Feature extinction enhances transfer of occasion setting

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In three experiments, transfer effects in appetitive serial feature-positive discrimination procedures ($X \rightarrow A+$, $A-$) were examined with rat subjects. Nonreinforced presentations of the feature (X) alone had little or no effect on that cue's ability to modulate responding to the target cue with which it had originally been trained (A) but enhanced its ability to modulate responding to another cue (B), which had been the target within another serial feature-positive discrimination ($Y \rightarrow B+$, $B-$). These effects were observed when the nonreinforced X presentations occurred either concurrently with $X \rightarrow A+$, $A-$ training or afterward. Regardless of whether or not nonreinforced X presentations were administered, X did not modulate responding evoked by a cue that had not been trained within a serial feature-positive discrimination. These data help resolve conflicts in published reports of transfer or its absence in this conditioning situation, and shed light on the nature of the modulatory or occasion-setting powers of feature cues in serial feature-positive discrimination learning.

In a feature-positive discrimination, a compound stimulus (XA) is reinforced, but one of its elements (A) is separately nonreinforced. Typically, as predicted by most conditioning theories, rats solve these discriminations by associating the more predictive element, X , with the reinforcer, while A acquires little control over behavior. However, I have argued that under some circumstances, rats solve feature-positive discriminations in quite a different manner: X may instead acquire the ability to modulate the action of an association between A and the reinforcer. Thus, X "sets the occasion" for responding to A , which is based on A -reinforcer (rather than X -reinforcer) associations (Moore, Newman, & Glasgow, 1969; Skinner, 1938).

Much of the evidence for this occasion-setting process comes from comparisons of Pavlovian feature-positive discriminations in which the elements of the compound are presented either simultaneously (XA) or serially ($X \rightarrow A$). I have claimed that with simultaneous presentations, X is associated with the unconditioned stimulus (US), but with serial presentations, X sets the occasion for responding based on A -US associations (e.g., Holland, 1983, 1985).

Three broad classes of data support this distinction. First, Ross and Holland (1981) found that simultaneous and serial feature-positive discrimination procedures generated conditioned responses (CRs) of different topographies. With simultaneous compounds, the form of the CR was appropriate to X , as would be expected if the CR

were the result of X -US associations. However, with serial compounds, A determined the topography of the CR, as if X modulated the expression of an A -US association.

Second, several experimental variables have different effects on the acquisition of presumed associative and occasion-setting functions by a conditioned stimulus (CS). For example, Holland (1986a) and Ross and Holland (1981) found that extending the $X \rightarrow A$ interval hindered the growth of simple associations, but enhanced occasion setting. Similarly, Ross (1983) found that $A \rightarrow$ US pairings prior to $X \rightarrow A+$, $A-$ serial feature-positive discrimination training blocked the acquisition of X -US associations but not X 's ability to set the occasion for responding based on A -US associations. Furthermore, Ross, Orr, Holland, and Berger (1984) found that bilateral hippocampectomy prevented the acquisition and performance of X 's occasion-setting powers but left CRs based on direct associations with the US untouched.

Third, and most germane to the experiments reported here, cues trained in serial $X \rightarrow A+$, $A-$ and simultaneous, $XA+$, $A-$ discriminations seem to acquire different transfer properties. For example, Holland (1983, 1986b) found that an X trained in an $XA+$, $A-$ discrimination evoked responding regardless of whether it was accompanied by A , accompanied by another cue, or was presented by itself, but that an X trained in an $X \rightarrow A+$, $A-$ discrimination modulated only responding controlled by A . Partly on the basis of these transfer data, I suggested that occasion setters act by modulating associations between their targets and the reinforcer.

However, Rescorla (1985, 1986) has insisted instead that occasion setters (which he terms "facilitators") act on a representation of the reinforcer, not on the associations between particular targets and the US. Not surpris-

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ingly, Rescorla's claim was based on data showing substantial transfer: in his laboratory, stimuli trained as occasion setters with one target readily modulated responding controlled by targets that were originally trained with other occasion setters.

Although most of Rescorla's investigations have used pigeon subjects, Davidson and Rescorla (1986) found substantial transfer of occasion setting using rat subjects in conditioning procedures much like those in which I found little or no transfer. The experiments reported here were intended to reconcile these conflicting observations.

I examined the effects of two variables on the transfer of occasion setting in appetitive serial feature-positive discrimination learning. The first variable was the nonreinforcement of the feature cue. Although my previous experiments used simple feature-positive procedures ($X \rightarrow A+$, $A-$), Davidson and Rescorla (1986) used serial positive-patterning procedures ($X \rightarrow A+$, $A-$, $X-$) in which there were nonreinforced presentations of the feature. In Experiments 1 and 2 of the present study, I compared transfer after $X \rightarrow A+$, $A-$ and $X \rightarrow A+$, $A-$, $X-$ procedures, and in Experiment 3, I examined the effects of a block of nonreinforced feature presentations after $X \rightarrow A+$, $A-$ training.

The second variable I examined was the nature of training of the target stimulus used in transfer testing, a variable that Lamarre and Holland (1987) showed to be an important determinant of transfer of occasion setting in serial feature-negative ($A+$, $X \rightarrow A-$) discrimination learning with an aversive US. In most of my previous experiments, the target was a cue that had received both reinforced and nonreinforced presentations but had not itself been a target of another $X \rightarrow A+$, $A-$ discrimination. Conversely, Davidson and Rescorla (1986) used as transfer targets cues that had themselves been targets within other $X \rightarrow A+$, $A-$, $X-$ discriminations.

In the experiments reported here, I compared transfer when the transfer test targets had been trained as targets within other serial discriminations to transfer when the transfer target had been both reinforced and nonreinforced, but in the absence of an explicit feature cue. Extreme versions of my claims about the locus of occasion setting demand no transfer to any cue other than the original target, and extreme versions of Rescorla's views demand transfer to any cue associated with the same reinforcer.

