Transfer of Control in Ambiguous Discriminations

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Rats' acquisition and transfer of performance in ambiguous discriminations was examined using discrete-trial operant lever-press procedures. Rats learned serial ambiguous discriminations (X→A+, A--; B+, X→B+) by acquiring both positive and negative occasion setting functions to the X feature. Mutual transfer occurred among cues from serial ambiguous, feature positive (Y→C+, C−), and feature negative (Y→C−, C+) discriminations, but that transfer did not extend to cues not trained within one of those serial discriminations. The ambiguous feature's positive occasion setting powers were unaffected by nonreinforced presentation of that feature alone, and posttraining counterconditioning did not eliminate the feature's ability to serve as a negative occasion setter. Occasion setting was not acquired with simultaneous ambiguous discriminations (XA+, A--; XB−, B+), which apparently were solved with a configural strategy.

Considerable evidence from Pavlovian conditioning experiments (e.g., Holland, 1985; Rescorla, 1985) suggests that under some circumstances, a stimulus can come to modulate the action of associations between another conditioned stimulus (CS) and the unconditioned stimulus (US). For example, in a serial feature positive (X→A+, A−) discrimination, X may set the occasion for responding based on an A-US association. This occasion setting power of X seems largely separate from any simple excitatory or inhibitory powers it may have as a consequence of its own associations with the US: Manipulations that affect the simple associative strength of X often leave its occasion setting powers unaltered, or even have opposite effects on occasion setting (e.g., Holland, 1985, 1989a, 1989b, 1989c; Rescorla, 1985, 1986).

Two casual descriptions of the action of occasion setters were offered initially. Rescorla (1985) suggested that they acted on a representation of the US, either raising or lowering the threshold of its activation by A. In an A→XA+, A− discrimination, for example, A's associative strength is insufficient to activate the US representation, unless the presentation of X has lowered the activation threshold of that representation. On the other hand, Holland (1983) proposed that X acted on the A-US association or unit itself in a hierarchical fashion. In a feature positive discrimination, the particular A-US association is ineffective in activating the US representation, unless it is enabled by X. Thus, in Holland's (1983) view, the action of occasion setters is highly specific, but in Rescorla's (1985) view, the action of occasion setters is quite general.

Neither view is consistent with existing data from transfer experiments. Within Holland's (1983) notion, X should only modulate responding based on A-US associations; according to Rescorla's (1985) notion, X should modulate responding of any CS associated with the US. However, the bulk of the available data indicate that X's occasion setting powers in transfer tests depend on the nature of training received by the transfer target. For example, in X→A+, A− discriminations, Holland (1986, 1989a) found that although X had no effect on responding elicited by a cue that had been nonreinforced, weakly trained, or first trained and then extinguished, X facilitated responding to a cue that had itself been trained as a target of an occasion setter (e.g., B, from a Y→B+, B− discrimination). This transfer to B contradicts Holland's view, and the lack of transfer to cues with other training histories denies Rescorla's view.

Recently, Holland and Reeve (in press) presented further evidence against the view that occasion setters act generally on a US representation (Wilson & Pearce, 1989, provided similar evidence from a slightly different conditioning preparation). Using a discrete-trial operant lever-pressing paradigm, Holland and Reeve trained rats on an "ambiguous" discrimination, in which a single feature cue (X) signaled reinforcement of one target and nonreinforcement of another target (X→A+, A−; X→B+, B−). If X's modulatory power involved raising or lowering the activation threshold of the US, then within Rescorla's (1985) view, the rats could use the modulatory strategy to solve either the X→A+, A− or the B+, X→B− discrimination, but not both: X could not both raise and lower that threshold, without some additional, CS-specific mechanism.

The rats learned these discriminations readily in Holland and Reeve's (in press) experiments. In fact, solution of the ambiguous discrimination was no more difficult than that of either component discrimination alone: Rats learned the X→A+, A−, X→B−, B+ discrimination as quickly as other rats learned either an X→A+, A−, X−, B+ (positive patterning) discrimination or an X→B−, B+, A−, X+ (negative patterning) discrimination. Furthermore, X did not enhance responding evoked by another, weakly trained cue or suppress responding evoked by an extensively trained cue.

