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SHAPE DISCRIMINATION IN THE
SIAMESE FIGHTING FISH
BETTA SPLENDENS

Thesis for the Degree of M. S.
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Veronica A. Cerny
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ABSTRACT

SHAPE DISCRIMINATION IN THE SIAMESE
FIGHTING FISH BETTA SPLENDENS

by Veronica A. Cerny

The experiments reported in this paper were designed to test the ability of the Siamese fighting fish Betta Splendens (Regan), to discriminate shape differences in floating forms in the nest-building situation. An effort was made to determine the possible basis for discrimination.

Conditioning was not employed in these experiments. Rather, advantage was taken of the fact that all males will build bubble nests under flat floating forms. When the fish were given a choice of two forms differing only in shape, the form under which the larger nest was built was considered to be preferred. Preference implies the ability to discriminate, but the reverse is not necessarily true. The observations consisted of three parts designated A, B, and C. Forty-eight males were tested in part A. Part B involved the same number but not the same individuals. Sixteen were used in part C.

The shapes tested were a circle, a square, and an equilateral triangle for part A; an elipse, an elongated

rectangle, and an isosceles triangle for part B; and a right triangle and an isosceles triangle for part C. In part A three different pair-combinations of the shapes were presented to the fish. These were circle-triangle, circle-square, and square-triangle. The three pair-combinations used in part B were: elipse-rectangle, elipse-triangle, and rectangle-triangle. In part C the one pair-combination used was: right triangle-isosceles triangle. The results were tested by a non-parametric sign test.[1]

Wherever discrimination was noted, rounded forms such as the circle or elipse were preferred over those with acute angles, e.g. equilateral triangle or isosceles triangle. The rounded forms were not favored when paired with the square or the elongated rectangle, forms having no acute angles. The rectangular form was preferred to the isosceles triangle, but the square was not favored over the equilateral triangle. It is suggested that the fish discriminated against "acuteness of angle" and that a difference greater than 30° was necessary for this to occur under the conditions of these experiments.

When the data were pooled, significant preference was indicated for the circle and the elipse, while there was discrimination against the isosceles triangle. No significant preference was shown either for or against the square, the elongated rectangle, or the equilateral triangle. In the case of the latter, however, the results approached the level of significance (8.8%), and it is suggested that a larger sample might have indicated discrimination against this shape. In general, these results are in agreement with those cited above.

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[1]Dixon, W. J. and F. J. Massey, Introduction to Statistical Analysis (New York, McGraw-Hill Book Co., 1957), pp. 280-302.

SHAPE DISCRIMINATION IN THE SIAMESE FIGHTING FISH *BETTA SPLENDENS*

By

Veronica A. Cerny

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INTRODUCTION

The Siamese fighting fish Betta splendens (Regan) belongs to the order Labyrinthici, family Anabantidae. All members of this family possess an air breathing apparatus, the labyrinth, which consists of a pair of cavities lined with vascular epithelium. The fish gulp air at the surface of the water and pass it into the labyrinth (Smith, 1945; Forselius, 1957).

Some species of this family are oral incubators while others are bubble nest builders. It is probable that the bubble nest building as part of the reproductive behavior evolved from the air breathing habit. The oral incubation which involves retaining the eggs in the buccal cavity until hatching, has probably evolved from the bubble nest building behavior. Betta pugnax (Cantor) and Betta picta (Cuvier and Valenciennces) are two oral incubating species which are closely related to Betta splendens.

The male Betta splendens build bubble nests. A bubble of air is taken into the mouth, covered with mucus, and deposited on the surface of the water. This is repeated until a nest is accumulated. In nature the bubbles are usually deposited under a floating leaf (Smith, 1945). The shape and size of the nest are not consistent either among the individuals nor in any one individual. The shape is usually adapted to the shape of the floating object (Braddock and Braddock, 1959), and the size may depend on such species specific factors as the intensity of nest building activity and/or availability of nesting material (Forselius, 1957). In nature the males will not build bubble nests in the presence of the female, but will drive her away. In the laboratory however, they will build nests while in visual contact with a female or even another male. They will also build nests when visually isolated (Braddock and Braddock, 1959).

Mating occurs directly underneath the nest. After mating the male catches the eggs in his mouth and deposits them in the nest where they remain until hatching. The eggs which fall from the nest are caught and returned to the nest. The male also replaces bubbles which have burst, and frequently enlarges the nest by adding a new layer of bubbles (Braddock and Braddock, 1959). This addition of bubbles to the nest increases the firmness of the nest and raises the eggs slightly above the water where the oxygen is plentiful (Forselius, 1957).

B. splendens has been cultivated for its fighting quality in Thailand for at least a hundred years and thus the literature concerning it varies from folklore to scientific studies. Among the earliest scientific studies are those of Regan (1909), who identified the species, and Lissman (1932) who presented information concerning its stimulus-response system. Smith (1937, 1945) published information concerning certain aspects of the behavior and ecology of the species. Forselius (1957) published an extensive monograph covering the behavior, ecology and certain aspects of the endocrinology of Anabantid fishes in general. Braddock and Braddock (1955) published a study of the aggressive behavior of the female B. splendens, and (1959) presented information concerning the development of nesting behavior.