EXPERIMENT 1

In Experiment 1, I compared transfer after $X \rightarrow A+$, $A-$ and $X \rightarrow A+$, $A-$, $X-$ procedures under conditions intended to maximize the likelihood of transfer in both conditions. In most of my previous experiments, transfer may have been discouraged by differences between training and test sessions. First, I typically did not deliver reinforcement in test sessions, and second, I usually gave massed training of the transfer target after the comple-

tion of discrimination training. Conversely, Davidson and Rescorla (1986) intermixed target training with original discrimination training, and maintained reinforcement during test sessions. These procedures may have encouraged transfer.

Consequently, procedures more like those of Davidson and Rescorla (1986) were used in these experiments. In Experiment 1, each subject received training with two separate discriminations, with all trials intermingled. For half of the subjects, both discriminations were feature-positive ($X \rightarrow A+$, $A-$ and $Y \rightarrow B+$, $B-$); for the other half, both discriminations were positive-patterning ($X \rightarrow A+$, $A-$, $X-$ and $Y \rightarrow B+$, $B-$, $Y-$). For half of the subjects in each of those groups, the features were visual and the targets auditory; for the other half, the features were auditory and the targets visual. In addition, all subjects received conditioning and then extinction of another cue, C , intermixed with discrimination training trials. Finally, responding during $X \rightarrow A$, $X \rightarrow B$, $X \rightarrow C$, $Y \rightarrow A$, $Y \rightarrow B$, and $Y \rightarrow C$ compound trials, and during X , Y , A , B , and C trials was examined in a series of transfer tests, some of which included reinforced compound presentations. Thus, each feature's ability to control responding during its original target, during the target trained with the other feature, during the trained and extinguished cue, and during an empty interval corresponding to the usual time of target presentation, could be compared.

Method

Subjects and Apparatus. The subjects were 32 male Sprague-Dawley rats bred locally from Charles River stock. They were 80–100 days old at the beginning of the experiment, and were experimentally naive. The rats were housed in individual cages in a colony room that was illuminated from 6:00 a.m. to 8:00 p.m. Experimental sessions were conducted between 5:00 a.m. and 8:00 p.m. Throughout the experiment, the rats had free access to water and were maintained at 80% of their free-feeding weights by limiting their access to food.

Eight experimental chambers, each $22.9 \times 20.3 \times 20.3$ cm, were used. The two end walls of each chamber were aluminum, and the side walls and top were clear acrylic. A dimly illuminated food cup was recessed in the center of one end wall; an identical cup protruded from the opposite end wall, but was not used in this experiment. A 6-W jeweled panel light 6 cm above the recessed food cup provided a source of background illumination. The chamber floors were made of .48-cm stainless steel rods spaced 1.9 cm apart. Each experimental chamber was enclosed in a sound-resistant shell that contained speakers for delivering auditory stimuli and a normally off 6-W houselight which served as one of the conditioned stimuli. Fans provided ventilation and masking noise (70 dB). The front wall of each shell contained an acrylic window to permit behavioral observations. Two low-light television cameras were mounted 2.1 m from the experimental chambers so that each could include four chambers in its field of view. Videocassette recorders were programmed to record behaviors occurring during, and 10 sec before and after, CS presentations.

Behavioral observation procedures. All observations were made from videotapes. Each rat's behavior was observed at 1.25-sec intervals during the 5-sec period immediately prior to CS presentations and during the CS presentations. The observations were paced

by auditory signals recorded on the videotapes. On each observation, one and only one behavior was recorded. Four behavioral categories were reported: *magazine*—standing motionless in front of the food magazine with head or nose within the recessed food cup; *head jerk*—short, rapid, horizontal and/or vertical movements of the head; *startle*—a rapid jump or change in position; and *rear*—standing on rear legs, with both front legs off the floor, but not grooming (see Holland, 1977, for more complete descriptions).

The frequency of each behavior, except startle, was divided by the total number of observations made, to obtain the measure "percentage of total behavior." Note that because the number of observations was constant in each observation interval, this measure is an absolute frequency measure, rather than a relative one. Two observers agreed on 996 of 1,028 joint observations during the test sessions. Because startle responding typically occurred only once in a single trial, at CS onset, the measure of that behavior was the percentage of trials on which startle behavior was observed.

Neither startle nor head-jerk behavior was ever observed to occur during pre-CS periods. Rear and magazine behaviors seldom constituted more than 8% (each) of the total pre-CS behavior in these experiments, and never differed reliably between groups. Consequently, pre-CS behavior is not described.

Holland (1977) noted that auditory stimuli paired with food delivery elicited startle, head jerk, and some magazine behaviors, but that visual stimuli paired with food evoked rear at CS onset, followed some seconds later by substantial magazine behaviors. Consequently, in these experiments, auditory-feature CS-food association was indexed by head-jerk and startle behaviors. Only head-jerk behavior was used to index associations between auditory targets and food: Holland and Ross (1981) noted that as feature-target associations are formed, startle responding to the target decreases. Rear and magazine behavior during the visual target CSs were used to index their association with food, and rear during the 5-sec visual features, and magazine behavior during the 5-sec empty interval after the features, were used as measures of their associations with food.

Holland (1985), Holland and Ross (1981, 1983), and Ross and Holland (1981, 1982) noted that in serial compounds like those used here, associations are also formed between the feature and target cues. We found that those associations often cause the first cue to evoke a response of a form characteristic of the second stimulus, as the time of the presentation of the second cue draws near. Consequently, in the experiments reported here, the occurrence of head-jerk behavior in the trace interval after the visual feature (but before the auditory target), and the occurrence of rear behavior after auditory features (but before the visual targets), were used as indexes of feature-target associations.

Experimental procedures. The rats were first trained to eat from the food cups. Eight deliveries of two 45-mg food pellets (the reinforcer used throughout these experiments) were given on a variable-time 2-min schedule in a single session.

