DISCRIMINATIVE RESPONDING ON ASSOCIATED MIXED AND MULTIPLE SCHEDULES AS A FUNCTION OF FOOD AND ICS REINFORCEMENT¹

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Performance on associated mixed and multiple variable-interval-extinction schedules was studied as a function of food *versus* intracranial stimulation (ICS) reinforcement. For the mixed schedule, differential responding was greater for an ICS reinforcement group than for a food reinforcement group, demonstrating that conditions affecting resistance to extinction help to determine the control exerted by a mixed schedule. Performance on the multiple schedule demonstrated greater differential responding for an ICS group than for a food reinforcement group during the early training sessions, indicating that the control exerted by mixed schedules interacts with that exerted by the exteroceptive discriminative stimuli. The results suggest that the influence of the associated mixed schedule on discriminative responding would be greater, the greater the difficulty of the stimulus discrimination.

A multiple schedule of reinforcement involves alternating two or more exteroceptive stimuli, each associated with a particular schedule of reinforcement. An operant discrimination is a special subclass of multiple schedules, in that one of several reinforcement schedules may be used in the presence of the positive stimulus (S^D), while extinction prevails in the presence of the negative (S^Δ) stimulus.

A mixed schedule of reinforcement similarly involves alternating two or more schedules of reinforcement, but without any exteroceptive stimuli associated with these schedules. It should be apparent, then, that an operant discrimination involves the superimposition of exteroceptive stimuli on the associated mixed schedule of reinforcement determined by the particular schedules of reinforcement chosen for a given study.

However, very little attention has been di-

rected toward the control of differential responding by mixed schedules of reinforcement, or to the possible interaction of such control with that exerted by scheduled exteroceptive stimuli. A number of studies have shown that mixed schedules can control substantial levels of differential responding (Perkins and Cacioppo, 1950; Bullock and Smith, 1953; Weissman, 1960; Bullock, 1960). These studies found that rate of responding during extinction decreased progressively with repeated exposure to the extinction component, and that the rate of elimination of extinction responding differed as a function of the particular schedule of reinforcement employed in the positive component. Thus, greater amounts of differential responding were evidenced with 100% reinforcement than with 50%, and with fixed-ratio (FR) schedules as compared to fixed-interval (FI) schedules.

These studies suggest the possibility of locating mixed schedules along some dimension of difficulty of discrimination, with schedules of reinforcement producing the least amount of differential responding considered to be the more difficult discriminations. These studies further suggest that one of the major determinants of the difficulty of a mixed schedule may be the resistance to extinction engendered by the reinforcement conditions employed, so that conditions producing less resistance to extinction will result in greater amounts of differential responding.

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A few studies have investigated discrimination acquisition as a function of the reinforcement schedule employed in the positive component of the multiple schedule. Haber and Kalish (1963) found more rapid discrimination learning the smaller the mean interval of a series of variable-interval (VI) schedules. Hegge (1964) studied discrimination acquisition as a function of having either a VI 1-min or an FI 55-sec schedule in the presence of the positive stimulus. His results indicated more rapid acquisition of the discrimination during the initial sessions for the FI group. In addition, the major difference between the two groups was in the rate of S^A responding.

These results suggest that the control over differential responding by the exteroceptive stimuli interacted with the control exerted by the associated mixed schedules of reinforcement. That is, for an identical stimulus discrimination, the differences in differential responding may have been due to differences in the difficulty of the mixed schedules employed. Furthermore, it is possible that the relative difficulty of these mixed schedules was a function of the resistance to extinction produced by the schedules of reinforcement used. It seems reasonable to assume that smaller VI schedules will result in less resistance to extinction, as will an FI schedule when compared to an equivalent VI schedule.

The present study attempted to determine directly whether or not conditions involving known differences in resistance to extinction result in differential performance on a mixed schedule of reinforcement. In addition, the present study attempted to determine whether or not, or to what extent, performance on a given stimulus discrimination will be a function of the difficulty of the associated mixed schedule of reinforcement.

