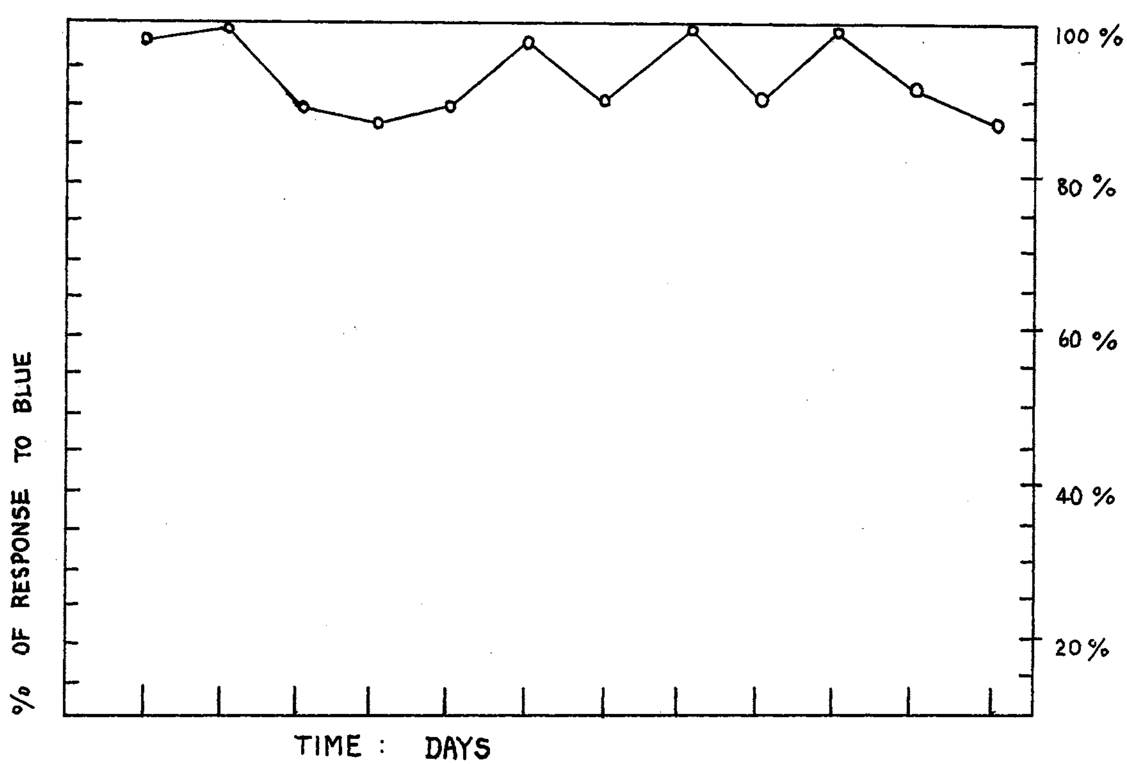
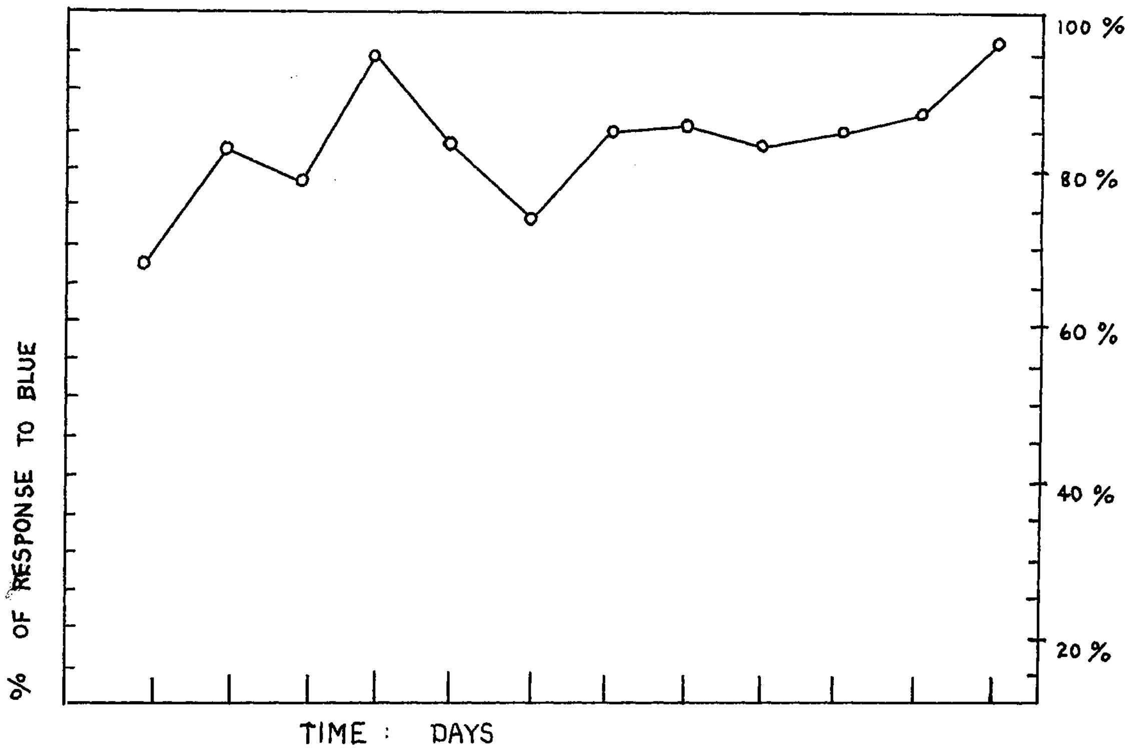