The experiments reported here further explored the nature of stimulus control established in X→A+, A−, X→B−, B+

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discriminations by examining X's ability to modulate responding to other cues that were trained as targets of feature positive (Y → C+, C−), feature negative (Y → C−, C+), or ambiguous (Y → C+, C−; Y → D−, D+) discriminations. The primary empirical question was whether an ambiguous X's powers would transfer to cues that were themselves trained as targets of occasion setters, as in Holland's (1989a, 1989c) experiments with positive or negative features. Furthermore, would transfer be limited to cues trained as the targets of other ambiguous discriminations, or would a target of any occasion setter be sufficient? Information about the nature of training that is necessary for a cue to be an adequate transfer target in this ambiguous discrimination would be informative about the nature of occasion setting.

These experiments also considered a configural account for the establishment of ambiguous discrimination performance. Perhaps Holland and Reeve's (in press) rats simply learned to respond in the presence of a cue unique to the X → A configuration and to withhold responding in the presence of a unique X → B configuration. As long as those two configurations were perceptually distinct, the rats should have relatively little difficulty learning the ambiguous discrimination. Similarly, because their response tendencies were established to particular configural cues, the lack of transfer to compounds of X with other cues (e.g., X → C) would be anticipated. Consistent with this view, Holland and Reeve found the major patterns of acquisition and transfer to be similar, regardless of whether simultaneous or serial compound cues were used in the ambiguous and patterning discriminations described earlier.

A simple configural view would, however, predict lack of transfer to new compounds of the ambiguous feature with other targets, regardless of the training history of those targets, whereas an occasion setting account would anticipate transfer to depend on the transfer target's training history. Experiments 1 and 2 examined the transfer of an ambiguous feature's stimulus control after serial and simultaneous ambiguous discrimination training, respectively. The patterns of transfer were very different in those two experiments and were consistent with the notion that occasion setting was used to solve the serial discrimination and that a configural process was used to solve the simultaneous discrimination. Experiment 3 then investigated the independence of the ambiguous feature's occasion setting and response-evocation powers after serial ambiguous discrimination training. All three experiments used the discrete-trial operant lever-press conditioning procedure used by Holland and Reeve (in press).

Experiment 1

Experiment 1 examined the mutual transfer of the occasion setting powers of features trained in serial ambiguous, feature positive, and feature negative discriminations. If ambiguous discrimination training endows the ambiguous feature with the properties of both a positive and negative occasion setter, then it should modulate responding to the targets of other feature positive and feature negative discriminations as well as to the targets of other ambiguous discriminations.

All subjects were trained with an ambiguous C → H+, H−, C → N−, N+ discrimination procedure (the letters signify the identities of the cues, which will be described later). In separate groups, those ambiguous training trials were intermixed with training on a P → T+, T− serial feature positive discrimination (Group FP); a P → T−, T+ serial feature negative discrimination (Group FN); a P → T±, T± pseudodiscrimination, in which the serial compound and T alone were both reinforced and nonreinforced with equal probability (Group PD); a P → T+, T−, P → D−, D+ serial ambiguous discrimination (Group AMB+); or a P → D+, D−, P → T−, T+ serial ambiguous discrimination (Group AMB−). The purpose of running two groups with an additional ambiguous discrimination was to counterbalance the T and D cues, so that comparisons across all groups would involve responding during the same transfer target cue, T. Thus, in Group AMB+, T was the target of the positive component of the ambiguous discrimination, and in Group AMB−, it was the target of the negative component. Finally, the ability of the ambiguous feature (C) to modulate responding evoked by the T target and the ability of the other feature (P) to modulate responding to the H and N targets were examined in transfer tests.

Method

Subjects and apparatus. The subjects were 20 male and 20 female albino rats, bred from Charles River (Raleigh, North Carolina) stock in a Duke University psychology department facility. At the beginning of the experiment, they were 150 days old and experimentally naive. The rats were maintained at 80% of their ad lib body weights throughout the experiment by limiting their access to food. Water was available at all times in their individual home cages.

