Changes in response to S+ and S- during acquisition and overtraining of simultaneous discriminations in rats

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Two experiments with rats investigated learning about S+ and S- during various stages of discrimination training. Transfer tests, in which either S+ or S- was retained, or two new stimuli were presented, were used to assess learning early in acquisition, at criterion, or following overtraining. Both choice and latency measures were used. Results indicated that learning about S+ occurs early in acquisition when noncorrection training is given, and little improvement occurs after that time, at least up to 70 trials of overtraining under present conditions. Learning about S- begins somewhat later in acquisition and continues throughout overtraining. When correction training is used, learning about S- occurs earlier in acquisition, and further learning about both S+ and S- occurs during overtraining.

Most theories of simultaneous discrimination learning have been more concerned with the rate of discrimination between two stimuli than with possible differences in rate of learning about the two stimuli considered separately. In simultaneous discrimination experiments, the two stimuli to be differentiated are present on every trial. Relative choice of the two stimuli is measured, and the organism is said to have learned the discrimination when it consistently chooses the positive stimulus (S+) over the negative stimulus (S-). Some theories, such as Spence's (1936), make provision for differential growth of approach and avoidance tendencies, but the parameters have rarely been pursued in simultaneous discrimination designs. Sutherland and Mackintosh's theory (1971) places primary emphasis on the growth of attention to the dimensions comprising the stimuli and leaves unspecified rate of development of approach to positive values of those dimensions vs. avoidance of negative values. Some of the relevant literature is reviewed below.

Response to S+ and S- in Early Acquisition (Presolution Stage)

Some early studies with rats provide a small amount of conflicting data (Krechevsky, 1938; McCulloch & Pratt, 1934). In some of these studies it was shown that at least some early learning about reinforcement contingencies took place because acquisition was retarded when the contingencies were reversed. In other studies, no retardation was found. In either event, the reversal method used does not allow a determination of separate response tendencies to S+ and S-, since the

reinforcement values of both stimuli were changed at the same time. One set of studies reversed only one stimulus and combined it with a new stimulus (Lashley & Wade, 1946). Greater retardation in learning a discrimination was found when S- was made positive than when S+ was made negative. This result suggests earlier learning about S- than S+, since changing S- was more disruptive. However, the technique of changing a stimulus from positive to negative or vice versa may be unnecessarily complex. A simple technique would be to substitute a new stimulus either for S+ or S-, rather than reversing reinforcement values.

Response to S+ and S- at Criterion

Several studies have shown that when mastery of a discrimination has been reached, rats have learned something about both stimuli. For example, Mandler (1968) showed that when either S+ or S- was paired with a new stimulus in a transfer task, rats learned faster than when two new stimuli were presented. Transfer was faster when S- was retained than when S+ was retained, but the difference was not significant. Stevens and Fechter (1968) and Stevens and Schofield (Note 1) did find significantly faster learning when S- was retained. In an extension of the Lashley and Wade studies, Mackintosh (1965) included conditions in which either S+ or S- was compared with a new stimulus; the group in which S- was retained learned the transfer task faster. Thus, there is some indication that at mastery of a discrimination the tendency to avoid S- contributes more to transfer learning than does approach to S+.

Response to S+ and S- Following Overtraining

Mandler (1968) found that following overtraining on a simultaneous discrimination, transfer learning was

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faster when S+ was retained than when S- was retained. It was suggested that changes in orientation to and scanning of the stimuli occurred during overtraining, with more attention being paid to the positive stimulus. Another hypothesis which might account for reduced effectiveness of S- in mediating transfer learning was offered by D'Amato and Jagoda (1961). These investigators suggested that S- becomes less negative during overtraining due to the reduced exposure to S- during the extended run of choice of S+ that overtraining involves. Neither hypothesis was supported, however, in the Stevens and Schofield (Note 1) study, in which transfer learning following overtraining was faster when S- was retained than when S+ was retained.