The rats were then randomly assigned to four groups of 8 subjects each, and discrimination training was begun. The rats in Group FP-V and Group FP-A received five types of trials in each session: (1) a serial compound, which comprised a 5-sec *X* cue followed, after a 5-sec empty interval, by a 5-sec *A* cue, and reinforced with two 45-mg food pellets; (2) a second serial compound, which comprised a 5-sec *Y* cue followed, after a 5-sec empty interval, by a 5-sec *B* cue, reinforced with two 45-mg food pellets; (3) a 5-sec, nonreinforced presentation of *A*; (4) a 5-sec, nonreinforced presentation of *B*; and (5) a 5-sec presentation of an auditory *C* cue; *C* was reinforced in Discrimination Training Sessions 1–40 and was nonreinforced in Sessions 41–60. In Group FP-V, the features *X* and *Y* were visual stimuli, and *A* and *B* were auditory; in Group FP-A, *X* and *Y* were auditory, and *A* and *B* were visual. The two visual cues were the intermittent illumination of the houselight (3 Hz) and the steady illumination of the panel light, counterbalanced within

each group. The auditory *A* cue was an intermittent (3 Hz) 1,500-Hz, 78-dB tone for all subjects, and the auditory *B* and *C* cues were either a steady 78-dB white noise or a 7-Hz, 72-dB clicker, counterbalanced. Thus, Group FP-V received feature-positive discrimination training with serial compounds whose features were visual, and Group FP-A received feature-positive discrimination training with serial compounds whose features were auditory.

The rats in Groups PP-V and PP-A received the same kinds of trials as Groups FP-V and FP-A, respectively, plus nonreinforced presentations of *X* and *Y*. Thus, those rats received positive-patterning discrimination training with either visual or auditory features.

Each discrimination training session was 90-min long. Initially, each rat received two sessions per day; the second daily session started 8 h after the start of the first daily session. After the first 20 sessions on this schedule, the rats received only one session in each remaining day of the experiment.

In each of the first 16 discrimination training sessions, there were two of each of the five kinds of trials in Groups FP-V and FP-A, and two of each of the seven kinds of trials in Groups PP-V and PP-A. In each of Discrimination Training Sessions 17–60, there were three presentations of each of the nonreinforced trial types and one presentation of each of the reinforced trial types.

Throughout discrimination training, the trials were randomly intermixed and were changed for each session, with two constraints. First, there was always at least one reinforced trial in the first 45 min and one reinforced trial in the last 45 min of each session. Second, in Sessions 1–20, the trial order of each second daily session was the reverse of the trial order used in the first session of that day. In Groups FP-V and FP-A, the intertrial intervals averaged 491 sec in Sessions 1–16, 540 sec in Sessions 17–40, and 450 sec in Sessions 41–60. In Groups PP-V and PP-A, the intertrial intervals averaged 360 sec in Sessions 1–16, 338 sec in Sessions 17–40, and 300 sec in Sessions 41–60. The intervals were randomized for each session by a program designed to generate a rectangular distribution of values that ranged between 0.5 and 1.5 times the mean interval.

Finally, all rats received four test sessions. The first and third sessions examined the powers of *X*, and the second and fourth sessions examined the powers of *Y*. In the first test session, all rats received seven kinds of trials, all nonreinforced: (1) *X*→*A* trials, identical to those received in discrimination training; (2) *X*→*B* trials, which tested transfer of *X*'s powers to a target that had been trained as a target in the other discrimination; (3) *X*→*C* trials, which tested transfer to a target that had been separately conditioned and extinguished; (4) *X* trials, which examined responding to *X* and in the empty intervals after *X* (which had been occupied by *A* in training); (5) *A*-alone trials; (6) *B*-alone trials; and (7) *C*-alone trials. There were two of each kind of trial, in the order 1, 7, 6, 2, 3, 5, 4, 4, 5, 3, 2, 6, 7, 1.

The second session was similar to Session 1, except that *Y* replaced *X*. The third and fourth test sessions were identical to the first and second, respectively, except that the first three kinds of trials described above were reinforced.

I used a significance level of $p < .05$, with two-tailed, distribution-free tests.

Results and Discussion

Discrimination training. Conditioned responding was rapidly acquired to the features in all four groups, but was maintained at higher levels in the feature-positive (FP) groups than in the positive-patterning (PP) groups. Responding to the two features (*X* and *Y*) did not differ in any of the groups, so those data were averaged in each subject. Figure 1 shows conditioned responding controlled

Figure 1. Conditioned responding evoked by the features in Experiment 1. The three left panels display startle and head-jerk responding of Groups PP-A and FP-A during the two auditory features (combined), and rear behavior during the trace interval after the features. The three right panels display rear behavior of Groups PP-V and FP-V during the two visual features (combined), and magazine and head-jerk behavior during the trace interval after the features.

by the combined feature stimuli over the course of discrimination training. The three left panels show startle and head-jerk behavior during the auditory features, and rear behavior during the trace intervals, in Groups FP-A and PP-A. The three right panels show rear behavior during the visual features, and magazine and head-jerk behaviors during the 5-sec empty intervals after the visual features in Groups FP-V and PP-V.

Over the last six blocks of sessions of training, the subjects in Group FP-A showed more startle (Mann-Whitney $U = 3$) and head-jerk ($U = 0$) behavior during the features (indicating stronger feature-US associations), and more rear behavior ($U = 13$) during the trace interval (indicating stronger feature-target associations) than did the subjects in Group PP-A. Similarly, the subjects in Group FP-V showed more rear ($U = 3.5$) behavior during the feature (indicating stronger feature-US associations) and more magazine ($U = 11.5$) and head-jerk ($U = 13.5$) behavior during the trace interval (indicating stronger feature-target associations) than did the subjects

in Group PP-V. Thus, the nonreinforced feature presentations in the two positive-patterning groups indeed reduced conditioned responding elicited by the features themselves.

Discriminated responding to the target stimuli was rapidly acquired in all four groups. Figure 2 shows conditioned behaviors that occurred during the target cues (*A* and *B*, averaged) on both compound and target-alone trials. (There were no differences in responding during the two target cues within any group.) The top panel shows head-jerk behavior during the auditory targets in Groups FP-V and PP-V, and the lower two panels show rear and magazine behaviors during the visual targets in Groups FP-A and PP-A. Every subject learned the discriminations (i.e., responded more to the target on reinforced compound trials than on target-alone trials). On the whole, the subjects in the positive-patterning and feature-positive conditions learned the discriminations equally well; over the last six blocks of sessions, there were no differences between FP and PP groups with any measure ($U_s \geq 23$).