There were eight identical experimental chambers, each 22.9 × 20.3 × 20.3 cm. The front and back walls of each chamber were aluminum; the side walls and top were clear acrylic. A food cup was recessed behind a 5 × 5 cm opening in the front wall; the bottom of the opening was 2 cm from the floor, and its center was 2 cm to the right of the center of the front wall. A 6-W jewelled lamp ("panel light") was centered on the front wall, 4 cm above the top of the food cup opening. Four centimeters to the left of the food cup opening was a 2 × 2 cm lever, mounted 3 cm above the floor. During the first 4 sessions of lever-press training, the lever was enlarged by clipping a 3.3 × 1.5 cm metal paper clamp over it. The floor of the chamber was composed of 0.48-cm stainless steel rods spaced 1.9 cm apart. Each of the chambers was enclosed in a sound-attenuating shell.

A 6-W houselight was mounted on one wall of the shell, 10 cm above the top of the chamber and 2 cm in front of and 10 cm to the left of the front wall of the chamber. Another 6-W lamp (door light) was mounted directly opposite the houselight, behind a directional lens. Thus, facing the food cup, the houselight was to the left and above the front panel of the chamber; the door light was to the right and above that wall; and the panel light was in the center, near the top of that wall panel. Except when one of the three lights was illuminated as a signal, the chambers were dark.

Ten centimeters below the houselight, there were two speakers for delivering the auditory CSs: a 72-dB (A) square wave, 1500-Hz tone; a 72-dB white noise; and a 68-dB, 8-Hz clicker. The tone and clicker were presented through one speaker and the noise through the other.

Finally, each shell was enclosed in another sound-attenuating box. Constant background noise (62.5 dB) was provided by a ventilating fan on each box.

Procedure. The rats were first trained to eat from the food cup and to press the lever. Each rat received two 1-hr sessions in which
each lever press was reinforced with a 0.3-ml delivery of 0.2 M sucrose, and sucrose was delivered on a variable time (VT) 2-min schedule during the first 40 min of the session. Any rat that did not make at least 50 presses during the second session received a third session, which was terminated as soon as the rat made 50 presses in that session.

Next, all rats were trained to respond during a noise cue for two 30-min sessions. In each session, there were 40 presentations of the noise, during which each lever press produced sucrose delivery. In the first session, each noise presentation was 30 s long, and in the second session, each noise presentation was 15 s long.

Four male and 4 female rats were then randomly assigned to each of the eight sessions of preliminary training, the rats in all groups received 20 C–→ H+ and 20 N+ trials, the reinforced cues to be used within the ambiguous discrimination in the next phase. C–→ H+ trials comprised a 5-s presentation of the clicker, followed, after a 5-s trace interval, by a 5-s steady illumination of the houselight; lever pressing during the houselight was reinforced with sucrose. N+ trials comprised 5-s noise presentations, during which each lever press was reinforced.

In addition to these trials from the ambiguous discrimination, the rats in each group received presentations of the reinforced cues to be used in the other discrimination. In each session, the rats in Group FP received 20 P–→ T+ trials, which comprised a 5-s intermittent (3 Hz) illumination of the panel light, followed, after a 5-s empty interval, by a 5-s presentation of the tone; lever presses during the tone were reinforced. The rats in Group FN received 20 T+ trials (5-s reinforced tone presentations), and the rats in Group PD received 10 T+ and 10 P–→ T– trials. The rats in Group AMB+ received 10 P–→ T+ trials and 10 reinforced 5-s D+ trials (reinforced illuminations of the door light). The rats in Group AMB– received 10 T+ trials and 10 P–→ D– trials, which comprised a 5-s illumination of the panel light, followed, after a 5-s empty interval, by a 5-s illumination of the door light; lever presses during the illumination of the door light were reinforced. The first 6 sessions of this phase were 60 min long, and the last 2 sessions were 90 min long.

All rats then received 40 sessions of discrimination training. Table 1 shows an outline of the procedures of this and the remaining phases of Experiment 1. In each session, all subjects received training on the ambiguous discrimination, which consisted of four kinds of trials: reinforced C–→ H+ and N+ trials, just described, and nonreinforced H– and C–→ N– trials. H– trials were 5-s presentations of the houselight, and each C–→ N– trial comprised a 5-s presentation of the clicker, followed, after a 5-s empty trace, by a 5-s presentation of the noise. Each 90-min session contained 10 of each of these trial types.