Thus, there is a limited amount of somewhat inconsistent data concerning learning about S+ and S- during acquisition and overtraining on a discrimination. The experiments reported here investigated this problem by interrupting acquisition after different amounts of training and then giving transfer tests in which either S+ or S- was retained or two new stimuli were presented. Easily discriminable stimuli were used. Experiment I, using the noncorrection method of training, studied transfer at three points: one early in acquisition, one shortly before criterion was reached (1 day of 80% correct responding), and one following overtraining. Experiment II used the correction method of training and studied two points, one early in acquisition and one following overtraining. Some differences in learning under the two methods of training have been reported (Hooper, 1967). Mandler and Hooper (1967) suggested that orientation to S+ and S- may differ under the two training methods. Consequently, it might be expected that differential learning about the stimuli would occur. It was hoped that a comparison of the two methods might also shed light on the conflicting data from the various experiments just discussed, which used a variety of training methods.

Transfer tests require substituting a neutral stimulus for one of the previously trained stimuli. "Neutral" implies that generalization between either of the old stimuli and the new stimulus will be equal. One way to check that neutrality is to study the rate of acquisition of discrimination between the substituted stimulus and each of the other stimuli.

Stimuli were chosen on the basis of equal discriminability. After trying out a number of patterns, it was found that the stimuli best meeting an equal discriminability criterion were an all-black stimulus, an all-white stimulus, a horizontally striped stimulus consisting of equal amounts of black and white, and a vertically striped stimulus also consisting of equal amounts of black and white.

This stimulus set may seem surprising because the striped stimuli were composed of black and white. In terms of a dimensional analysis, they consisted of a relevant dimension of orientation combined with an

irrelevant brightness dimension. If rats analyze stimuli in terms of dimensions, one would assume that a black-white discrimination would be easier than, e.g., a black-stripe discrimination, because the stripe stimulus is 50% black and therefore closer in brightness to black than the all-white stimulus. Similarly, a horizontal-vertical stripe discrimination would be expected to be more difficult than a black-white discrimination since it includes an irrelevant dimension whereas the black and white stimuli contain only a single relevant dimension.

Although black-white discriminations tend to be slightly easier and horizontal-white discriminations slightly harder, these differences are small and insignificant. Since all combinations of these stimuli are learned in approximately the same number of trials, it appears that dimensional analysis at best is playing a minor role in mastering the discrimination task. This assertion does not imply that rats are incapable of dimensional analysis but only states that such analysis may not be carried out unless necessary. In this type of discrimination task in which easily discriminable stimuli are associated in a consistent way with differential reinforcement, fine analysis of the stimuli's composition probably is *not* necessary. This point has been made several times in the study of human learning, namely, that subjects do no more stimulus analysis than is necessary for the task and where possible tend to react to stimuli in a global, iconic fashion, rather than going through the more complex process of abstracting the attributes of the stimuli (e.g., Garner, 1974; Posner, 1973).

Transfer data also support this hypothesis. In two previous studies (Mandler, 1966; 1968), training on a vertical-horizontal stripe discrimination, in which the stripes were composed of black and white, had no deleterious effects on transfer to a black-white discrimination, even though such a shift involves transfer from an irrelevant to a relevant dimension. In fact, extremely rapid positive transfer occurred when the second task followed overtraining on the first. Similar results were obtained when black-white training was followed by the stripe discrimination; in this case, a previously relevant dimension becomes irrelevant.

Such data suggest that the stimuli are treated as separate discrete entities, and that little generalization occurs among them. If the stimuli have been subjected to dimensional analysis, such analysis seems not to determine performance in this situation. We stress this point because generalization is often an important factor in many kinds of animal research; however, it appears to be a minor factor with the stimuli, apparatus, and type of task used in the present experiments. Thus, the question of independent rates of learning about those stimuli can legitimately be asked and the stimulus substitution method can reasonably be used to answer that question. The phrase "learning about stimuli" is

used rather than "learning reinforcement contingencies associated with stimuli," because learning about reinforcement contingencies is itself a complex process, presumably including increased attention to the relevant stimuli (acquired distinctiveness).