Figure 2. Conditioned responding during the target cues in Experiment 1. The top panel shows head-jerk behavior to the auditory targets in Groups PP-V and FP-V, and the lower two panels show rear and magazine behaviors during the visual targets in Groups PP-A and FP-A. "+" signifies responding during the target on reinforced compound trials; "-" indicates responding on non-reinforced target-alone trials.

These data are consistent with other data from my laboratory in which the rates of acquisition of $X \rightarrow A+$, $A-$ and $X \rightarrow A+$, $X-$, $A-$ discriminations were compared (e.g., Holland, 1989a).

Transfer tests. Figure 3 shows the principal data of Experiment 1—the results of the transfer tests. Because the addition of food to Sessions 3 and 4 did not affect performance, the data from all four test sessions were combined. To demonstrate unequivocal transfer of a feature's occasion-setting power to a target cue, two criteria must be met. First, responding to that target must be greater when it was preceded by the feature (e.g., shaded TR or TE bars in Figure 3), than when it was presented alone (open TR or TE bars). Second, responding to that target when it was preceded by the feature must be greater than the responding observed during the corresponding interval on feature-alone trials (shaded N bars).

The top panel of Figure 3 shows head-jerk behavior during the auditory targets in Groups FP-V and PP-V.

In both groups, occasion setting transferred to the targets trained with the other feature. (Because there was no difference in responding during *A* and *B* targets when they were preceded by comparable features, i.e., original or transfer, the data analyzed were the averages of *A* and *B* performance in each subject.) First, head-jerk behavior was more frequent during the targets when they were preceded by the other, transfer feature (shaded TR bars) than when they were presented alone (open TR bars) in both Group PP-V (Wilcoxon $T = 0$) and Group FP-V ($T = 3$). Second, head-jerk behavior was more frequent during the targets on those transfer feature-compound trials than during the corresponding empty interval on feature-alone trials (shaded N bars), in both Group PP-V ($T = 0$) and Group FP-V ($T = 3.5$).

However, in both groups, transfer to those targets was not complete: there was more responding to the targets

Figure 3. Conditioned responding during the various target cues in the four transfer tests (combined) of Experiment 1. Group designations are above each set of bars. Shaded bars show responding during a given type of target when it was preceded by a feature; open bars show responding during that target when it was not preceded by a feature. The target types were: OR = original target; TR = transfer target, trained in the other serial discrimination; TE = separately trained and extinguished target; and N = no target (empty interval normally occupied by a target).

when they were preceded by their training feature (the shaded bars labeled OR) than when they were preceded by the other (TR bars) feature ($T_s \leq 2$). The difference in responding during the targets when they were preceded by their original versus their transfer features provided a simple measure of the amount of transfer observed, which I used to compare the amounts of transfer across groups. The difference between responding to the targets when they were preceded by their original versus their transfer features was larger in Group FP-V than in Group PP-V ($U = 3$). Thus, transfer to the other feature-positive target was greater in Group PP-V than in Group FP-V.

Conversely, there was no transfer to the trained and extinguished cue in either group. Head-jerk responding during that cue was no greater ($T_s \geq 14$) when it was preceded by a feature (shaded TE bars) than when it was presented alone (open TE bars). Finally, base rate (open N bars) was not elevated by prior feature presentation (shaded N bars) in either group.

The bottom two panels of Figure 3 show rear and magazine behaviors during the visual targets in Groups FP-A and PP-A. Group PP-A showed transfer to targets trained with the other features: both behaviors were more frequent during the targets when they were preceded by the other feature than when they were presented alone ($T_s = 0$), and were more frequent on transfer-target compound trials than on feature-alone trials ($T_s = 0$). In fact, transfer was nearly complete: there were no reliable differences ($T \geq 8$) between responding during the targets when they were preceded by the original, relative to the other, transfer features.

Conversely, there was no transfer to trained and extinguished exciters or to context cues. (Head-jerk behavior during the auditory TE cue, not shown, was also unaffected by prior feature presentation; 9% vs. 11%; $T = 13$).

Group FP-A showed little evidence for transfer of any kind. Rear responding to the *A* and *B* targets was not affected by prior presentation of the other, transfer feature ($T = 17$). Although magazine responding to *A* and *B* was greater when they were preceded by the transfer feature than when they were presented alone ($T = 4$), magazine behavior on those compound trials was no greater than on feature-alone trials ($T = 10$). Similarly, rear responding during the trained and extinguished cue was not reliably elevated when it was preceded by the features ($T = 8$), nor was compound responding greater than responding on feature-alone trials ($T = 17$). Likewise, head-jerk behavior during the auditory TE target (11%; not shown) was no greater than on feature-alone trials (9%; $T = 17$).

As in Groups PP-V and FP-V, transfer was greater in Group PP-A than in Group FP-A. The absolute level of both rear and magazine behaviors on transfer trials was greater in Group PP-A than in Group FP-A ($U_s = 6$ and 12, respectively), and the difference between responding on original and transfer trials was smaller in Group PP-A than in Group FP-A ($U_s = 6$ and 12, respectively). Note

that this greater responding on transfer trials in Group PP-A occurred despite the fact that the features in that group controlled *less* rear responding during the empty interval (N bars) than in Group FP-A.

Thus, intermixed, nonreinforced presentations of the feature cue, as in the serial positive-patterning discriminations used by Davidson and Rescorla (1986), reduced that feature's ability to evoke conditioned responding but enhanced its ability to modulate responding to other targets, relative to performance in serial feature-positive discriminations, such as those used by Holland (1983, 1986b). However, that enhanced transfer was specific to targets that were trained in the same manner as the original target, that is, as targets in another serial discrimination. No transfer to a trained and extinguished cue was observed with either procedure.