Unfortunately, very little information exists regarding the relative resistance to extinction afforded by the more generally used schedules of reinforcement. The present study approached this problem, not by varying the schedule of reinforcement, but by comparing performance on multiple and mixed schedules of reinforcement as a function of reinforcement by food and by intracranial stimulation (ICS). One of the best established facts about the conventional administration of ICS reinforcement is the very little resistance to extinction it affords as compared to food rein-

forcement (Seward, Uyeda, and Olds, 1959; Herberg, 1963; Culbertson, Kling, and Berkley, 1966). Utilizing differences in resistance to extinction based on differences in the type of reinforcement employed, it is possible to study mixed schedules that are identical in terms of reinforcement density, response-reinforcement contingencies, and the temporal alternation of reinforcement and non-reinforcement conditions. In addition, by superimposing an identical stimulus discrimination on identical mixed schedules, differing only in terms of the resistance to extinction afforded by the nature of the reinforcing stimuli, the effects of these schedules on discriminative responding can be compared more directly.

EXPERIMENT I

To compare food and ICS reinforcement adequately, the effect of ICS intensity on differential responding must be examined. The available literature with separate group designs indicates that amount of food reinforcement does not affect discriminative behavior (see Pubols, 1960). However, were ICS intensity an important determinant of discriminative behavior, the specific intensity given each animal would have to be carefully controlled. In addition, food and ICS intensity would have to be equated along some dimension of magnitude of reinforcement in order to compare the two legitimately. Thus, the present experiment was designed to determine whether or not differences in intensity of ICS do in fact affect differential responding.

An additional consideration involves the question of the relative independence of response rates in the presence of the discriminanda during the formation of a discrimination. It is well established that, up to some maximal value, increases in ICS intensity result in higher rates of response (Reynolds, 1958; Keesey, 1962). It is thus reasonable to assume that higher response rates would be evidenced in the presence of the S^D the higher the intensity of ICS reinforcement. Were rate during S^A independent of the rate during S^D , then higher intensities of ICS would result in greater differential responding.

In an attempt to separate the possible effects of response rate during S^D from those of ICS intensity *per se*, the present study utilized the differences that exist in the rate-intensity func-

tions of individual animals. Because of the wide differences in rates evidenced by animals at different intensities, it is possible to obtain similar rates at nominally high and low intensities for different animals. Thus, high and low ICS intensity can be compared while controlling for rate of response. In addition, at both high and low intensities, the subjects can be partitioned into a group that responds at lower rates and a group that responds at higher rates. It is thus possible to examine differential responding as a function of response rate during SP, while controlling for intensity of reinforcement.

METHOD

Subjects

Sixteen naive male albino rats of the Charles River COBS strain, weighing from 330 to 470 g at the time of electrode implantation, were used. A stainless steel bipolar electrode, insulated except at the tip and constructed of wire 0.010 in. (0.025 mm) in diameter (Plastic Products Company), was chronically implanted in each animal with the aid of a stereotaxis. Using level-skull coordinates, the electrodes were positioned 3.25 mm posterior to bregma, 0.75 mm lateral to the midline, and 9.00 mm below the surface of the skull. The animals were given at least seven days to recover from the operation before the start of experimentation; they had free access to food and water throughout the experiment.

Apparatus

The experimental enclosures consisted of two identical Scientific Prototype Rat Chambers, modified to a height of 21 in. (53.4 cm) and mounted in refrigerator shells for purposes of sound attenuation. Each chamber was equipped with a Scientific Prototype Rat Lever, a food magazine, and a Physiological Electronics pellet dispenser. In addition, each enclosure contained a speaker, a blower, and a mercury filled swivel that prevented twisting of the electrode leads. Electrical connections were made from the rear of each enclosure to the control apparatus located in an adjacent room.

The scheduling and recording apparatus consisted of tape programmers, time-delay relays, Gerbrands cumulative recorders, and associated counters, switches, timers, and relays.

Click-rate stimuli were provided by a Foringer Model 1293 Click Generator.³

Electrical brain stimulation was obtained via an isolation transformer, a Powerstat autotransformer, and a variable resistor. The 60-Hz sine wave stimulation was delivered to the animal via a network of time-delay and switching relays. Train duration was held constant at 0.5 sec. Current levels were monitored by a Tektronix Model 504 oscilloscope across a fixed resistor in series with the animal. All connections of the animal's chamber with earth ground were eliminated to prevent possible shunting of potentials to ground through the rat.