EXPERIMENT I

Method

Apparatus

The apparatus was a semi-automated Y maze (described fully in Mandler, 1966) constructed of unpainted aluminum with a 60-cm stem and goalboxes located 30 cm from the choicepoint. The goalbox doors had Plexiglas fronts behind which could be placed 9 x 6 cm stimulus cards. Photocells at the startbox door, 3 cm before the end of the runway, 2.5 cm inside each arm of the Y, and microswitches on the goalbox doors registered elapsed times on electric timing clocks. Gray plastic doors were placed at the entrance of each arm and could be lowered by E to prevent retracing once an alley had been entered.

Subjects

Subjects were 72 naive male Long-Evans hooded rats from Rockland Animal Farms, varying in age from 120 to 160 days at the start of the experiment and ranging in weight from 270 to 340 g. Approximately 2 weeks prior to the experiment, each subject was placed on a 24-h deprivation schedule and reduced to and maintained at 80% of its log ad lib weight by a single daily controlled-amount feeding. Water was available in the home cages at all times. Subjects were run approximately 1 h before their feeding time.

Design

All subjects were first given training on acquisition of a simultaneous visual discrimination and then trained on a transfer task. A 3 by 3 design was used which varied (a) amount of training in acquisition, and (b) type of stimulus changed in the transfer task. Three levels of acquisition training were used: 30 trials, which meant that transfer occurred early in acquisition (Group E); attainment of an easy criterion of mastery consisting of 1 day of 80% correct responding, representing a moderate amount of training (Group M); and overtraining, consisting of 70 trials of training after a criterion of 2 successive days of 90% correct responding had been reached (Group O). Each of these three groups was divided into three subgroups, varying type of stimulus changed in the transfer task. In the *same S+* subgroups, *S+* was retained and *S-* was replaced by a novel stimulus. In the *same S-* subgroups, *S-* was retained and *S+* was replaced. In the *both new* subgroups, both stimuli were replaced by novel stimuli. Subjects were trained on the transfer task until they reached a criterion of 2 successive days of 90% correct responding.

Stimuli

Stimulus cards were painted in enamel and consisted of an all-black card (B), an all-white card (W), a horizontally striped card consisting of 10 mm black and white stripes (H), and a vertically striped card consisting of 10 mm black and white stripes (V). Each subject received one of four stimulus combinations in acquisition training: B vs. W, B vs. V, H vs. V, and H vs. W. Thus, if a subject was in a *same S+* subgroup, it might be trained on B+W- in acquisition and receive B+V- in the transfer task. These stimulus combinations were counterbalanced across groups so that each combination appeared equally often in each group for both acquisition and transfer. A summary of the stimulus combinations used is shown in Table 1.

Table 1
Stimulus Combinations Used in Acquisition and Transfer for Groups E, M, and O

Subject	Acquisition		Same S+		Same S-		Both New	
	+	-	+	-	+	-	+	-
1	B	W	B	V	H	W	H	V
2	W	B	W	H	V	B	V	H
3	B	V	B	W	H	V	H	W
4	V	B	V	H	W	B	W	H
5	H	V	H	W	B	V	B	W
6	V	H	V	B	W	H	W	B
7	H	W	H	V	B	W	B	V
8	W	H	W	B	V	H	V	B

As mentioned in the introduction, these stimuli were chosen on the basis of pilot work because they were approximately equally discriminable. In testing various stimuli, one type of difficulty was found. Rats nose open the stimulus doors at the bottom and characteristics of the bottom portions of the stimulus cards are more salient than those at the top. For example, in an H-W discrimination, when the bottom stripe is white, discrimination is retarded. Therefore, the H stimulus was inverted randomly from trial to trial so that sometimes the bottom stripe was white and sometimes black. This variation in presentation of the H stimulus averted problems of stimulus generalization in the transfer tests, but it did result in H-W discrimination problems becoming consistently, although nonsignificantly, more difficult than the other three combinations used, whether in initial acquisition or in transfer tests. Nevertheless, this stimulus set approximated the goal of equal discriminability better than any other. In the experiment proper, the assumption of equal discriminability was tested by comparing the various combinations of the stimuli in acquisition. For this test, trials and errors to criterion in uninterrupted acquisition were used (the O groups). Mean number of trials for B vs. W, B vs. V, H vs. V, and H vs. W were 66.7, 71.7, 83.3, and 91.7, respectively, $F(3,20) = 1.63$, $p > .10$. Mean number of errors were 21.2, 23.5, 25.7, and 33.2, $F(3,20) = 2.42$, $p > .05$.