Consequently, although Experiment 1 at least in part resolved the discrepancy between Davidson and Rescorla's (1986) observation of transfer of occasion setting, and my (Holland, 1983, 1986b) failures to observe transfer, neither my nor Rescorla's views were supported in their entirety. In Experiments 2 and 3, I attempted to refine these notions by investigating why nonreinforced feature presentations should encourage transfer to other similarly trained targets but not to a trained and extinguished excitor.

EXPERIMENT 2

In Experiment 2, I considered whether the addition of nonreinforced feature presentations encourages transfer by altering the feature or by altering the nature of the target. That is, was transfer observed with the positive-patterning procedure because the feature was better able to act on other targets, or because the target was better able to be acted upon by other features? To address this question, in Experiment 2, each rat received training with one feature-positive, $X \rightarrow A+$, $A-$ discrimination, and one positive-patterning, $Y \rightarrow B+$, $B-$, $Y-$ discrimination, followed by transfer tests. As in Experiment 1, the action of both features on another excitor, which had been trained and extinguished outside of any explicit discrimination, was also examined.

Earlier, I (Holland, 1986a) suggested that transfer may have been masked in my previous experiments by some sort of novelty reaction when an anticipated target was replaced by another cue. Holland and Ross (1981) and Ross and Holland (1981) showed that feature-target associations are formed in serial compounds like these. The addition of nonreinforced feature trials in the patterning groups of Experiment 1 might be expected to reduce the strength of those feature-target associations (see Experiment 1, above, and Ross & Holland, 1982), consequently reducing the presumed novelty reaction and permitting the observation of transfer. If so, then in Experiment 2, the *Y* feature, from the $Y \rightarrow B+$, $B-$, $Y-$ discrimination, should readily set the occasion for responding to the *A* tar-

get, which was trained within the $X \rightarrow A+$, $A-$ discrimination, but the X feature would not be expected to modulate responding during the B target.

On the other hand, other data from both my laboratory (e.g., Experiment 1, above; Holland, 1986a, 1989a; Lamarre & Holland, 1987) and Rescorla's (e.g., Rescorla, 1985) suggest that the nature of target training is an important determinant of transfer. Responding to cues trained in some ways, such as consistent reinforcement or nonreinforcement, is not modulated by occasion setters, but responding to cues trained in serial feature-positive discriminations is affected. Perhaps serial positive-patterning training establishes targets that are especially amenable to being affected by occasion setters. If so, then in Experiment 2, responding during the B target (from the $Y \rightarrow B+$, $B-$, $Y-$ discrimination) should also be facilitated by the X feature, but responding during the A target (from the $X \rightarrow A+$, $A-$ discrimination) would not be affected by the Y feature.

Method

Subjects and Apparatus. The subjects were 8 female rats, bred locally from Sprague-Dawley stock. They were about 80 days old at the beginning of the experiment, and were experimentally naive. The rats were maintained as in Experiment 1; experimental sessions occurred between 8:00 p.m. and 10:30 p.m.

The apparatus was the same as that used in Experiment 1.

Procedure. The rats were first trained to eat from the food cups, as in Experiment 1. All rats received six types of trials in each session. The first two trial types formed the feature-positive discrimination: (1) a serial compound, which comprised a 5-sec X cue followed, after a 5-sec empty interval, by a 5-sec A cue, and reinforced with two 45-mg food pellets; and (2) a 5-sec, nonreinforced presentation of A . The next three kinds of trials formed the positive-patterning discrimination: (3) a serial compound, which comprised a 5-sec Y cue followed, after a 5-sec empty interval, by a 5-sec B cue, reinforced with two 45-mg food pellets; (4) a 5-sec, nonreinforced presentation of B ; and (5) a 5-sec, nonreinforced presentation of Y . Finally, each rat received (6) a 5-sec presentation of an auditory C cue; C was reinforced in Discrimination Training Sessions 1–28, and nonreinforced in Sessions 29–40. The features X and Y were the intermittent illumination of the houselight (3 Hz) and the steady illumination of the panel light, counterbalanced, and the targets A and B were an intermittent (3 Hz) 1500-Hz, 78-dB tone and a steady 78-dB white noise, counterbalanced. C was a 7-Hz, 72-dB clicker.

Each daily discrimination training session was 150-min long. In each of the first eight discrimination training sessions, there were four of each of the six kinds of trials. In each of Discrimination Training Sessions 9–40, there were six presentations of each of the nonreinforced trial types and two presentations of each of the reinforced trial types.

Throughout discrimination training, the trials were randomly intermixed and were changed for each session, with constraints like those described in Experiment 1. The intertrial intervals were generated as in Experiment 1, and averaged 360 sec in Sessions 1–28 and 310 sec in Sessions 17–40.

Finally, all rats received four test sessions. In the first and third sessions, the powers of the houselight were examined; in the second and fourth sessions, the powers of the panel light were examined. Thus, half of the rats were tested first with the feature used in the feature-positive discrimination (X), and half with the feature used in the positive-patterning discrimination (Y). In the first test session, all rats received seven kinds of trials, all nonreinforced. Three were compounds, in which the 5-sec houselight was followed

first by a 5-sec empty interval and then by a 5-sec presentation of the target with which it was originally trained, the target from the other discrimination, or the clicker. The other four kinds of trials were presentations of the three targets separately, and the houselight feature alone (behavior was also recorded during the two 5-sec intervals after that feature). There were four of each kind of trial in each test session.

The second session was similar to Session 1, except that the panel light replaced the houselight. The third and fourth test sessions were identical to the first and second, respectively, except that the first three kinds of trials described above were reinforced.

Results and Discussion

Discrimination training. Both discriminations were acquired rapidly. Over the last 10 sessions, rear behavior was less frequent ($T = 1$) during the Y (positive-patterning) feature (32%) than during the X (feature-positive) feature (54%), and magazine behavior was less frequent during the empty interval after Y than in the interval after X (36% vs. 52%; $T = 3.5$). Thus, nonreinforced presentations of Y apparently reduced its association with the US. Furthermore, head-jerk behavior was less frequent ($T = 3$) in the empty interval after Y (3%) than in the interval after X (17%), suggesting that the added nonreinforced Y presentations reduced the association between Y and B .