Several discrimination studies of B. splendens have also been carried out. Herter (1953) showed that many fishes, including Betta splendens can be trained to make visual discrimination. Braddock, Braddock and Kowalk (1960) published studies concerning size discrimination in the species. This was later extended by Childs (1963). Gude (1965) has carried out studies on color discrimination, and Picciolo (1964) has published information on the importance of color and other factors in sex discrimination in Anabantids. Braddock, Braddock and Richter (1960) presented information concerning shape discrimination in Betta splendens. They found that the fish exhibited a marked preference for three compact* forms, a circle, a square, and an equilateral triangle, over a rectangle. However they did not find discrimination or preference at a significant level for any form among the three compact forms. This work represents an attempt to learn whether shape discrimination exists among the compact forms and, if possible what aspect of the shape is preferred by the species.

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*In this thesis the description "compact form" is used to signify a form which has the shortest possible axes for a particular area and shape.

MATERIALS AND METHODS*

The fish were housed, and the experiments took place, in a laboratory on the third floor of the Natural Science Building at Michigan State University, East Lansing, Michigan. This room contained steam heating apparatus plus an automatic air conditioner, which kept the room temperature quite uniform (80°-81°F). However, on five days the temperature fell as low as 78°F, and on three days it rose as high as 82°F.

The three windows, facing north, were covered with venetian blinds to reduce the amount of natural light entering the laboratory which was lighted with sixteen 40-watt fluorescent bulbs. These provided 12 hours of light (8:00 AM - 8:00 PM), and 12 hours of darkness, and were controlled by an automatic timer. In addition, the experimental aquaria, which were located on a bench next to the windows, each received 24 hours of light from a 25-watt bulb in a gooseneck lamp. A lamp was centrally placed on one side of each aquarium (Fig. 1). The purpose was to provide enough light

*The experimental design used here was approved by the late Dr. P. J. Clark, and the final statistical analysis was approved by Dr. H. M. Slatis.

for the fish to see their nests, since in total darkness, they tend to destroy them.

The fish were kept in wide-mouthed, gallon (3.78 L) jars, filled to the depth of 17.5-18.7 cm. with aged water,[1] and arranged in double rows on wooden racks. They were visually isolated from each other by partitions made of white index cards placed between the bottles where they touched side to side, and by brown-paper partitions where they met back to back. They were not visually isolated from the experimenter during feeding. When evaporation reduced the water level 1.3 cm, it was raised to its original level by the addition of a mixture of aged and tap water, in a ratio of 5 to 1.

Five test aquaria were used. Each had a total capacity of 75.6 L and the dimensions of 76.2 x 33 x 35 cm. They were filled to the depth of 17.5-18.7 cm, and thus contained approximately 40.7-43.5 L of water. The floors of the aquaria were covered with gravel to the depth of 0.64 cm. The sides were covered with a layer of 0.001" white opaque plastic sheeting, and the tops were covered with clear glass on which rested a sheet of 0.0075" transluscent laminating vinyl of the color of standard white waxpaper. This allowed

[1]Aged water, as used here, means tap water aged for not less than three days.

some light to enter the aquaria while preventing the fish from being disturbed by visual events occurring outside.

A stimulus aquarium was centrally placed against one side of each test aquarium opposite to the side where the gooseneck lamp was located (Fig. 1). Where the stimulus aquaria were in contact with the test aquaria the sheeting was omitted in order that the two fish involved might see each other. This was done to encourage nesting activity, since two males in visual, but not in physical, contact tend to exhibit displacement nest-building. The increased amount of bubbles enabled more accurate measurements to be taken.

The total capacity of the stimulus aquaria was 9.5 L. They were placed upon supports 5 cm high, and were filled to a depth of 12.5-13.7 cm which brought the surfaces of the water in both test and stimulus aquaria to the same level, and thus they contained approximately 8.3 L of water. Their floors were covered with gravel 0.64 cm deep. The sides and tops were covered in the same manner and with the same material as those of the test aquaria.

Forms, constructed from 0.001" transluscent laminating vinyl, were suspended in the test aquaria in contact with the water surface. When each form was cut, a small tab was left in the center of each side. These tabs were turned up, perforated with a needle and threaded with a white thread. The threads were knotted above the center of the form and were attached to a copper wire suspended from the central plate of glass covering the aquarium. This arrangement prevented the forms from moving about on the surface of the water.

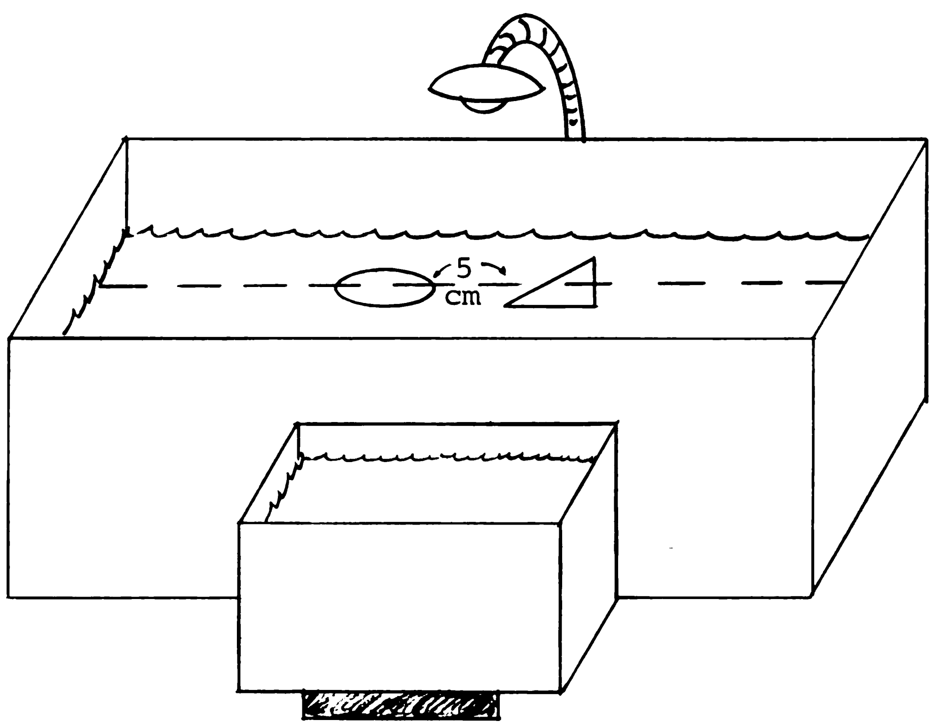

Fig. 1. Experimental Set Up

The forms were separated by a space of 5 cm where they were closest to each other (Fig. 1) and were centrally located in the aquarium.