As a check on the validity of these results, analyses were carried out on transfer scores to determine whether any stimulus-specific or dimensional generalization occurred. For example, it might be assumed that transfer from W+B- to W+H- is a relatively easy task since *S+* was the brighter stimulus in both cases. No differences on any analysis even approached significance. Further, as found in previous experiments, no differences were found between transfer from a brightness (B-W) discrimination to a stripe (H-V) discrimination (in which brightness became an irrelevant dimension) and transfer from the stripe discrimination to the brightness discrimination (in which a previously irrelevant dimension became relevant). Further, these transfer discriminations were no different than transfer from a stripe-brightness discrimination to another stripe-brightness discrimination (e.g., H-W to B-V).

We conclude from this pattern of results that the stimuli were independent as far as discrimination between them is concerned. That such independence is not always the case, even in simple discrimination learning, is shown by Mackintosh (1963) in which direct transfer between stripes and brightness was found in a jumping stand.

Procedures

Three to 4 days of familiarization training were given to accustom subjects to the working of the automatic goalbox doors. At first, the doors were left open and then they were gradually closed; no stimulus cards were used during this period.

Subjects were then assigned haphazardly to treatment groups.

Discrimination training consisted of 10 noncorrection trials per day. As soon as the subject entered an alley, the retrace door was dropped behind it. On incorrect trials, the goalbox door was locked, and the subject was retained in the arm of the Y for approximately 30 sec. On correct trials, the subject entered the goalbox and received three 97-mg Noyes pellets. Upon completion of a trial, the subject was removed to a holding cage. Intertrial interval was approximately 150 sec. Placement of the correct stimulus in the left or the right arm was determined by Gellermann orders.

To insure no overlap in amount learned during acquisition between Group E, trained for 30 trials, and Group M, trained until a criterion of 80% correct responding had been reached, any subject that reached the 80% criterion in 30 trials (including subjects in Group O) was removed from the experiment. Approximately 5% of the subjects in the experiment did meet this criterion and were replaced. Thus, all subjects in Group E made three or more errors on their last day of acquisition training (mean number of errors on Day 3 was 4.8).

Results

Choice Measures

Effects on acquisition of stimulus change at Trial 30.

Any effect of the stimulus change occurring at Trial 30 for Group E can be evaluated by comparing Group E's performance after the stimulus change with that of Group O, which was trained to criterion without interruption. Therefore, the first 30 trials of Group E's training were excluded from analysis and their transfer performance following the stimulus change was contrasted with Group O's acquisition data. If faster learning is found in the E groups following the stimulus change, the difference in trials and errors to criterion in comparison with the O group's uninterrupted acquisition scores provides an estimate of how much has been carried over from the first 30 trials. The relevant data are shown in the row labeled "E" and columns labeled "Acquisition" in the top panel of Table 2.

Analyses of variance comparing Group O and Group E showed superior performance for Group E on both errors to criterion, $F(1,42) = 8.12$, $p < .01$, and trials to

criterion, $F(1,42) = 6.00$, $p < .05$. Newman-Keuls tests showed that the three O groups, which had received identical treatment to this point, did not differ significantly from each other. Although all three Group E subgroups learned the discrimination faster than Group O, t tests comparing the three Group E subgroups to the mean of the overall sample of Group O's acquisition scores indicated that only the same S+ subgroup performed significantly better than Group O ($t = 2.71$, $p < .02$ for errors, and $t = 2.09$, $p < .05$ for trials). Thus, while there was some slight general facilitation due to the initial 30 trials, the data indicate that by the end of 30 trials, specific learning had occurred only about S+, not about S-.

Assessment of learning by transfer tests. The transfer data of Group E have already been discussed in terms of comparison to the uninterrupted acquisition of Group O. Assessment of learning at all three stages of acquisition was measured by comparing ability to transfer to a new task after different amounts of training. The top panel of Table 2 shows mean number of trials and errors to criterion on the three types of transfer task (retaining the same S+, retaining the same S-, or two new stimuli) for Groups E, M, and O (representing 30 trials of training, training to an easy criterion of mastery, and overtraining).