Head-jerk behavior during the target cues was acquired at similar rates; there were no significant differences between A and B responding in any block of 10 sessions. Over the last 10 sessions, head-jerk behavior comprised 52% of the total behavior to A and 47% of the total behavior during B ($T = 16$).

Transfer tests. Figure 4 shows the results of the transfer tests. As in Experiment 1, the addition of food to Sessions 3 and 4 did not affect performance, and the data

Figure 4. Head-jerk behavior during the transfer tests (combined) of Experiment 2. The left set of bars show responding after the Y feature, trained in the serial positive-patterning discrimination; the right set show responding after the X feature, trained in the serial feature-positive discrimination. Shaded bars show responding during a given type of target when it was preceded by a feature; open bars show responding during that target when it was not preceded by a feature. The target types were: OR = original target; TR = transfer target, trained in the other serial discrimination; TE = separately trained and extinguished target; and N = no target (empty interval normally occupied by a target).

from all sessions were combined. With the *Y* feature (from the positive-patterning discrimination), transfer was nearly complete. Responding to the *A* target when it was preceded by *Y* (shaded TR bar) was greater than responding to *A* alone (open TR bar; $T = 0$) and responding on *Y*-alone trials (shaded N bar; $T = 0$). Conversely, with the *X* feature (from the feature-positive discrimination), there was little transfer. Although responding to the *B* target when it was preceded by *X* (shaded TR bar) was greater than responding to *B* alone (open TR bar; $T = 1$), it was no greater than responding on *X*-alone trials (shaded N bar; $T = 9$). Thus, *Y*'s occasion-setting powers transferred more than *X*'s. This claim is further supported by greater difference scores between responding to the original and transfer targets after *X* than after *Y* ($T = 1$), and by greater difference scores between responding to the transfer and *N* (empty interval) targets after *Y* than after *X* ($T = 1.5$).

Thus, nonreinforced feature presentations apparently affected transfer by making the feature more able to modulate responding to another target, rather than by making the target more amenable to modulation. The positive-patterning feature (*Y*) readily facilitated responding to the feature-positive target (*A*), but the feature-positive feature (*X*) had little effect on the positive-patterning target (*B*). The further observation in both Experiments 1 and 2 that nonreinforced feature presentations reduced evidence for feature-target associations makes reasonable the claim that the transfer potential of feature-positive features may normally be masked when the original, anticipated target is replaced with a novel one.

EXPERIMENT 3

If intermixed, nonreinforced feature presentations enhance transfer by reducing feature-target associations, then any manipulation that reduces those associations should enhance transfer. In Experiment 3, I examined the effects on transfer of a block of feature-extinction trials after serial feature-positive training. Both Rescorla (1986) and Ross (1983) have noted only small or transient disruptions of a feature's occasion-setting power after extinction of the feature (but large losses in conditioned responding due to simple associations with the feature). Thus, posttraining feature extinction might be expected to have small, detrimental effects on responding to the original target cue but substantial facilitatory effects on responding to a transfer target.

In Experiment 3 two groups of rats each received training with two serial feature-positive discriminations and another cue, which was trained and then extinguished. One group then received a block of nonreinforced presentations of one of the features. Finally, both groups received transfer tests.

Method

Subjects and Apparatus. The subjects were 16 female rats, locally bred from Sprague-Dawley stock. They were experimentally

naïve, and about 140 days old at the start of the experiment. The rats were maintained as in Experiments 1 and 2; experimental sessions were conducted between 6:30 a.m. and 9:30 a.m.

The apparatus was the same as that used in Experiments 1 and 2.

Procedures. First, all rats were trained to eat from the food cups as in Experiments 1 and 2. Next, the rats received 32 sessions of discrimination training in which five kinds of trials were presented: (1) a serial compound, which comprised a 5-sec visual feature, *X*, followed by a 5-sec empty interval, followed by a reinforced 5-sec auditory target, *A*; (2) nonreinforced presentations of *A* alone; (3) a serial compound, which comprised a 5-sec visual feature, *Y*, followed by a 5-sec empty interval, followed by a reinforced 5-sec auditory target, *B*; (4) nonreinforced *B* presentations; (5) 5-sec presentations of an auditory cue, *C*, reinforced in the first 16 sessions and nonreinforced in the last 16. Each session included one of each reinforced trial and three of each nonreinforced trial. The two visual *X* and *Y* cues were the houselight and panel light described previously, and the two auditory *A* and *B* cues were the noise and tone described earlier. Both *X* and *Y*, and *A* and *B*, were counterbalanced within groups. *C* was the clicker for all subjects.

Next, half of the subjects (Group E) received eight nonreinforced *X* presentations in each of eight sessions. The other half of the rats (Group N) were placed in the experimental chambers, but no events were delivered. Finally, all rats received four transfer tests. In each transfer test, the effects of only one feature were examined; half of the subjects in each group were tested with *X* in Sessions 1 and 4 and *Y* in Sessions 2 and 3, and the other half received the opposite sequence of tests. Each test comprised two randomly intermixed presentations each of three different serial feature-target compounds (the 5-sec feature followed, after a 5-sec trace interval, by its original target, the target from the other discrimination, or the trained and extinguished clicker) and the three targets alone. All compounds were reinforced and all target-only trials were nonreinforced in all four test sessions.

Results and Discussion

The discriminations were acquired readily, as in Experiment 1. There were no differences in the rate or level of acquisition of the discriminations either within or between groups. Over the last four sessions, rear behavior during the visual targets averaged 67% and head-jerk behavior during the auditory targets averaged 62%. Unlike in Experiments 1 and 2, only low levels of head-jerk behavior (4%–9%) were observed during the empty interval after the features. In Group E, rear behavior during the *X* feature decreased to 12% on the eighth extinction session.