The fish were fed ground frozen shrimp once a day, with a supplement of live brine shrimp nauplii once every two weeks. Uneaten food was removed from the bottles daily. The fish were fed just prior to being placed in the test situation. The temperature of the water in the aquaria was measured and recorded. The fish were then gently netted and placed in the centers of the test aquaria between the two forms, and the covers were put in place. Twenty-four hours later, the covers were removed and the areas of any bubble-nests present were measured in cm^2. In actual practice the area of the nests under any particular form was measured with the aid of a form which was identical in shape and size to the form under which the nest was constructed. These forms were made of clear 0.01" acetate on which a grid consisting of 1 cm squares had been drawn. This form was held above the floating disc, and the number of square centimeters, which the nest covered, was read off the grid. The number of layers of bubbles in the nest was considered, and a nest with 2 layers of bubbles was recorded as twice as large as one with only one layer. After all measurements were taken the temperature of the water in the aquaria was measured and recorded, and the fish were returned to their home-jars. The forms were removed and dried, and all bubbles were removed from the aquaria. The forms for another set of observations were then placed in the aquaria, thus preparing the aquaria for the next trial. Tests were conducted daily from April 30 to June 17, 1964; from July 21 to September 9, 1964; and from August 25 to September 9, 1964; for parts A, B, and C of the experiments respectively.

A total of 150 adult male *Betta splendens* (Regan) were used in the observations reported here. These experiments consisted of three parts which were designated as A, B, and C. A total of 48 test fish and 6 stimulus fish each were used for parts A and B, while 16 test fish and 4 stimulus fish were used for part C. These were purchased from a New York firm on two separate dates, approximately four months apart with the exception of 8 fish purchased at a local pet shop. Nineteen individuals died, eleven during the period of experimentation, and were replaced from a group of 26 fish held in reserve.

All forms used in parts A, B, and C of the experiments had an area of 200 cm^2. Their dimensions are indicated in Fig. 2.

Three forms were used in part A of the experiment. The shapes were: an equilateral triangle, a circle and a square. These were presented to the fish in pairs, thus giving three pair combinations {O△, O□ and □△} which were designated as {A, B and C} respectively.

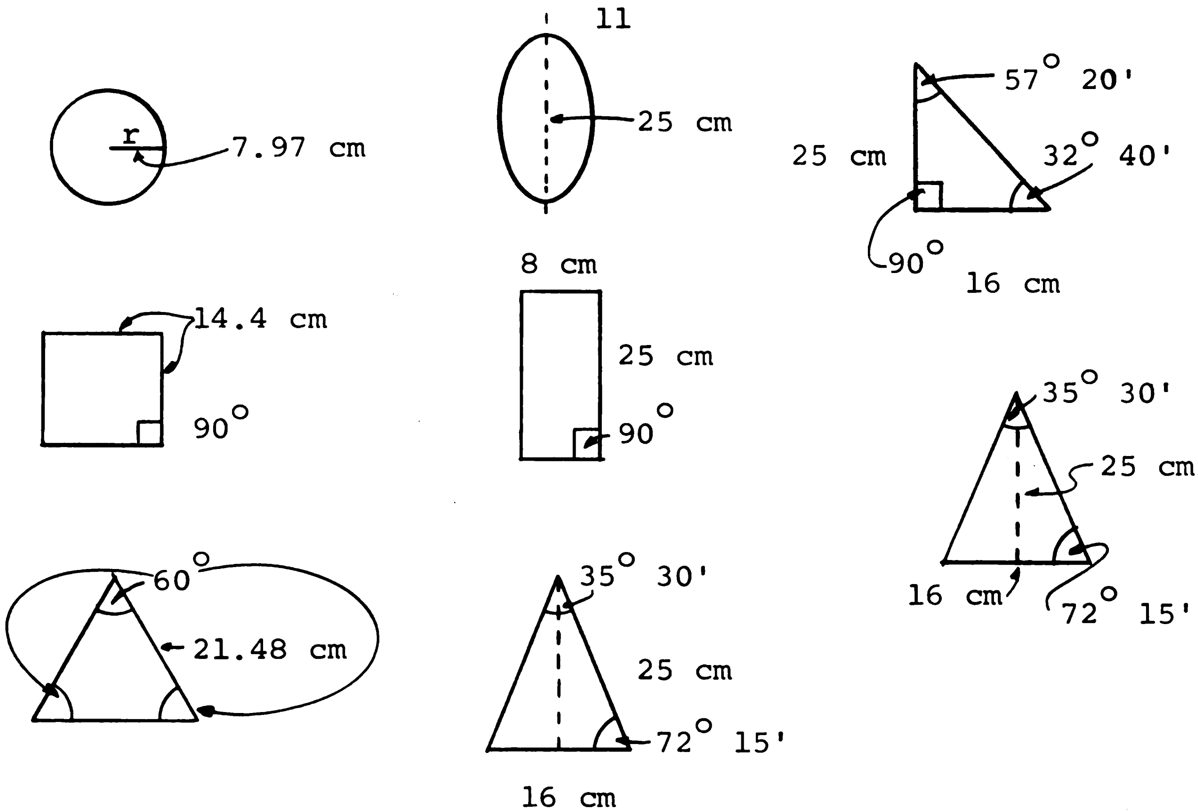

Fig. 2. Dimensions of Forms Used

The test aquaria were designated as T-I, T-II, and T-III[2], and when randomized with the above three pair-combinations, gave rise to 6 possible form situations (Fig. 3).