Analyses of variance on errors and trials to criterion showed that increasing amount of training was associated with better performance on the transfer tasks, $F(2,63) = 41.41$ and 24.74 , respectively, each $p < .001$. Individual comparisons among the means of Groups E, M, and O showed that the improvement was significant from E to M, and also from M to O. Thus, ability to use information acquired during training increased significantly from a point early in training through an easy criterion of mastery to overtraining.

There was also a significant interaction between amount of training and type of transfer task on the error measure, $F(4,63) = 3.27$, $p < .05$. (Analysis of trials to criterion is uninformative in this situation because of the

Table 2
Trials and Errors to Criterion for Group O in Acquisition and for All Groups on Transfer Tasks
in Experiments I and II and in the Mandler (1968) Experiment

	Trials						Errors				
	Acqui- sition	Group	Transfer Task				Acqui- sition	Transfer Task			
			Same S+	Same S-	Both New	Mean		Same S+	Same S-	Both New	Mean
Experiment I (Noncorrection)	78.3	E	56.3	73.8	62.5	64.2	25.9	15.4	23.5	18.4	19.1
		M	33.8	42.5	43.8	40.0		4.4	8.5	9.6	7.5
		O	31.3	22.5	35.0	29.6		4.9	1.0	6.0	4.0
Experiment II (Correction)	83.3	E	71.2	62.5	86.2	73.3	26.2	21.6	18.5	27.5	24.0
		O	23.8	23.8	35.0	27.5		1.5	2.0	6.0	3.2
Mandler, 1968 (Correction)	95.0	C*	65.0	55.0	72.5	64.2	29.7	11.9	8.9	19.8	13.5
		O*	23.8	37.5	55.0	38.8		2.2	4.8	11.5	6.2

*In the Mandler (1968) experiment, C refers to groups trained to a 2-day 90% correct criterion before transfer and O refers to groups given 150 trials of overtraining before transfer.

insensitivity of the 2-day criterion when learning is rapid.) Newman-Keuls tests showed that when transfer tasks were begun after only 30 trials of acquisition, retention of S+ resulted in better performance than retention of S- or two new stimuli, which did not differ significantly from each other. When transfer was begun following attainment of the 80% correct criterion, all three subgroups performed better than groups transferred at 30 trials, but they did not differ significantly from each other. When transfer occurred following 70 trials of overtraining, there was no further improvement in the *same S+* or *both new* subgroups, but the *same S-* subgroup was significantly better than either of those two subgroups and also better than Group M.

These results, graphed in Figure 1, indicate a progression in what is being learned about S+ and S- during various stages of acquisition. The *both new* curve shows an increase in learning rate, not associated with either stimulus, continuing throughout acquisition, but with the bulk of the improvement occurring by the time an 80% criterion has been reached (cf. Sperling, 1970). This improvement in performance represents what has been called "maze wiseness"; that is, subjects have eliminated some sources of error, such as not knowing where to look, and thus the period of random responding, which typically occurs at the beginning of acquisition in naive subjects, is considerably reduced. The *same S+* curve shows that specific learning about S+ occurs early in acquisition and levels off by the 80% criterion, showing no improvement after that point. The *same S-* curve suggests that no specific learning about S- occurs before the 80% criterion is reached but that significant further learning about S- occurs during overtraining. Comparison of slopes such as those presented in Figure 1 seems to be an informative way of assessing what has been learned at various stages of acquisition, but it should be noted that the exact shape of these curves can only be determined by studying transfer at more points in acquisition.

Latency Measures

Goal approach times (the time between entering an arm of the Y and touching a goalbox door) were recorded on every trial. These times were converted to $\log_{10}$ scores for purposes of analysis, and the first trial of every day (typically a highly variable score) was eliminated. Analysis of these latency scores can be used to determine whether the three E subgroups responded to the stimulus change that occurred at the end of 30 trials of acquisition. Latencies have been shown to be more sensitive than choice responses in measuring reaction to stimulus change (Mandler & Goldberg, 1973).