Procedure

Bar training. Each animal's bar press was shaped with low to moderate levels of ICS (60 to 140 μ A) and was allowed to produce 1000 stimulations on a continuous reinforcement schedule (CRF). Those animals that failed to learn to bar press, or that showed highly disruptive motor effects, were discarded. Positive stimulus (18.3 clicks per second) was present at all times for bar training, VI training, and rate-intensity tests.

Variable-interval training. Each animal was given 2 hr of training on a VI 15-sec schedule of reinforcement, and 6 hr of training on VI 30-sec. The VI 30-sec schedule remained in effect for the remainder of the experiment.

Rate-intensity functions. Three to five functions were obtained for each animal until successive day-to-day changes in the shape of the functions were minimal. The functions were obtained by increasing the voltage every 10 min in 2-v steps, from 2 v to 20 v. Response rate in each 10-min period was plotted as a function of the peak-to-peak current, in microamperes, obtained at each voltage level.

³In an attempt to specify the intensities of the click-rate stimuli, a General Radio sound-level meter (Model 1551-B) was connected to the input of a Tektronix Model 504 oscilloscope. The microphone was placed at the rat's ear position in the experimental chamber and was connected to the meter via a 25-ft cable. With the sound-level meter set at the 80-db range, on the "C" weighting scale, the meter output resulted in a 4-v deflection at the leading edge of each click pulse. This intensity measurement was identical for both click-rate stimuli employed in the experiment. The background noise level in the experimental chambers, including the sound of the blower, was approximately 75 db, as measured on the "C" weighting scale.

for each of the four groups. In addition, Table 1 presents the mean response rates for the four main conditions of the experiment, demonstrating the similarity in overall response rates for the Low-Intensity and High-Intensity conditions, and the difference in response rates for the Low-Rate and the High-Rate conditions.

Figure 2 presents the mean discrimination index (DI) per session, the mean rate of response during S^A per session, and the mean rate of response during S^D per session for the four groups in the experiment. Figure 3 presents the data for a representative individual animal from each of these four groups. The discrimination index was calculated by dividing the response rate during S^D by the summed response rates during S^D plus S^A . This index represents the weighted proportion of the total responses emitted in the presence of S^D . An index of 0.50 represents equal rates of response in both components of the multiple schedule, and an index of 1.00 indicates that all responses were emitted in the presence of S^D .

The DI functions in the left-hand panels of Fig. 2 and 3 reveal a very rapid acquisition of the discrimination. The mean DIs for all four groups are above chance levels of differential responding during the first 2-hr session, and begin to approach asymptote by the fifth session. There are no large, systematic differences in the discrimination acquisition functions or in the degree of differential responding for the four groups.

The response rates during S^A for the four groups are presented in the middle panels of Fig. 2 and 3. The response rates for the two High-Rate groups begin at a higher level and approach a higher asymptote than those for the two Low-Rate groups. There is no appreciable difference between the Low- and High-Intensity groups for the Low-Rate condition; for the High-Rate condition, the curve for the Low-Intensity group is slightly above that for the High-Intensity group.

The curves showing the rate of response during S^D , in the right-hand panels of Fig. 2 and 3, indicate the differences in response rates between the two Low-Rate groups and the two High-Rate groups, and indicate the extent to which the equating of rates for the Low-Intensity and High-Intensity conditions was successful. The response rates for the two

Low-Rate groups are more similar than those for the High-Rate groups, although in the latter case, as with response rates during S^A , it is the Low-Intensity group that has the somewhat higher rate.

The results of a Type III analysis of variance (Lindquist, 1953) performed on each of the three measures presented in Fig. 2 support and extend the above findings. There were no significant differences among the discrimination indices of the four groups for any of the main conditions of the experiment. There was a significant difference in the rate of responding during S^A between the Low-Rate and High-Rate conditions ($F = 14.49$, $df = \frac{1}{12}$, $p < 0.005$), but there was no statistical difference between S^A response rates for the Low-Intensity and High-Intensity conditions, nor any significant Rate $\times$ Intensity interaction. Similarly, there was a significant difference in the rate of responding during S^D between the Low-Rate and High-Rate conditions ($F = 31.82$, $df = \frac{1}{12}$, $p < 0.001$), but no significant differences between the Low-Intensity and High-Intensity conditions, and no significant interactions.