Since an aquarium has right and left sides there were 8 permutations of each situation (Fig. 4). This then resulted in 48 possible final situations. A random number[3] was

[2]Their companion stimulus aquaria were S-I, S-II, and S-III.

[3]Dixon, W. J., and F. J. Massey, "Table A-I Random Numbers," Introduction to Statistical Analysis (New York: McGraw-Hill Book Co., 1957), p. 336.

Aquarium Situation	T-I	T-II	T-III
1	A	B	C
2	A	C	B
3	B	A	C
4	B	C	Z
5	C	A	B
6	C	B	A

Fig. 3. Form Situations

Aquarium Situation I	T-I	T-II	T-III
1	A(RL)	B(RL)	C(RL)
2	A(RL)	B(RL)	C(LR)
3	A(RL)	B(LR)	C(RL)
4	A(RL)	B(LR)	C(LR)
5	A(LR)	B(RL)	C(RL)
6	A(LR)	B(RL)	C(LR)
7	A(LR)	B(LR)	C(RL)
8	A(LR)	B(LR)	C(LR) etc.

Fig. 4. Final Situations

(For example since A was designated as O△, A(RL) means, that the O is on the right side of the aquarium and the △ is on the left. A(LR) means that the △ is on the right side and the O is on the left.)

assigned to each final situation and these were then run, one per day in the order of increasing magnitude of their random numbers.

The test fish were labeled T-I, T-2, T-3, . . . T-48, and were used three per day in this order. Each individual was thus used three times at intervals of 16 days. The stimulus fish were labeled S-1, S-2, . . . S-6, and were used every other day. To equalize the possibility of one fish having more stimulus value than another, the stimulus fish were rotated (Fig. 5).

Trials	Aquaria		
	S-I	S-II	S-III
1.	S-1	S-2	S-3
2.	S-4	S-5	S-6
3.	S-3	S-1	S-2
4.	S-6	S-4	S-5
5.	S-2	S-3	S-1
6.	S-5	S-6	S-4
7.	S-1	S-2	S-3 etc.

Fig. 5. Rotation of Stimulus Fish

The same procedure was used in part B but the forms were changed to an elipse, an isosceles triangle and a rectangle. The aquaria used were the ones used in part A, but new fish, labeled T'-1, T'-2, T'-3, . . . T'-48, and S'-1, S'-2 . . . S'-6, were used. Part C was conducted in a similar manner but only two shapes, an isosceles triangle and a right triangle were used. This gave rise to only four final situations with regard to the shapes tested. However, by also considering the position of the right angle of the right trianble with regard to the other form and the side of the aquarium, it was possible to get eight situations. Each of these was used four times, thus giving 32 trials. These were randomized by the method using random numbers as described previously (p. 11). Two test aquaria, T-IV and T-V, and two stimulus aquaria, S-IV and S-V, were used. New fish were used and were labeled T"-1, T"-2, T"-3, . . . T"-16, and S"-1, S"-2, . . . S"-4.

RESULTS

Forty-eight individuals were tested in part A of the experiments. The purpose of this part was to determine whether or not the fish were able to discriminate among the shapes; namely circle, square, and equilateral triangle when these were presented in pair-combinations. Preference was measured in terms of the areas of the bubble nests constructed under each form and the preferred form was considered to be that one under which the larger had been constructed.

Each fish was used for three trials at sixteen-day intervals. Of the 48 fish tested, 10 were presented with all three pair-combinations, 31 with two, and seven with only one. This was due to the method of randomization involved in the experimental design. A sign test[1] indicated that the forms presented in preceding trials did not influence the choice in subsequent trials. The same test was also used to determine whether preference was shown for any of the forms. Results which gave a probability for chance occurrence (α) of 5% or less were considered significant.

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[1]Dixon, W. J. and F. J. Massey, Introduction to Statistical Analysis (New York: McGraw-Hill Book Co., 1957), pp. 280-302.

Pair-combinations presented	Number of choices made			2 (α)[2]
	Total	+	−	
(+) O / △ (-)	37	29	8	<.008
(+) O / □ (-)	34	19	15	>.392
(+) □ / △ (-)	39	16	23	.236

Table I. Form Preferences (Part A)

The results obtained in part A (Table I) indicate that the fish were able to discriminate between a circle and a triangle and preferred the circle with a departure from chance of less than 0.8%. They were either unable to discriminate between, or had no preference for, either shape in circle-square and square-triangle combinations. The experimental procedures and method of analysis of the data used in parts B and C were identical with those used in part A, with the exception that in part B the forms tested were an elipse, an isosceles triangle, and an

[2] Dixon, W. J. and F. J. Massey, "Table A-10B: Distribution for the Sign Test," Introduction to Statistical Analysis (New York: McGraw-Hill Book Co., 1957), pp. 418-420.

elongated rectangle while those used in part C consisted of a right triangle and an isosceles triangle. These results are presented in Tables II and III. The information presented in Table II indicates that the fish were able to discriminate between an elipse and an isosceles triangle and between a rectangle and an isosceles triangle at significant levels (both 2.8%). The elipse and the rectangle were both preferred over the triangle. The fish were either unable to discriminate between, or showed no preference for, either an elipse or a rectangle when these shapes were tested against each other.