Change in log response times from Day 3 to Day 4 for the various groups is shown in the upper panel of

Figure 1. Mean number of errors in transfer as a function of amount of training in acquisition and type of stimulus change. The unfilled square represents mean number of errors in acquisition.

Figure 2. (The three 0 subgroups, which did not differ from each other in treatment at this point, have been combined.) An analysis of variance was carried out, comparing the effect of amount of training (E vs. 0) and subgroup (*same S+*, *same S-*, *both new*) on latencies on correct and incorrect trials over the 2 days. There was a significant interaction between amount of training, correct vs. incorrect trials, and days [$F(1,42) = 6.28$, $p < .05$]. Newman-Keuls tests on this interaction showed that Group 0 did not change speeds to S+ between Day 3 and Day 4 but slowed down significantly to S-. The point at which the S+ and S- curves separate can be considered the onset of discrimination, in the sense that S+ and S- are responded to differentially. That point had been reached by Day 4 in the OT groups [$F(1,42) = 25.83$, $p < .001$] even though percent correct choice on this day was only 60.4%.

Group E's latencies were quite different from those of Group 0 following the stimulus change. Group E slowed down significantly to S+ and overall were not significantly different in their speeds to S-. Further, there was no significant differentiation in speed to S+ and S- during this period. Looking at the three types of subgroups, it can be seen in Figure 2 that Group 0 and the *same S+* subgroup of Group E, both of whom retained the same S+, showed no change in latencies on S+ (correct) trials; whereas the other two E subgroups, who had a new S+ on Day 4, slowed down. Similarly, Group 0 and the *same S-* subgroup of Group E, all of whom retained the same S-, slowed down significantly on S- (incorrect) trials; whereas the other two E subgroups, who had a new S- on Day 4 did not change

Figure 2. Mean log goal approach times on Day 3 (Trials 22-30) and Day 4 (Trials 32-40) of acquisition in Experiments I and II. Left panels show times on correct trials, right panels on incorrect trials. Group 0 had uninterrupted acquisition. The three E groups had different stimulus changes beginning at the first trial of Day 4.

speeds. χ^2 tests on number of subjects who increased their running speeds to an old S+ and number of subjects who slowed down to an old S- were significant, $\chi^2 = 4.05$ and 5.32 , respectively, each $p < .05$.

The latency data show that something had been learned about both S+ and S- in the first 30 trials of acquisition. Subjects that retained S+ continued to respond to that stimulus appropriately while showing disruption to the new S-. Subjects that retained S- responded appropriately to that stimulus while showing disruption to the new S+. Subjects that were given two new stimuli showed disruption in latencies to both. Disruption is defined here as any change in direction from the expected decrease in speed to S- and the flat or increasing speed to S+ which are typically found during uninterrupted acquisition. These data may be contrasted with the choice data which indicated that only groups retaining S+ benefited from the first 30 trials of training in terms of a choice criterion of learning. The *same S-* subgroup slowed down to S- from Day 3 to Day 4, but this change in response to S- was not associated with change in choice behavior.

Similar discrepancies between these two measures on other discrimination tasks have been reported previously (Mandler, 1973; Mandler & Goldberg, 1973).

EXPERIMENT II

Experiment I showed that *same S+* transfer learning was faster than *same S-* transfer learning early in acquisition. It also showed that no further facilitation of *same S+* transfer learning occurred during overtraining, whereas facilitation of *same S-* transfer increased during overtraining. These results differ somewhat from a previous study (Mandler, 1968) which found that overtraining facilitated *same S+* transfer learning more than *same S-* transfer. That experiment used the correction method of training. It was suggested that the correction method orients the subject to S- early in training, especially when a position habit is operating, but that during overtraining, orientation to the stimuli changes, allowing further learning about S+ to take place.