These findings indicate that rate of response during S^D does not affect acquisition of differential responding, as measured by the present discrimination index. For the range of response rates obtained, response rate during S^A is not independent of response rate during S^D ; groups emitting higher response rates during S^D emitted proportionately higher response rates during S^A .

The finding that there were no differences in DIs, response rates during S^A , or response rates during S^D between the Low-Intensity and High-Intensity conditions indicates that, for the present discriminative situation, intensity of ICS reinforcement was not a determinant of differential responding. These results are in accord with the general findings of traditional amount of reinforcement studies employing separate group designs, and in addition, support the recent findings of Keesey (1966) and Johnson (1966). In Keesey's study, which employed a discrete trial brightness discrimination, it was found that although running speed varied directly with intensity of ICS reinforcement, discriminative choice behavior was equivalent for all intensities studied.

Table 1 includes the verified electrode place-

Fig. 2. Mean discrimination indices, and rates of response during S^A and S^D, for the four groups in Exp. I.

Fig. 3. Discrimination indices, and rates of response during S^A and S^D, for an individual animal from each of the four groups in Exp. I.

ments for the individual animals in this study. The electrode locations are based on the coordinates given by Konig and Klippel (1963). The three dimensions represented are anterior-posterior ($A\mu$), medial-lateral (M-L), and dorso-ventral (D-V). In addition, the anatomical region closest to the site of the electrode tip is given for each animal.

EXPERIMENT II

The results of Exp. I do not preclude the possibility that, although variations in ICS intensity do not affect differential responding, food and ICS reinforcement are quantitatively and/or qualitatively different. If differences between the two reinforcers did exist, it is reasonable to assume that they would be reflected in both VI and S^D response rates. To control for the possibility of such differences, it is necessary to attempt to equate rates for food reinforced responses with ICS reinforced responses.

In addition, due to the importance of the known differences in resistance to extinction of the two present reinforcers, this experiment also focussed on the comparison of rates of response during S^A . Knowing from Exp. I that rate of response during S^A is affected by the rate of response during S^D , a failure to control S^D response rate for the two reinforcement conditions would confound the comparison of S^A response rates.

Since, with ICS reinforcement, both rate of response and intensity of stimulation can be varied over a wide range of values without affecting differential responding, it is possible, by manipulating response rate via intensity, to achieve response rates comparable to those evidenced by animals working for food. By determining VI 30-sec response rates for a group whose responses are reinforced with food at the same time rate-intensity functions are being obtained for an ICS group, it is possible to compare response rates after equal exposure to the variable-interval reinforcement contingencies. It is then possible to find intensities of ICS that yield response rates that, on the average, are similar to response rates produced by food reinforcement. In this way, intensity of ICS, which is not a determinant of differential responding, is varied, similar rates of response can be approximated, and a comparison of discriminative

behavior may be achieved that is not confounded by the presence of large response-rate differences.

METHOD

Subjects

Sixteen naive male albino rats of the Charles River COBS strain, weighing 400 to 540 g at the time of electrode implantation, were reduced to 80% of their free-feeding body weights and maintained at this level throughout the experiment.

The implantation procedure, apparatus, and electrical brain stimulation were identical to that used in Exp. I.

Procedure

Bar training. Each animal's bar press was shaped with low to moderate levels of ICS (60 to 140 μA) and was allowed to produce 1000 stimulations on CRF. Animals that failed to learn to bar press, or that exhibited highly disruptive motor effects while responding, as well as animals for which ICS was positively reinforcing, were used as Food animals. All Food animals' bar presses were shaped with 45-mg Noyes pellets, and were allowed to produce 250 pellets on CRF. The 18.3 clicks per second positive stimulus (S^D) was present at all times during bar training, VI training, and the rate-intensity tests.