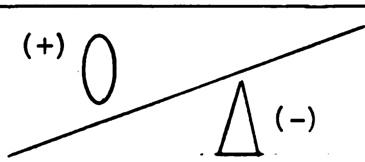
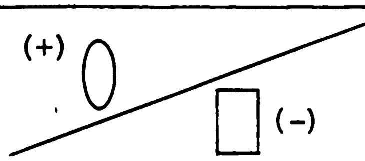
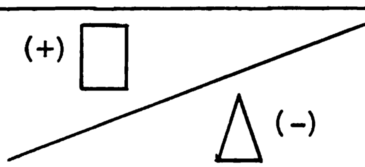
Pair-combinations presented	Number of choices made			2 (α)
	Total	+	-	
	36	25	11	.028
	39	23	16	.336
	36	25	11	.028

Table II. Form Preferences (Part B)

From Table III it can be determined that the fish were either unable to discriminate between, or indicated no preference for, a right triangle and an isosceles triangle, when these two forms were presented in a pair-combination.

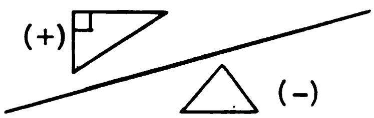
Pair-combinations presented	Number of choices made			2 (α)
	Total	+	-	
	28	18	10	.184

Table III. Form Preferences (Part C)

The data were then pooled to indicate whether a preference existed for or against any particular shape. This information is presented in Tables IV and V.[3]

Form tested	Number of choices made			2 (α)	
	Total	For the form	Against the form	For	Against
○	71	47	24	.008	.992
□	73	33	40	>.350	<.650
△	78	31	47	.912	.088

Table IV. Combined Form Preferences (Part A)

[3]Since only two forms were used in part C, the data are already arranged in this manner (Table III).

Form tested	Number of choices made			2(α)	
	Total	For the form	Against the form	For	Against
⬯	75	48	27	.020	.980
□	75	40	35	>.358	<.642
△	72	22	50	<.994	>.006

Table V. Combined Form Preferences (Part B)

The information presented in Table IV indicates that a preference was demonstrated for the circle, and against the triangle at significant levels 0.8% and 8.8% respectively. Although the discrimination against the equilateral triangle cannot be considered significant since its confidence limits are above 5%, it does approach significance quite closely and there is possibly a need for a more adequate sample. No preference was demonstrated for or against the square. The information presented in Table V demonstrates that a preference was indicated for an elipse at the 2% level and against an isosceles triangle at the 0.6% level. No preference was indicated either for or against the rectangle.

The differences between bubble nest areas under each form of all pair-combinations is indicated in Tables VI and VII. The medians, and the upper and lower quartiles are included in these tables to inform the reader concerning the distribution of the area differences of the nests. The quartile deviations are also included for this purpose. The information concerning part A (Table VI) indicates that the ranges were +59 to -26, +69 to -58, and +68 to -58, for the circle-triangle, circle-square, and square-triangle combinations respectively. The upper quartile, the median, the lower quartile, and the quartile deviation, for the circle-triangle combination were +15, +2, +0.5, and 7.75 in that order. The circle-square combination had an upper quartile of +12, a median of +0.5, and lower quartile of -6, and a quartile deviation of 9 . For the square-triangle combination, the upper quartile, the median, and the lower quartile were +4, -1, and -7 respectively. The quartile deviation was 5.5.

This information for parts B and C (Table VII) indicates that the ranges for elipse-isosceles triangle, elipse-rectangle, rectangle-isosceles triangle, and right triangle-isosceles triangle combinations were +43 to -36, +33 to -27, +85 to -51, and +32 to -26 respectively. The upper quartiles, the medians, and the lower quartiles for elipse-isosceles triangle, elipse-rectangle, rectangle-isosceles triangle, and right triangle-isosceles triangle combinations were +2,

+2, and -2; +14.5, +1, and -6.5; +11, +2, and -2; and +17.5, +2.5, and -9.5 respectively. The quartile deviations for the above mentioned combinations were 7, 10.5, 6.5 and 13.5 in that order.

As previously mentioned the data collected were pooled in order to learn whether or not a preference existed for or against a particular shape. The upper quartiles, the medians, the lower quartiles, and the quartile deviations for the pooled data are given in Tables VIII and IX.[4] The information for part A (Table VIII) indicates that the ranges for the circle, the square, and the triangle respectively, were +69 to -58, +68 to -59, and +58 to -68. The upper quartiles were +15, +4, and +14. The medians were +1.5, -0.5, and -1; while the lower quartiles were -4, -915, and -11 in that order. The quartile deviations were 9.5, 6.75 and 12.5.

From Table IX (part B) it can be seen that the ranges for the elipse, the rectangle, and the isosceles triangle were +43 to -36, +85 to -51, and +51 to -85, respectively. The upper quartiles were, in the above mentioned order, +14, +8.5, and +2. Again in the same order the medians and the

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[4]Since only two forms were used in part C the data already are in this form (Table VII).