Figure 5 shows head-jerk behavior during the transfer tests. As in Rescorla's (1986) studies, extinction of the *X* feature had relatively little impact on subsequent responding to *A* (the original target of *X*) on *X*→*A* trials. In Group E, within-subject comparison of responding to the original targets showed no reliable difference ($T = 6$) between head-jerk behavior during the original targets of the *X* (open OR bar) and *Y* (shaded OR bar) features, and between-groups comparison of responding to the original target of the *X* feature was unreliable ($U = 24$). Nevertheless, there was more transfer with the *X* feature (which had been extinguished) than with the *Y* feature. The difference between responding on *X*→*A* (original) and *X*→*B* (transfer) trials was less than that between responding on *Y*→*B* (original) and *Y*→*A* (transfer) trials ($T = 2$).

Figure 5. Head-jerk behavior during the transfer tests (combined) of Experiment 3. Shaded bars show responding during a particular kind of target when it was preceded by Y; open bars show responding when that target was preceded by X; slashed bars show responding when that target was presented alone. In Group E, nonreinforced X presentations were given between training and testing. The three types of targets were: OR = original target; TR = transfer target, trained in the other serial discrimination; and TE = separately trained and extinguished target.

In Group N, in which neither feature was extinguished, there was no differential transfer: the difference between responding on X-A and X-B trials did not differ from that between responding on Y-B and Y-A trials ($T = 15.5$). Furthermore, the responding on X-B transfer trials was greater in Group E than in Group N ($U = 12.5$), and the difference between responding on X-A (original) and X-B (transfer) trials was greater in Group N than in Group E ($U = 10$). Thus, both within-subject and between-group measures indicated that posttraining extinction of X enhanced its ability to facilitate responding to a target trained in another, similar discrimination. This finding supports the conclusion from Experiment 2 that nonreinforced feature presentations broaden the action of that feature, rather than of the target: because the targets were not presented during the feature-extinction phase, it is unlikely that they showed substantial change (but see Holland & Forbes, 1982, and Holland & Ross, 1981). Furthermore, this result is consistent with the view that feature-target associations interfere with the display of transfer, and that minimizing those associations enhances transfer. Nevertheless, as in Experiments 1 and 2, in neither group did either X or Y affect responding to C.

GENERAL DISCUSSION

Nonreinforced feature presentations, either during or after serial feature-positive discrimination training, had different effects on several aspects of conditioned behavior in these experiments. First, they reduced conditioned responding evoked by the features themselves—responding that was most likely due to feature-US (Experiments 1-3) and feature-target (Experiments 1 and 2) associations. Second, they had no reliable effect on those features' ability to modulate responding to their original targets. Third, they had no effect on the features' inability to modulate responding evoked by a trained and extinguished cue. Finally, they enhanced those features' ability to modulate responding to targets that had been trained with other features.

Thus, these data may resolve the discrepancy between my previous observations of little or no transfer with serial feature-positive discriminations (e.g., Holland, 1983, 1986b) and Davidson and Rescorla's (1986) finding of substantial transfer with serial positive-patterning procedures. Although these experiments provided no direct evidence, one possible account for this enhanced transfer is that nonreinforced feature presentations reduce specific feature-target associations, which normally interfere with performance to otherwise appropriate targets of transfer. However, despite our direct observation of the rats' behavior, there was no evidence of a novelty or surprise reaction when the transfer targets were presented. Thus, the mechanism of any such disruption remains unspecified.

The minimal effect of either intermixed or posttraining nonreinforced feature presentations on the feature's ability to set the occasion for responding to its original target supports earlier data of Ross and Holland (1982) and Rescorla (1986). In contrast, in simultaneous feature-positive discrimination procedures, in which occasion-setting powers are typically not acquired by the feature, nonreinforced feature presentations degrade discrimination performance significantly (Holland, 1989a), just as simple CRs evoked by the features were degraded in the present experiments. Thus, these data support earlier claims (e.g., Holland, 1983; Rescorla, 1985) for distinctions between occasion setting and simple conditioning.

It is worth considering the potential contribution of stimulus generalization to these transfer data. Considerable data from simple conditioning experiments in my laboratory indicate excellent discrimination between the auditory cues used here (near-perfect discrimination after a few presentations of each). Similarly, the observation of transfer to a given (counterbalanced) auditory target when it was trained within another serial discrimination, but not when it was trained and extinguished, makes an account of transfer based on generalization among the targets unlikely in the present experiments. However, comparable discriminations among the visual cues used here often take 10 or more sessions. Thus, it might be claimed that generalization between those visual

cues may have been the source of the transfer. In this regard, however, it is worth noting that Davidson and Rescorla (1986) and Holland (1989a), in related investigations of serial positive-patterning, and Lamarre and Holland (1987), in a study of serial feature-negative learning, found similar transfer even when the pairs of features and pairs of targets were of different modalities.

Also difficult for a generalization-based account of the transfer observed here is why that generalization was affected by nonreinforcement of the features. One possible mechanism involves the specific feature-target associations alluded to earlier. Perhaps the effective occasion setter is not just the feature, but the feature and the expectancy of the target it evokes (see Trapold, 1970). If so, then consistent pairing of each feature with its unique target, as in training with two feature-positive discriminations, would make the two features maximally discriminable. Conversely, intermixing nonreinforced presentations of both features, as in the patterning procedure of Experiment 1, would weaken those outcome-specific expectancies, and would thus make the features less discriminable. Hence, more transfer would be observed after positive-patterning than after feature-positive training.

Although that account is consistent with the transfer data of Experiment 1, it is not clear in Experiments 2 and 3 why any increased generalization between the features as a result of extra presentations of one of them should be asymmetrical, as would be necessary for one, but not the other, feature to show enhanced transfer, as observed. Thus, the data reported here, as well as those of Davidson and Rescorla (1986), may force a revision of my earlier claims that occasion setting in rats is target-specific (Holland, 1983, 1986b). Note, however, that a weaker version of my claims about transfer is still viable: there is less transfer of occasion setting than of simple conditioning powers of CSs. In all of the circumstances in which I found little or no transfer of occasion setting, the simple response-evoking powers of CSs transferred very well (e.g., Holland, 1983, 1985, 1986a, 1986b, 1989a, 1989b; Lamarre & Holland, 1987).