Variable-interval training. Each animal was given 2 hr of training on a VI 15-sec schedule of reinforcement, and 6 hr of training on VI 30-sec. The VI schedule was identical to that used in Exp. I and remained in effect throughout the experiment.

Rate-intensity functions. Each ICS animal was given three rate-intensity tests. The procedure for obtaining the rate-intensity functions was identical to that of Exp. I. In order to equate for total number of reinforcements and exposure to the VI contingencies, each Food animal was given a comparable amount of additional training on the VI schedule.

In an attempt to match response rates for the ICS and Food animals under both the multiple and mixed schedule conditions, the final VI rate for each Food animal was first determined. These animals were then randomly assigned to either the multiple schedule or mixed schedule group. On the basis of their rate-intensity functions, the ICS animals were assigned to the multiple or mixed schedule

group in such a way that a current level could be used that, on the average, would result in response rates comparable to those of the Food animals. Thus, four groups of four animals each were formed: multiple schedule with ICS reinforcement (Mult-ICS), multiple schedule with food reinforcement (Mult-Food), mixed schedule with ICS reinforcement (Mix-ICS), and mixed schedule with food reinforcement (Mix-Food).

Discrimination training. A. Multiple schedule: All animals were given twelve 2-hr sessions on the same multiple VI 30-sec extinction schedule used in Exp. I. Food animals received 45-mg Noyes pellets as reinforcers and ICS animals received a 0.5-sec train of electrical brain stimulation at the current levels chosen from the rate-intensity function. *B. Mixed schedule:* All animals were given twelve 2-hr sessions on a mixed 30-sec extinction schedule. This schedule was identical in all respects to the multiple schedule used in this experiment and in Exp. I, except that no differential click-rate stimuli were associated with the schedule components. A click-rate of 18.3 clicks per second was present at all times during mixed-schedule training. Responses were partitioned according to the same temporal intervals that obtained in the multiple schedule. That is, the reinforcement component was considered as S^D, the extinction component was considered S^A, and any differential

response rates in the two components were considered to represent a measure of discrimination.

RESULTS AND DISCUSSION

Table 2 presents the individual VI response rates, and for the ICS animals, the current levels chosen, for the various groups in the experiment. Table 2 also presents the mean rate of response for each of the four groups, indicating the degree to which response rates were matched for the multiple- and mixed-schedule conditions respectively.

The mean discrimination index, the mean rate of response during S^A, and the mean rate of response during S^D, are plotted as a function of sessions for each of the four groups in Fig. 4. Figure 5 presents the data for a representative individual animal from each of the groups.

Considering the two multiple-schedule groups first, the DI curves indicate a very rapid acquisition of the discrimination, similar in most respects to the four groups of Exp. I. The curve for the ICS group, however, is well above that for the Food group during the first few sessions, but approaches asymptote somewhat below the curve for the Food group. To determine whether or not these curves were statistically different, a trend analysis was employed (Lewis, 1960). This analysis revealed no significant difference in the overall means

Table 2

Response rates, current levels, and electrode placements for the individual animals in each of the four groups of Exp. II.

	ICS						FOOD	
	S	R/M	μA	A(μ)	M-L	D-V	Region	S R/M
MULTIPLE SCHEDULE	H1	29.0	100	4230	1.2	-3.2	lateral nucleus	H2 20.0
	H10	58.0	100	3750	0.6	-2.6	posterior nucleus	H5 21.0
	N11	44.0	240	3290	1.2	-3.2	medial prosencephalic fasciculus	H6 53.0
	N16	28.0	240	4230	0.6	-3.2	ventro-medial nuc.	I9 40.0
	Mean Rate-39.75 R/M							Mean Rate-33.50 R/M
MIXED SCHEDULE	S	R/M	μA	A(μ)	M-L	D-V	Region	S R/M
	H4	20.0	200	3990	0.6	-3.3	betw. dorso-medial and ventro-medial nuc.	H8 14.0
	H7	34.0	200	4230	0.7	-2.8	dorso-medial nucleus	H9 27.0
	N7	27.0	240	3750	0.9	-3.7	vental premamillary nucleus	N2 44.0
	N9	25.0	240	3990	0.8	-3.6	ventro-medial nucleus	N13 43.0
	Mean Rate-26.50 R/M							Mean Rate-32.00 R/M

Fig. 4. Mean discrimination indices, and rates of response during S^A and S^D , for the four groups in Exp. II.