Pair-combinations					
○ (+) / △ (−) cm²		○ (+) / □ (−) cm²		□ (+) / △ (−) cm²	
+59	+ 1	+69	− 1	+68	− 1
+42	+ 1	+38	− 2	+39	− 2
+41	+ 1	+37	− 3.5	+37	− 3
+37	+ 1	+29	− 4	+36	− 4
+34	+ 0.5	+18	− 4	+20	− 4
+33.5	+ 0.5	+18	− 6	+19	− 4
+24	+ 0.5	+15	− 6	+17	− 5
+22	+ 0.5	+15	− 8	+ 6	− 6
+21	− 2	+12	−19	+ 4	− 6
+15	− 2	+10	−22	+ 4	− 7
+15	− 3	+ 9	−23	+ 3	− 9
+14	− 7.5	+ 4.5	−34	+ 1	−10
+10	−12	+ 4	−57	+ 1	−10
+ 8	−15	+ 3	−58	+ 0.5	−11
+ 5	−25	+ 2		+ 0.5	−15
+ 3.5	−26	+ 1.5		+ 0.5	−16
+ 3		+ 1		0	−26
+ 3		+ 0.5		0	−34
+ 2		+ 0.5		− 0.5	−57
+ 1.5		0		− 0.5	−58
+ 1.5		− 1		− 0.5	
§ = +15, * = +2		§ = +12, * = +.5		§ = +4, * = −1	
★ = +.5, QD = 7.75		★ = − 6, QD = 9		★ = −7, QD = 5.5	

Table VI. The Distribution of Area Differences in Part A

(§ = upper quartile, * = median, ★ = lower quartile, and QD = quartile deviation.)

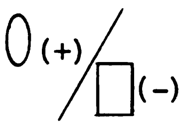
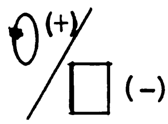
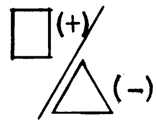
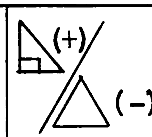
Pair-combinations							
	cm^2		cm^2		cm^2		cm^2
+43	+ 1	+33	+ 1	+85	+ 2	+32	-10
+37	+ 1	+28	+ 0.5	+47	+ 1.5	+31	-10
+33	+ 1	+25	0	+42	+ 1	+28	-11
+26	+ 1	+25	- 1	+40	+ 0.5	+26	-11
+26	+ 1	+23	- 3	+40	0	+25	-13
+20	0	+21	- 4	+27	0	+22	-21
+19	0	+18	- 5	+25	0	+18	-26
+19	- 1.5	+16	- 6	+23	0	+17	
+16	- 2	+16	- 6	+21	- 1	+12	
+11	- 2	+15	- 7	+13	- 3	+ 8	
+10	- 5	+14	- 9	+ 9	- 3	+ 8	
+ 8	- 9	+ 8	-10	+ 8	- 6	+ 7	
+ 5	- 9	+ 4	-12	+ 8	- 6	+ 7	
+ 4	-11	+ 4	-12	+ 7	- 9	+ 3	
+ 3	-13	+ 4	-15	+ 5	-11	+ 2	
+ 2	-14	+ 3	-17.5	+ 4	-14	+ 1	
+ 2	-14	+ 2	-18	+ 3	-20	+ 0.5	
+ 2	-36	+ 2	-25	+ 3	-36	+ 0.5	
+ 2		+ 1	-27	+ 2	-51	- 6	
+ 2		+ 1		+ 2		- 8	
+ 1		+ 1		+ 2		- 9	
§ = +12, * = +2		§ = +14.5, * = +1		§ = +11, * = +2		§ = 17.5, * = + 2.5	
★ = -2, QD = 7		★ = -6.5, QD = 10.5		★ = -2, QD = 6.5		★ = 9.5, QD = 13.5	

Table VII. The Distribution of Area Differences in Parts B and C

(§ = upper quartile, * = median, ★ = lower quartile, and QD = quartile deviation.)

Form tested	○ cm²			□	cm²
+69	+10	+ 0.5	-15	+68	+ 3.5
+59	+10	+ 0.5	-19	+58	+ 3
+42	+ 9	+ 0.5	-22	+57	+ 2
+41	+ 8	+ 0.5	-23	+39	+ 1
+48	+ 5	+ 0.5	-25	+37	+ 1
+37	+ 4.5	+ 0.5	-26	+36	+ 1
+37	+ 4	0	-34	+34	+ 1
+34	+ 3.5	- 1	-57	+23	+ 0.5
+33.5	+ 3	- 1	-58	+22	+ 0.5
+29	+ 3	- 2		+20	+ 0.5
+24	+ 3	- 2		+19	0
+22	+ 2	- 2		+19	0
+21	+ 2	- 3		+17	0
+18	+ 1.5	- 3.5		+ 8	- 0.5
+18	+ 1.5	- 4		+ 6	- 0.5
+15	+ 1.5	- 4		+ 6	- 0.5
+15	+ 1	- 6		+ 6	- 0.5
+15	+ 1	- 6		+ 4	- 0.5
+15	+ 1	- 7.5		+ 4	- 1
+14	+ 1	- 8		+ 4	- 1
+12	+ 1	-12		+ 4	- 2
§ = +15, * = +1.5		★ = -4, QD = 9.5		§ = +4, * = 0.5	