It seemed advisable to replicate part of Experiment I, using the correction method, because somewhat different portions of acquisition had been investigated in the previous correction experiment, and because improved control procedures in our laboratory in the intervening years have resulted in faster learning and fewer position habits in this type of discrimination task.¹

Method

All details of method were the same as in Experiment I, except that the M groups, which showed no difference in response to S+ and S- in Experiment I, were omitted. There were 48 subjects, divided into three E subgroups, given 30 trials of acquisition training, and three O subgroups, given 70 trials of training beyond criterion. In addition, eight subjects were given 150 trials of overtraining [the amount of overtraining used in the previous correction experiment (Mandler, 1968)]. Four of these subjects were assigned to a *same S+* subgroup, and four to a *same S-*.

The correction method of training allowed subjects to retrace after touching the incorrect door and to enter the correct goalbox. Thus, subjects were rewarded on every trial. An error was scored only if the subject actually touched an incorrect door.

The same type of analyses used in Experiment I was carried out on discriminability of the various stimulus combinations, as well as tests of stimulus-specific or dimensional transfer. No differences even approaching significance were found.

Results

Choice Measures

Effects on acquisition of stimulus change at Trial 30. Errors and trials to criterion following the stimulus change for the E subgroups were compared with Group O's uninterrupted acquisition scores. These scores are shown in the row labeled "E" and the columns labeled "Acquisition" in the middle panel of Table 2. None of the E subgroups differed significantly from Group O's acquisition scores on either measure of learning. The *same S-* subgroup of Group E learned the fastest but was not significantly better than Group O. This result indicates that relatively little learning about reinforcement contingencies had taken place by the third day of acquisition, nor any generalized learning that might improve transfer performance.

The correction groups did differ, however, from the noncorrection groups of Experiment I. Analysis of variance comparing the *same S+* and *same S-* subgroups in the two experiments resulted in a significant interaction between training method, type of stimulus change, and amount of training, $F(1,56) = 4.26, p < .05$. Newman-Keuls tests on this interaction showed that when trained under noncorrection, the *same S+* subgroup of Group E performed better, and when trained under correction, the *same S-* subgroup performed better.

Assessment of learning by transfer tests. Trials and errors to criterion in the transfer test for the three O subgroups are shown in the row labeled "O" in the middle panel of Table 2. Analysis of variance comparing the correction trained and noncorrection trained O subgroups showed a significant interaction between method of training and type of stimulus change, $F(2,42) = 3.68, p < .05$. Newman-Keuls tests showed that when trained under correction, both the *same S+* and *same S-* subgroups made fewer errors than the *both new* subgroup ($p < .01$), but did not differ significantly from each other. Thus, although the correction *same S+* subgroup was significantly better following overtraining than the noncorrection *same S+* subgroup ($p < .01$), it did not show the superiority over the *same S-* subgroup found in the previous correction experiment (Mandler, 1968).

Inspection of Table 2 suggests that this lack of difference was due to essentially asymptotic performance having been reached by both the *same S+* and *same S-* subgroups after 70 trials of overtraining. If learning about both S+ and S- is asymptotic, either stimulus might be expected to maintain error-free transfer performance. The bottom panel of Table 2 presents the relevant data from the previous correction experiment. A comparison of acquisition and transfer scores at the various stages of training that were sampled in the two correction experiments shows that the same relationships obtain among groups, but asymptotic performance occurred for both S+ and S- after 70 trials of overtraining in the present experiment, whereas asymptotic performance occurred after 150 overtraining trials only for the S+ group in the previous experiment. To check on this finding, it seemed advisable to replicate the amount of overtraining used in the previous study. Therefore an additional eight subjects were given 150 overtraining trials, half in a *same S+* subgroup and half in a *same S-* subgroup. The expected virtually errorless performance was obtained: all eight subjects reached the 2-day criterion in 2 days, with a mean of one error in the *same S-* subgroup and .75 errors in the *same S+* subgroup.

In addition to faster learning, position responding occurs less frequently in current experimentation. During acquisition, noncorrection subjects displayed position habits on 14% of the days to criterion and correction subjects on 42% of the days. Position responding during the transfer task was uniformly low, ranging from 0 to .4 days. These figures contrast with the data from Mandler (1968) in which position responding in acquisition was nearly universal and during transfer ranged from 1.4 to 2.5 days.

Latency Measures

Goal approach times on Days 3 and 4 of training were analyzed to see if latency measures might register effects of stimulus change not shown by the choice measures.