Fig. 5. Discrimination indices, and rates of response during S^A and S^D , for an individual animal from each of the four groups in Exp. II.

of the two groups, but did indicate a difference in the slopes of the two curves ($F = 4.50$, $df = 11/66$, $p < 0.01$). This difference is primarily attributable to the differences in the DIs during the initial sessions, as t -tests indicated no difference for the last session, whereas the DIs for the first session were significantly different ($t = 3.57$, $df = 6$, $p < 0.05$).

The S^A curves for the two multiple-schedule groups in the middle panels of Fig. 4 and 5 reveal much the same differences as the DI curves. The ICS group emitted many fewer S^A responses during the first several sessions, although the two curves ultimately converge.

The rates of response during S^D for these two groups are presented in the right-hand panels of Fig. 4 and 5. The mean curves in Fig. 4 indicate that, although the Food group exhibited somewhat higher rates during the earlier sessions, the two curves are similar in the overall levels of response output. This demonstrates the efficacy of the rate-matching procedure based on the rate-intensity functions. Although the matched rates were not perfectly equated, the differences were small enough to result in relatively comparable mean rates of response. In addition, it is important to note that the differences in the mean DIs for the first session are solely attributable to the differences in responding during S^A , as the mean rates during S^D were identical for this session.

The DI curves for the two mixed-schedule groups are obviously quite different. The ICS group reveals a very rapid rate of acquisition and approaches asymptote by the third session. The Food group is well below the ICS group, starts at around chance levels of differential responding, and demonstrates a very gradual rate of acquisition without approaching asymptote by the end of the experiment. In addition, there is virtually no overlap in the ranges for the two groups.

The S^A curves in the middle panels of Fig. 4 and 5 indicate an even greater accentuation of the differences between the two mixed-schedule groups. The Food group emits three times as many S^A responses as the ICS group, at both the beginning and end of the experiment. The overall shapes of the two curves are analogous to those of the DI curves; the ICS group approaches asymptote rapidly, while the Food group demonstrates a very gradual elimination of S^A responses.

The S^D curves for the mixed-schedule groups indicate more than a twofold difference in response rates. This difference exists despite the fact that the degree to which matched response rates were approximated was similar to that obtained for the multiple-schedule groups. Thus, the small differences obtained in the matched rates for the mixed-schedule groups are not sufficient to account for the very large differences in response rate during S^D .

Rather, the low rates of response exhibited by the ICS animals appear to be determined by the distinctive pattern of responding engendered by the mixed schedule. Figure 6 presents portions of the cumulative records for the first and twelfth training sessions for a representative animal from each of the two mixed-schedule groups. Note that the pen is displaced downward during S^D , and the vertical pips indicate reinforcements. The record for the Food animal during the first session reveals a relatively high constant rate of response throughout both the S^D and S^A inter-

Fig. 6. Portions of the cumulative records from the first and twelfth sessions for representative animals from the Food and ICS mixed-schedule groups. The pen is displaced downward during S^D , and the pips indicate reinforcement.

vals, and consequently, very little differential responding. In contrast to this, the ICS animal exhibited lower response rates and a greater degree of differential responding. In general, the ICS animal responded only occasionally, until reinforcement occurred. At that point, the animal emitted a relatively high constant rate of responding until shortly after reinforcement was no longer forthcoming, and again began emitting occasional "testing responses". The response patterns during the early portions of the S^A intervals often resemble miniature extinction curves. This distinctive pattern of responding by the ICS animals accounts for both the relatively low rates evidenced during S^D , and the very low rates of response during S^A , as compared to the Food animals.