Table VIII. The Distribution of Area Differences for

(§ = upper quartile, * = median, ★ = lower quartile, and

		△	cm^2		
- 2	-15	+58	+ 4	- 1	-19
- 3	-16	+57	+ 3	- 1	-20
- 3	-18	+34	+ 3	- 1	-21
- 4	-18	+26	+ 2	- 1	-22
- 4	-26	+26	+ 2	- 1.5	-24
- 4	-29	+25	+ 2	- 1.5	-33.5
- 4	-34	+16	+ 1	- 2	-34
- 4.5	-37	+15	+ 0.5	- 3	-36
- 5	-38	+15	+ 0.5	- 3	-37
- 6	-57	+12	+ 0.5	- 3	-37
- 6	-58	+11	0	- 3.5	-39
- 7	-69	+10	0	- 4	-41
- 9		+10	- 0.5	- 4	-42
- 9		+ 9	- 0.5	- 5	-59
-10		+ 7.5	- 0.5	- 6	-68
-10		+ 7	- 0.5	- 8	
-10		+ 6	- 0.5	-10	
-11		+ 6	- 0.5	-14	
-12		+ 5	- 0.5	-15	
-15		+ 4	- 1	-15	
-15		+ 4	- 1	-17	
★ = -9.5, QD = 6.75		§ = +14, * = -1		★ = -11, QD=12.5	

Combined Forms in Part A

QD = quartile deviation.)

Form tested	⬯ cm^2			□	cm^2
+43	+10	+ 1	- 9	+85	+ 8
+37	+ 8	+ 1	- 9	+47	+ 7
+33	+ 8	+ 1	-10	+42	+ 7
+33	+ 5	+ 1	-11	+40	+ 6
+28	+ 4	+ 1	-12	+40	+ 6
+26	+ 4	+ 0.5	-12	+27	+ 5
+26	+ 4	0	-13	+27	+ 5
+25	+ 4	0	-14	+25	+ 4
+25	+ 3	0	-14	+25	+ 4
+23	+ 3	- 1	-15	+23	+ 3
+21	+ 2	- 1.5	-17.5	+21	+ 3
+20	+ 2	- 2	-18	+18	+ 3
+19	+ 2	- 2	-25	+17.5	+ 2
+19	+ 2	- 3	-27	+15	+ 2
+18	+ 2	- 4	-36	+13	+ 2
+16	+ 2	- 5		+12	+ 2
+16	+ 2	- 5		+12	+ 1.5
+16	+ 1	- 6		+10	+ 1
+15	+ 1	- 6		+ 9	+ 1
+14	+ 1	- 7		+ 9	+ 0.5
+11	+ 1	- 9		+ 8	0
§ = +14, * = +1		★ = -5, QD = 9.5		§ = +8.5, * = +0.5	

Table IX. The Distribution of Area Differences for

(§ = upper quartile, * = median, ★ = lower quartile,

		△ cm^2			
0	- 9	+51	+ 1	- 2	-21
0	-11	+36	0	- 2	-23
0	-14	+36	0	- 2	-25
0	-14	+20	0	- 3	-26
- 0.5	-15	+14	0	- 3	-26
- 1	-16	+14	0	- 3	-27
- 1	-16	+14	0	- 4	-33
- 1	-18	+13	- 0.5	- 4	-37
- 1	-20	+11	- 1	- 5	-40
- 1	-21	+11	- 1	- 5	-40
- 2	-23	+ 9	- 1	- 7	-42
- 2	-25	+ 9	- 1	- 8	-43
- 3	-25	+ 9	- 1	- 8	-47
- 3	-28	+ 6	- 1	- 9	-85
- 3	-33	+ 6	- 1.5	-10	
- 4	-36	+ 5	- 2	-11	
- 4	-51	+ 3	- 2	-13	
- 4		+ 3	- 2	-16	
- 6		+ 2	- 2	-19	
- 6		+ 2	- 2	-19	
- 8		+ 1.5	- 2	-20	
★ = -5, QD = 6.75		§ = +2, * = -2		★ = -11, QD = 6.5	

Combined Forms in Part B

and QD = quartile deviation.)

lower quartiles were +1 and -5, +0.5 and -5, and -2 and -11. The quartile deviations were 9.5 (elipse), 6.75 (rectangle) and 6.5 (isosceles triangle).

DISCUSSION

Studies involving the ability to discriminate among various shapes have been performed by a number of investigators and have covered a large variety of species. Thus, Young (1958) reported discrimination between a compact form (circle) and an elongated form (rectangle) in *Octopus vulgaris* (Lamarck). Sutherland (1960), working with the same species, demonstrated discrimination between a square and an elongated rectangle. He also reported that the octopus can distinguish between an elongated rectangle and a diamond-shaped form. This animal also distinguishes a vertical from a horizontal rectangle (Sutherland, Mackintosh, and Mackintosh, 1963). Again, using this same species, Boycott (1965) determined that the ability existed to distinguish between the presence and absence of a square form in feeding situations. Typical examples taken from studies of vertebrate species are Dodwell (1957), who discovered that male hooded rats can distinguish a square from a circle and Rensch (1957) who reported elaborate discriminatory ability in the Indian elephant. Perhaps the discriminatory abilities of birds have received more attention than those of any comparable group of animals. Tinbergen's work with the

European robin (Turdus merula L.) is famous (Tinbergen, 1958). The least common denominator of all of these studies is the fact that conditioning is used as the criterion for ability to discriminate.

Studies of shape discrimination among fish are less numerous than those concerning birds and mammals, but significant examples exist. Thus, it has been demonstrated that the common goldfish, Carassius auratus, can distinguish between horizontal and vertical rectangles (Mackintosh and Sutherland, 1963). Hemingway and Mathews (1963) discovered that the Egyptian Mouth breeder, Tilapia macrocephala, is able to discriminate between a circle and a rectangle, a square and a rectangle, a circle and a triangle, and a triangle and a square. Once again, as was the case with the studies involving birds and mammals, all of these analyses of discrimination by fish were based upon criteria of conditioning.

