OPERANT DISCRIMINATION REVERSALS: COMPARATIVE DATA

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Speed of "problem solving" and the rate of development of a single discrimination have generally been unsatisfactory dependent variables in comparative studies of learning, primarily because any obtained differences might possibly be attributed to artifacts such as differences in sensory capacity or response repertoires. Progressive changes in the rate of development of a discriminative response over extended series of S^D and S^A manipulations, on the other hand, are extremely useful in inter-species studies of what Harlow (1949) has labeled "the formation of learning sets." Successive discrimination problems, discrimination reversals, and successive acquisitions and extinctions have provided data of this sort. Under all three of these procedures, subjects show a progressive decline in the number, percentage, or rate of unreinforced responses. Species differences have been reported in the rate at which unreinforced responses decline under these conditions, although the same general trends have typically appeared.

Wodinsky and Bitterman (1957) have tentatively identified species differences during reversal learning in fish and rats, the same species used in the present study. Although these investigators are unwilling to conclude that their data have unequivocally isolated a species difference, the present findings are in agreement with theirs.

Most of the "learning set" studies, and related experiments dealing with discrimination reversals and successive acquisitions and extinctions, have made use of discrete trials and simultaneous presentations of S^D and S^A . This report is based on a comparative study of discrimination reversals in the fish and the rat in a free-operant procedure using successive presentation of S^D and S^A conditions.

METHOD

Subjects

The subjects were one mature, male African mouthbreeder (*Tilapia macrocephala*), about 4 inches long, and a male albino rat, Sprague-Dawley strain, about 120 days old. The fish was maintained on a 23-hour, food-deprivation schedule, and the rat on a 23-hour, water-deprivation schedule. Both subjects had completed a series of successive acquisitions and extinctions on the day prior to the first day of discrimination training (reported in Deterline 1957, 1960).

Apparatus

The fish apparatus has been described previously (Deterline, 1956). A wooden platform, with a food magazine mounted on its top surface, fit snugly over the standard 5-gallon fish tank that housed the subject. A lever-arm was suspended down into the tank to a point approximately 1 inch below the surface of the water. The fish activated the food magazine by moving horizontally against the wedge-shaped target on the end of the lever-arm. The food magazine dropped powdered food onto the surface of the water inside a floating glass ring

¹The fish data were collected at the University of Pittsburgh, and are reported in Deterline (1957). The rat data were collected at Alma College.

that was fastened to one end of the tank. The distance from the target to the ring was approximately 2 inches. Each response to the lever activated the stepper of a cumulative recorder, and each operation of the food magazine produced a diagonal pip below the cumulative curve. The closing of the food-magazine solenoid produced a vibratory S^D for the food-approach response.

A DRL programmer with a 30-second nonresponse criterion controlled the magazine circuit and two sources of illumination. The two discriminative stimuli were a bright light (169 foot-candles at the surface of the water) and a dim light (2.4 foot-candles).

The rat apparatus was a 9.125-inch-by 8.625-inch-by 8-inch lever box (Scientific Prototype Co., Model 101), with water reinforcement provided by a syringe pump (Lon R. Davis Model LR-130). The stainless-steel lever required a movement of 5 millimeters to operate the control circuits. Two illumination levels (provided by either a shielded 3-watt bulb or an unshielded 6-watt bulb) were used in the rat apparatus. A relay mounted in parallel with the water reinforcer provided the S^D for the cup-approach response. A DRL programmer, identical in function to that used with the fish, was added to the circuitry. A cumulative recorder produced equivalent data for the rat.

The DRL programmer presented the S^D illumination until a single response was made. Food reinforcement was given and the programmer reset to the beginning of its 30-second cycle. The resetting of the programmer also changed the illumination from S^D to S^A . Each S^A response reset the programmer, and S^D was withheld until the 30-second criterion of nonresponding had been met. The discrimination was reversed simply by reversing the illumination relationships to S^D and S^A conditions.

Procedure

Both subjects had completed a series of 15 days of successive acquisitions and extinctions prior to the first day of discrimination learning. The first discrimination consisted of five 1-hour experimental sessions 24 hours apart. During the first discrimination the brighter light was the S^D and the dimmer light the S^A . The first reversal consisted of three daily sessions, and each of the four subsequent reversals covered two daily periods. Each experimental session began with the S^D present, and the 1-hour period began with the first response.

RESULTS

Both of the subjects, to some extent, showed the usual pattern of reversal learning. The typical reversal data show negative transfer *between* reversals, with improvement *within* reversals and over the entire series. Figure 1 shows that the fish was still showing a decline in number of S^A responses on the fifth reversal, while the rat had apparently reached its maximum efficiency by the end of the first reversal. The use of a response criterion during each S^A period would be expected to produce a high terminal level of reversal efficiency (Dufort, Guttman, & Kimble, 1954); but the difference between the subjects in rate of approaching this terminal level was quite striking. The fish and rat also differed in relative amounts of negative transfer on the first reversal, with the rat making about the same number of S^A responses as it had on the third day of the original discrimination. The fish, however, made over 300% more S^A responses on the first day of the first reversal than it had made during any one of the original discrimination sessions. Even on the first day of the fifth reversal, the

Figure 1. Operant discrimination reversals. The circles indicate the number of S^A responses; and the crosses, the number of S^D responses. The upper portion of the figure represents the fish data, and the lower portion summarizes the performance of the rat. Each series of connected points represents the same S^D - S^A relationship, and each gap between points indicates a reversal of the stimulus relationship to reinforcement.

fish was responding during S^A about as frequently as it had on the first 2 days of the original discrimination.²

The same differences may be seen in another form in the cumulative curves for both subjects (Fig. 2 and 3). The curves for the rat, except for the original discrimination and the first day of the first reversal, are essentially parallel, with only ephemeral local effects appearing during the first 5 or 10 minutes of each daily curve. The curves for the fish are not parallel, although the trend in that direction is apparent.