One way to deal with transfer of occasion setting is to accept Rescorla's (1985) claims that occasion setters act by raising the excitability of a representation of the US. Thus, in the presence of an occasion setter, any cue with normally subthreshold association with that US (such as the target in a serial feature-positive discrimination) might be capable of eliciting a CR. However, in these and other recent experiments (Holland, 1989a, 1989b), despite observing substantial transfer to cues trained as targets of other occasion setters, I have not observed transfer to cues not so trained, even when those cues evoked larger CRs when presented alone than did the former targets. On the other hand, with pigeons, Rescorla (1985, 1986) typically observed transfer to trained and extinguished cues, but not to weak, consistently reinforced exciters. He suggested that only exciters with ambiguous relationships to the US are susceptible to the changes in US excitability

caused by occasion setters. Hence, Rescorla's account must also be modified to deal effectively with the existing transfer data.

The observation that transfer of occasion setting is limited to targets of other occasion setters is consistent with other claims that simple associative and occasion-setting properties of CSs are largely independent (e.g., Holland, 1983, 1985; Rescorla, 1985; Ross & LoLordo, 1986). Furthermore, it is consistent with Holland's (in press) and Ross et al.'s (1984) suggestion that occasion setting involves different memory pathways than does simple association: transfer within a memory system might be more likely than transfer between systems.

REFERENCES

- DAVIDSON, T. L., & RESCORLA, R. A. (1986). Transfer of facilitation in the rat. *Animal Learning & Behavior*, **14**, 380-386.
- HOLLAND, P. C. (1977). Conditioned stimulus as a determinant of the form of the Pavlovian conditioned response. *Journal of Experimental Psychology: Animal Behavior Processes*, **3**, 77-104.
- HOLLAND, P. C. (1983). Occasion-setting in Pavlovian feature positive discriminations. In M. L. Commons, R. J. Herrnstein, & A. R. Wagner (Eds.), *Quantitative analyses of behavior: Discrimination processes* (Vol. 4, pp. 183-206). New York: Ballinger.
- HOLLAND, P. C. (1985). The nature of conditioned inhibition in serial and simultaneous feature negative discriminations. In R. R. Miller & N. E. Spear (Eds.), *Information processing in animals: Conditioned inhibition* (pp. 267-297). Hillsdale, NJ: Erlbaum.
- HOLLAND, P. C. (1986a). Temporal determinants of occasion setting in feature-positive discriminations. *Animal Learning & Behavior*, **14**, 111-120.
- HOLLAND, P. C. (1986b). Transfer after serial feature positive discrimination training. *Learning & Motivation*, **17**, 243-268.
- HOLLAND, P. C. (1989a). Acquisition and transfer of conditional discrimination performance. *Journal of Experimental Psychology: Animal Behavior Processes*, **15**, 154-165.
- HOLLAND, P. C. (1989b). Conditioned stimulus intensity affects occasion setting in simultaneous feature positive discriminations. *Journal of Experimental Psychology: Animal Behavior Processes*, **15**, 183-193.
- HOLLAND, P. C. (in press). Forms of memory in Pavlovian conditioning. In J. L. McGaugh, N. M. Weinberger, & G. Lynch (Eds.), *Brain organization and memory: Cells, systems, and circuits*. New York: Oxford University Press.
- HOLLAND, P. C., & FORBES, D. T. (1982). Representation-mediated extinction of flavor aversions. *Learning & Motivation*, **13**, 454-471.
- HOLLAND, P. C., & ROSS, R. T. (1981). Within-compound associations in serial compound conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, **7**, 228-241.
- HOLLAND, P. C., & ROSS, R. T. (1983). Savings test for associations between neutral stimuli. *Animal Learning & Behavior*, **11**, 83-90.
- LAMARRE, J., & HOLLAND, P. C. (1987). Acquisition and transfer of serial feature negative discriminations. *Learning & Motivation*, **18**, 319-342.
- MOORE, J. W., NEWMAN, F. L., & GLASGOW, B. (1969). Intertrial cues as discriminative stimuli in human eyelid conditioning. *Journal of Experimental Psychology*, **79**, 319-326.
- RESCORLA, R. A. (1985). Inhibition and facilitation. In R. R. Miller & N. E. Spear (Eds.), *Information processing in animals: Conditioned inhibition* (pp. 299-326). Hillsdale, NJ: Erlbaum.
- RESCORLA, R. A. (1986). Extinction of facilitation. *Journal of Experimental Psychology: Animal Behavior Processes*, **12**, 16-24.
- ROSS, R. T. (1983). Relationships between the determinants of performance in serial feature positive discriminations. *Journal of Experimental Psychology: Animal Behavior Processes*, **9**, 349-373.
- ROSS, R. T., & HOLLAND, P. C. (1981). Conditioning of simultaneous

- and serial feature-positive discriminations. *Animal Learning & Behavior*, **9**, 293-303.
- ROSS, R. T., & HOLLAND, P. C. (1982). Serial positive patterning: Implications for "occasion setting." *Bulletin of the Psychonomic Society*, **19**, 159-162.
- ROSS, R. T., & LoLORDO, V. M. (1986). Blocking during serial feature-positive discriminations: Associative versus occasion-setting functions. *Journal of Experimental Psychology: Animal Behavior Processes*, **12**, 315-324.
- ROSS, R. T., ORR, W. B., HOLLAND, P. C., & BERGER, T. W. (1984). Hippocampectomy disrupts acquisition and retention of learned conditional responding. *Behavioral Neuroscience*, **98**, 211-225.
- SKINNER, B. F. (1938). *The behavior of organisms*. New York: Appleton-Century.
- TRAPOLD, M. A. (1970). Are expectancies based upon different positive reinforcing events discriminably different? *Learning & Motivation*, **1**, 129-140.

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Announcement

19th Annual Meeting of the Society for Computers in Psychology Atlanta, Georgia November 16, 1989

The 19th Annual Meeting of the Society for Computers in Psychology will be held at the Hyatt Regency Hotel in Atlanta, Georgia on November 16, 1989. As usual, this meeting will feature papers on applications of computers to all areas of psychology—experimental, clinical, and educational.

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