The cumulative records for the twelfth mixed-schedule session indicate that the Food animal is first beginning to demonstrate a pattern of responding similar to that of the ICS animal. Although the Food animal continues to emit a much higher overall level of responding, accounting for the higher rates during S^D , the rate during S^A decreases toward the end of each S^A interval, accounting for the gradual decrease in S^A response rates over sessions. The record for the ICS animal demonstrates the same general pattern as on the first session, except that the characteristic pattern of responding during S^A is even more accentuated.

Figure 7 presents portions of the cumulative records for the first and twelfth sessions for representative animals from the Food and ICS multiple-schedule groups. Note that the differences in the response patterns for the Food and ICS multiple-schedule animals in the first session are highly similar to the differences between the Food and ICS mixed-schedule animals. These records indicate that while rate during S^D is comparable for the two multiple-schedule groups, rate during S^A is not, resulting in the differences in DIs during the first few sessions shown in Fig. 4 and 5. The lower portion of Fig. 7 indicates the high degree of similarity in the pattern of responding, as well as the equivalent response rates during S^D and S^A , evidenced by both the Food and ICS animals by the end of training.

The present results demonstrate that performance on a mixed schedule of reinforcement is markedly affected by the reinforce-

ment conditions prevailing in the positive component. Although the differences in obtained response rates preclude any direct comparison of the magnitude of the differences in resistance to extinction for the two mixed-schedule groups, the differences in the discrimination indices demonstrate the greater amount of differential responding evidenced by the low resistance to extinction (ICS) group. Thus, the original assumption, that the control of differential responding, or the difficulty, of a mixed schedule is a function of resistance to extinction, is supported by the present results.

The superimposition of an identical stimulus discrimination on mixed schedules of unequal difficulty results initially in different rates of acquisition of differential responding. This finding supports the contention that the control over differential responding exerted by the mixed schedule interacts with the control exerted by the exteroceptive stimuli. The fact that, during the first several sessions, the differences between the Food and ICS multiple-schedule groups are highly similar to the differences between the Food and ICS mixed-

Fig. 7. Portions of the cumulative records from the first and twelfth sessions for representative animals from the Food and ICS multiple-schedule groups.

schedule groups, suggests that the multiple-schedule animals may initially be responding to some extent on the basis of the mixed-schedule cues, with the control by the exteroceptive stimuli superseding that by the mixed-schedule cues as training progresses.

The multiple and mixed schedules used in this study can be considered to differ in terms of exteroceptive stimulus difficulty. The multiple schedule was relatively easy, as evidenced by the very rapid rates of acquisition. The mixed schedule represents the opposite end of the continuum, in that the stimuli are identical. When viewed in this respect, the present results seem to indicate that the influence of cues associated with a mixed schedule on a stimulus discrimination would be greatest the greater the difficulty of the stimulus discrimination. Thus, on the mixed schedule, the differences between the Food and ICS groups were maximal; on the multiple schedule, the differences between the two groups were apparent initially, but then disappeared with continued training.

A few studies in the literature help to support this contention. Kling and Berkley (1968) compared discrimination learning for food-reinforced and ICS-reinforced animals in a situation similar in many respects to the present study. However, they used a proportionately larger $S^D - S^A$ click-rate difference, and found no differences between their two groups. Sherman, Hegge, and Pierrel (1964) trained animals to discriminate a 40-decibel auditory intensity difference, and varied the total amount of exposure to S^A while keeping S^D exposure constant. Presumably, the difference in the temporal lengths of the S^A intervals relative to those of the S^D intervals could serve as a differential mixed-schedule cue. These investigators found no differences between their various groups when DIs were plotted as a function of number of hours of exposure to S^A . However, Blue and Pierrel (personal communication) subsequently found that when animals were trained on a 10-decibel difference, large differences appeared between groups having longer S^A intervals and those having shorter S^A intervals, relative to the length of the S^D intervals. Finally, Jenkins (1965), who has also studied the effects of associated mixed schedules on discrimination learning, found that more difficult discriminations resulted in a greater predominance of

effects attributable to the mixed schedule, and that such effects appeared only early in training on an easy discrimination.

The present experiments have demonstrated that the difficulty of associated mixed schedules can be a major determinant of differential responding on multiple schedules of reinforcement, and indicate that what is often referred to as a "simple" discrimination is actually a case of complex, or compound, discriminative control.

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