The use of the 30-second criterion of nonresponding during each S^A period prevented any S^A response from being followed immediately by the S^D and a reinforced response. This permitted another stimulus component, the illumination *change*, to gain considerable stimulus

²The first point on each of the graphs in Fig. 1 does not actually represent the performance of these two subjects, but represents the average performance under similar conditions for other subjects of the same species. This substitution was made necessary by the temporary rate suppression shown by these two subjects on the first day of discrimination, a suppression that resulted from the previous experience with successive acquisitions and extinctions. The substitute points were added here only to indicate the general form of the original discrimination curve. For this same reason the cumulative curve for the first day of the original discrimination does not appear in either Fig. 2 or Fig. 3.

Figure 2. Cumulative curves from which the Fig. 1 summary of the fish data was taken. The horizontal time dimension covers a 1-hour period.

control over the response. The relative absence of negative transfer on the later reversals for the rat suggested that the change, regardless of its direction, had replaced any absolute-intensity characteristics as the functional S^D . During S^A periods, absence of change had always immediately preceded any unreinforced responses that occurred, while low-latency responses to the light S^D were also low-latency responses to the change itself.

To test the effectiveness of illumination change as the functional S^D , a third light, intermediate in intensity to the other two, was added to the apparatus. The three lights were operated manually by E rather than by the programmer, in the order of presentation shown in Table 1. Light 1, the brightest of the three, was turned on first, with the programmer (which still controlled the reinforcer circuit and the 30-second S^A criterion) set at S^D . When the first response was made and reinforced, Light 1 was turned off and Light 2 turned on. At the end of the S^A period, 2 was turned off and 3 was turned on until one response was

made and reinforced, and so on. Each of these illumination changes was correlated with the change in conditions controlled by the programmer. Each stimulus was presented twice in each series of six illumination changes, once as S^D and once as S^A . In this way, no intensity was consistently correlated with either the S^D or S^A conditions. Figure 4 shows the cumulative curve produced by the subject. Here, the change, rather than the absolute intensities, was an effective S^D . The subject left the lever area after about 50 minutes and did not return during the remainder of the hour. It should be noted that responding could not have been based on a time discrimination because the S^A period was lengthened by each S^A response, and because the programmer had a built-in reset error that occasionally—about one reset in 12—terminated the S^A period in less than 30 seconds.

DISCUSSION

The form of the curves (Fig. 1) reported here are typical of data collected on other subjects of the same species, and the course of reversal learning suggests a real species difference, although this difference cannot be identified as being qualitative rather than quantitative. The rat apparently was responding to the illumination change, independent of direction of change, by the end of the first reversal, while the absolute intensities continued to control the response of the fish through the fifth reversal. The fish had been discarded before the rat

Figure 3. Cumulative curves from which the Fig. 1 summary of the rat data was taken. The horizontal time dimension covers a 1-hour period.

Table 1

Order of presentation of illumination intensities and relationships to S^D and S^A conditions. Each S^A period had a nonresponse criterion of 30 seconds. Upon completion of the series shown in the table, the entire cycle was begun again. Light 1 was the most intense, Light 3 was the least intense, and Light 2 was intermediate in intensity.

<i>Illumination</i>	<i>Condition</i>	<i>Illumination</i>	<i>Condition</i>
1	S^D	1	S^D
2	S^A	3	S^A
3	S^D	2	S^D
1	S^A	1	S^A
2	S^D	3	S^D
3	S^A	2	S^A
2	S^D	3	S^D
1	S^A	1	S^A
3	S^D	2	S^D
2	S^A	3	S^A
1	S^D	1	S^D
3	S^A	2	S^A

data were collected, so that reversals in the fish could not be continued to asymptote, nor could change discrimination be tested using the multiple-stimulus procedure.

The notion that a modification in the functional S^D occurs during successive discriminations or discrimination reversals is the basis for Restle's (1958) analysis of learning sets, and these data support that view. Of course, the ability of the rat to respond efficiently to stimulus changes (Fig. 4) cannot be called either a necessary or sufficient condition to produce the type of reversal curve produced by the rat (Fig. 1).

The behavior of the fish during S^A periods should have facilitated the development of the illumination change as a powerful S^D . After consuming the reinforcement presented for the response to S^D , the fish moved directly to the target and remained motionless, except for positioning movements of the pectoral fins, a fraction of an inch from the target. The change to S^D was followed by a response, usually with a latency of less than 1 second. Additional data, over more reversals, should be collected for the fish, and the operant-discrimination reversal procedure should be more systematically investigated with a wider range of subjects. The relationship between simultaneous and successive presentations of S^D and S^A is far from clear in the discrete trials procedure, and the use of a free-operant procedure might shed light on that problem.

Figure 4. Cumulative curve representing discriminative responding under conditions of inconsistent stimulus pairings with reinforcement. Three illumination intensities were used as discriminative stimuli.

SUMMARY

Both a fish and a rat, given a series of five operant-discrimination reversals, showed a progressive decline in the number of S^A responses on successive reversals. The rat reached its maximum level of efficiency by the third reversal, while the fish showed a much more gradual change which was not yet complete by the fifth reversal. The rat was shown to have been responding effectively to the stimulus change, independently of the absolute intensity of the change.

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