FIGURE 4. MEAN PERFORMANCE IN BLUE V.S. GREEN



PART V. DISCUSSION

It is not my intention nor within my power to test the color vision in goldfish by this simple experiment. Perkins and Wheeler (1930) have proven that they can discriminate light intensities. Recent workers have shown that they can see color as well. My purpose was to study the goldfish's ability to form distinctive associations with one out of two targets differentiated by colors only. Actually configuration, size or relative positions can also be used in this kind of learning.

The reinforcement here was the availability of food after a peck at the positive blue target. There was no active punishment for responding toward the negative target, only a passive punishment in the failure of availability of food reward. Since this does not involve a clear cut reward-punishment conditioning situation, the rate of acquisition would be expected to be lower. I feel it necessary to acknowledge an association when they can discriminate between the target and respond to the blue (positive) target two-thirds of the total responses or about seventy percent positive responses.

All the subjects showed surprisingly high preference for the blue target initially in most trials. In the Blue-Yellow trials subjects B and C achieved 100 percent preference in the morning trial but dropped sharply in the night trial. The subsequent high preference for Blue in the following Blue-Red and Blue-Green trials must be the result of previous positive associations with this target. But the initial high preference in the Blue-Yellow trials may involve some chance initially, the fish swims to the nearest target (Blue, in this case) and after some positive reinforcement would continue to respond to this target.

Some difficulties which arose during the process of the experiment include the lack of great precision of the droppers. An ideal feeder would be one that dispensed a fixed amount of food for every peck. There was also the need to record the relative strength of each peck. Most of the pecks were light nudges on the lower end of the dropper, however all the subjects at times would suddenly swim away, turn around and then rush at the target and peck hard enough to actually rock and sway the dropper. Very often a fish would swim rapidly toward the target, the seemingly either "lose interest" or suddenly get "frightened" and swing away at the very last instant. Other times a subject would orient itself toward a target and would come very close but never actually touch it, and would maintain this position for as long as a minute or more. Under our earlier definition of a response peck, all the above responses were not recorded.

Originally I viewed the frequency of the bouts as the quanitative measure of the attraction for a certain target and the number of pecks in each bout as the indication of the state of motivation of the subjects during the time of the response bout. Sometimes the fish would dash out within one second after insertion of the dropper, swim up to the target, peck it once or twice and turn downwards to catch the food as it falls.

After the results were all gathered, the performance based on the total number of response bouts agreed very much with the performance based upon the total gross number of pecks. Since the difference between the two data was insignificant, the total number of pecks can be indicative of the overall picture. (See Tables X through XII.)

The time elapsed before the first response generally did not follow the expected decreasing reaction time with increased repetitions. Rather than a constant decline in the time elapsed, there were great fluctuations. The difference in hunger states and the relative positions of the subjects while the targets were being presented could be factors contributing to this deviation from the expected.

Because of the failure to actively punish the fish for a wrong response, they would continue to peck at the negative target on occasions. The behavior varied at this point; they would peck the negative target in succession then swim away "dejectedly" to the opposite corner or after some non-rewarding experience with the negative target they turned to the blue target and pecked vigorously. This non-rewarding situation could cause "frustration" which might affect association learning (Ansel 1958).

As expected, this investigation raised more questions than were answered. A very important question is raised by the great varieties of response patterns demonstrated by the three subjects at varying times toward the situation. The behaviors toward the targets were not just reflex responses to the visual stimuli of a couple of colored eye-droppers being lowered into their tanks. My reference earlier to the colors of the droppers as the CS and the pecking of a taped eye-dropper as a CR does not imply that this is a case of simple conditioning.

Many times a subject hovered between the two alternatives and changed it's orientations repeatedly before making a response run. Some processes of coordination and association were going on in the fish's CNS, though the exact mechanisms are not certain.

A drive concept (varying degrees of motivation) can be used to explain why an orientation sometimes leads to a complete response while at other times the response was not carried to completion.

PART VI. SUMMARY AND CONCLUSION

In the Blue-Yellow trials, both subjects A and B did fairly (68.6 and 59.6 percent respectively) and the overall mean performance of the three subjects is only 66.8 percent. However, by referring to the learning curve (Figure 2) we can see that all subjects were doing very well toward the end of this particular experiment.

By human perceptions, red and blue, with wave-lengths in the ranges 610 mu and 450-500 mu respectively, should offer the best contrast in hues. As expected, the overall performances in this experiment was the best, achieving a mean of 93.7 percent.

In the Blue vs Green trials, I expected the most difficult discrimination, with the slightest wave-length difference (400-450 mu for blue vs 510-550 mu for green). However, their performance was better than for Blue-Yellow, arriving at 83.27 percent.

In conclusion, the goldfish demonstrated sufficiently the ability to discriminate objects differing in visual properties, probably colors, only. Through instrumental learning they have achieved performance of 90 percent and better by the last days of each set of experiments.

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