Goal approach times are shown in the lower panel of Figure 1. Group 0 ran significantly slower than the three E subgroups on S- trials, $F(1,42) = 5.43$, $p < .05$. Group 0 also slowed down significantly from Day 3 to Day 4 on S- trials, $F(1,42) = 7.07$, $p < .05$, and ran slower to S- than to S+ during Day 4, $F(1,42) = 12.51$, $p < .01$. Thus, during uninterrupted acquisition, correction trained subjects, like the noncorrection subjects in Experiment I, showed latency differentiation between S+ and S- by the 4th day of training. However, unlike Experiment I, the correction E groups showed no differential sensitivity to change in S+, S-, or in both stimuli, on Day 4. This result is consistent with the choice data and is another indication that the formation of the discrimination between S+ and S- was proceeding at a slower rate than for noncorrection subjects.

Discussion

Noncorrection and correction methods of training in the Y maze usually result in approximately the same number of trials and errors to criterion in acquisition, with a slight superiority shown by noncorrection subjects. These two measures are relatively crude with respect to the presumed underlying processes occurring during the two types of learning. A combination of analyses, including latency measures and differential response to S+ and S- following interruption of acquisition at various points, indicated that there are differences in learning occurring at different stages of acquisition under the two types of training.

Learning about S+ occurs early in acquisition with noncorrection, and little improvement occurs after that time, at least up to 70 trials of overtraining. Learning about S-, on the other hand, begins somewhat later in acquisition and continues throughout overtraining. When the correction method is used, learning about S- occurs earlier in acquisition, and further learning about both S+ and S- occurs during overtraining.

These differences are consistent with the results of Hooper (1967) who found small differences in acquisition between the two methods but large differences in reversal learning following mastery training vs. overtraining.² The present results suggest that differences found in later learning (such as presence or absence of the overlearning reversal effect) depend in part upon how much has been learned about the positive and negative stimuli at the time a second task is begun. Merely knowing that an animal has reached a certain criterion of mastery does not tell us enough about *what* has been learned to predict accurately the rate of learning on a new task.

The present experiments do not support the suggestion originally made by D'Amato and Jagoda (1961) that S- becomes less aversive following overtraining. The suggestion was that aversiveness of S-

builds up during acquisition until criterion is reached, but that during overtraining when the subject no longer has contact with S-, its aversiveness becomes reduced. Noncorrection training is the situation in which the least contact with S- occurs during overtraining, yet Experiment I showed that during overtraining subjects became more sensitive to the negative stimulus, in the sense that it maintained transfer learning better than at criterion. This finding suggests that change in aversiveness of the negative stimulus is not the major factor that occurs during training. A more general hypothesis is that there are different rates of learning about S+ and S- at different stages of training.

Since neither acquisition nor transfer data showed any indication of generalization among the various stimuli, it was suggested that the learning which took place did not consist of improved dimensional analysis. Indeed the rapid transfer in the overtrained *both new* conditions, in which irrelevant dimensions became relevant or vice versa, would be difficult to account for in terms of any simple conditioning process or strengthening of dimensional analyzers. It appears that in this type of discrimination task, stimuli are treated from the outset as independent and responded to in a relatively global way. The first thing which must be learned is which stimuli (namely, the goalbox doors) are relevant to the task. In addition to this process, learning of their respective reinforcement contingencies must take place, and it seems to do so at two different rates. The method of training affects the latter learning (and there is some suggestion in the data that the first process may be affected by method of training as well). Although the present data do not provide direct evidence as to why different rates of learning occur under the two methods, it seems likely that different rates of development of orientation and/or attention to the positive and negative stimuli are involved.

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NOTES

1. More rapid and less variable learning was observed following three changes: insuring quiet at all times in the experimental room; eliminating differential external cues, e.g., repainting one different color wall so it matched the others (which markedly reduced position responding); and use of a feeding schedule determined by log ad lib weight, instead of the constant amount of food previously used.

2. Hooper's noncorrection method was slightly different than that used here. The groups most closely matching the present experiment were those in his "distinctive" condition.

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