There is a built-in disadvantage inherent in all discrimination studies based upon criteria of conditioning. This is the fact that, in the absence of suitable reinforcement, conditioning may not occur and thus ability to discriminate may not be made manifest. Thus, an animal may actually learn not to discriminate. Studies based upon the inherent behavior of all members of a species, or of all members of the same sex of that species are largely free from this defect when restricted to individuals naive to the particular experimental situation used. Thus, the experiments of Tinbergen with the 3-spined stickleback (*Gasterostelus oculeatus*) demonstrated the importance of certain semi-abstract characteristics of form to successful mating. Braddock, Braddock, and Kowalk (1960) employed differential nesting activity of *Betta splendens* under circular forms of a varying size as a criterion of size discrimination, and Braddock, Braddock, and Richter (1961) adapted this method to the first such studies of shape preference in the same species. It is important to note that studies of discrimination based upon instinctive behavior are not certain indicators of discriminatory ability under all circumstances. Under circumstances where choice plays no role in the ecology of the species, the animals may be able to discriminate but may not indicate this in terms of preference for a particular choice offered them.

This particular study is primarily an attempt to determine whether *B. splendens* discriminates among the compact forms: circle, square, and equilateral triangle. An attempt was also made to determine, if possible, what aspect or aspects of these forms were preferred. To a human observer the obvious differences among the forms are the roundness or absence of angles in the circle, the presence of 90° angles in the square, and the presence of more acute angles (60°) in the equilateral triangle. It was postulated that if the presence or absence and acuteness of angles was the basis for preference and hence discrimination, similar preferences should exist among the elongated forms: elipse, rectangle, and isosceles triangle. The fish should also be able to discriminate between a right triangle and an isosceles triangle.

It was found that male _B_. _splendens_ were able to discriminate between a circle and an equilateral triangle at significant levels but indicated no preference for a circle paired with a square, nor between a similar pairing of a square with a triangle. Among the elongated forms significant discrimination was found between elipse and isosceles triangle and between a rectangle and an isosceles triangle, although no preference was shown for either shape when an elipse was paired with a rectangle.

It thus seems probable that the fish either are not able to discriminate or have no preference under the conditions of these experiments for "roundness" or the presence of 90° angles, as presented in the circle versus square, elipse versus rectangle combinations. A similar situation exists also between equilateral triangle and square pairings. It should be noted that the difference between the smallest angle of the triangle (60°) and the largest angle of the square (90°) is only 30°. On the other hand this angular difference (54° 30') is much greater between an isosceles triangle (smallest angle 35° 30') paired with a rectangle (largest angle 90°). Since in all cases where preferences were demonstrated, they involved absence of angles or the less acute angles, it seems probable that the fish discriminate against acuteness of angles. They exhibit such preference, however, only when there is a sufficient minimum difference in the size of the angles. Thus, it is suggested that discrimination between angles is on the basis of relative size. Childs (1963) found that size discrimination of circular discs in _B_. _splendens_ was made on a relative basis such as this.

The fish failed to show preference when a right triangle was paired with an isosceles triangle. In this particular instance the most acute angle of the right triangle had a value of 32° 40', while that of the isosceles triangle was 35° 40'. If, as has been previously postulated, the quality of acuteness of angle is the basis for preference, this result is consistent with the rest of the observations reported here. Thus, if a right triangle with two 45^{o} angles had been used, it is possible that it would have been preferred over the isosceles triangle actually used.

When the pooled data are reviewed, one notes significant preferences for the circle and the elipse and discrimination against the isosceles triangle. Thus further supports the hypothesis that the basis of discrimination is the degree of acuteness of the angles of the forms used. While the equilateral triangle was neither preferred nor discriminated against, the confidence level was only 8.8%. It is suggested that a larger sample might add this shape to the list of those discriminated against.

Further work is required to determine whether or not limits exist above and below which the degree of acuteness of angle cannot be discriminated. It is postulated here that the upper limit may be close to 90^{o} since this was not differentiated from an absence of angles as in those instances where a circle was paired with a square and an elipse with an elongated rectangle. Nothing in these data suggests the lower limit except that it must lie at or below 32^{o} 40', the most acute angle involved in any of the forms used.

The preference for compact, rather than elongated, shapes as revealed in this study can well have adaptive significance in the nesting situation. A bubble nest is easily disrupted by water movements, and this is much more likely to occur when a nest is deposited under a long narrow leaf than if it is built under a broad one.

SUMMARY

1. Male Siamese Fighting Fish were presented with pair combinations of floating plastic forms under which they could construct bubble nests. The actual combinations tested were: circle-equilateral triangle, circle-square, square-equilateral triangle, elipse-isosceles triangle, elipse-elongated rectangle, elongated rectangle-isosceles triangle, and right triangle-isosceles triangle. Preference, and thus ability to discriminate, was indicated when larger nests were consistently placed under one form in a pair combination.

2. The fish were able to discriminate between a circle and a triangle, but did not discriminate between a circle and a square, or between a square and a triangle. They also discriminated between an elipse and an isosceles triangle and between a rectangle and an isosceles triangle. They did not discriminate between an elipse and a rectangle nor between a right triangle and an isosceles triangle.

3. The data were pooled to indicate whether any of the shapes offered were preferred or discriminated against, and significant preferences were shown for the circle and the elipse. The isosceles triangle was discriminated against, and some discrimination was also found against an equilateral

triangle. No preference for or against was indicated with regard to the square and the rectangle.

5. It is suggested that the fish may discriminate on the basis of "roundness" or the presence or absence of acute angles.

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