The ambiguous discrimination-training trials were intermixed with various sorts of training of one or more transfer target stimuli. In group FP, the tone was the target of a serial feature positive, P–→ T+, T– discrimination. Each session included 10 P–→ T+ trials (described previously) and 10 nonreinforced 5-s presentations of the tone alone (T–). In Group FN, the tone was the target of a feature negative T+, P–→ T– discrimination. Each session included 10 reinforced 5-s presentations of the tone alone (T+) and 10 nonreinforced P–→ T– trials, which comprised a 5-s panel light, followed, after a 5-s trace interval, by a 5-s tone presentation. In Group PD, the tone was the target of a pseudosequential discrimination, T+, P–→ T+, T–, T+, T–. Each session included five of each of those four kinds of trials. In Groups AMB+ and AMB–, the tone and door light (D) cues were the targets of another ambiguous discrimination. In Group AMB+, that discrimination was P–→ T+, D+, P–→ D–; and in Group AMB–, it was P–→ T–, D+, P–→ D–. For these two groups, each discrimination-training session included 10 presentations of each of these trial types.

The rats then received four 90-min test sessions. Test Sessions 1 and 4 examined the ambiguous clicker (C) feature’s ability to modulate responding to its original targets, H and N, and to the transfer target, T. For each group, each of these sessions included all of the trial types experienced in discrimination training, plus nonreinforced C–→ T–, C–→ N– trials, and nonreinforced C–→ D– presentations, randomly intermixed. In addition, the rats in Groups AMB+ and AMB– received nonreinforced C–→ O– presentations. In each session, there were eight of each kind of trial, except in Group PD in which there were four each of Trial Types T+, T–, P–→ T+, and P–→ T– and eight of each of the other trial types.

Test Sessions 2 and 3 examined the ability of the other feature to modulate responding evoked by H and N, the original targets of C. These sessions included all of the trial types from discrimination training, plus nonreinforced P–→ O–, P–→ H–, and P–→ N– trials, randomly intermixed. In each session, there were eight of each of the trial types.

### Table 1

#### Outlines of Major Procedures of Experiments 1 and 2

<table>
<thead>
<tr>
<th>Group</th>
<th>Discrimination</th>
<th>Test 1 &amp; 4</th>
<th>Test 2 &amp; 3</th>
<th>Retrain</th>
<th>Test 5</th>
</tr>
</thead>
</table>

**Note:** The procedures of Experiment 2 were identical to those for Experiment 1, except that all compounds were simultaneous, rather than serial, and there was no Group AMB–. A plus (+) indicates that lever presses during that cue were reinforced, a minus (−) indicates that lever presses were not reinforced, and an arrow (→) indicates a serial compound in which two 5-s cues were separated by a 5-s empty trace interval. C = clicker; D = door light; H = houselight; N = noise; P = panel light; T = tone; and 0 = no event.
kind of trial, except in Group PD in which there were four each of Trial Types T+, T−, P→T− and eight each of the other trial types.

Because near-maximal levels of responding were controlled by the T target when it was presented alone in Groups FN, PD, and AMB−, Tests 1 and 4 did not permit examining whether an ambiguous feature would further facilitate responding to such targets. Similarly, because near-minimal levels of responding were controlled by the T target in Groups FP and AMB+, Tests 1 and 4 did not permit examining whether an ambiguous feature would further suppress responding to those targets. To answer these questions, after Test 4, the level of responding controlled by T alone was manipulated to intermediate levels in all groups, and Transfer Test 5 was conducted. In each of four retraining sessions—along with 10 each of Trial Types C−H+, H−, C−N−, and N+−the rats in Groups FN and PD received 20 nonreinforced T− presentations; the rats in Group FP received 20 reinforced T+ presentations; the rats in Group AMB+ received 20 reinforced T+ and 20 nonreinforced D− trials; and the rats in Group AMB− received 20 reinforced D+ and 20 nonreinforced T− trials. Finally, the rats received Test Session 5, which was identical to Test Session 1.

Data analysis. We recorded the rate of lever pressing, the percentage of trials on which at least one response occurred, and the latency of the first response, during each 5-s interval of the CS presentations and the 5-s pre-CS interval. However, response rates did not provide an appropriate measure of performance on reinforced trials: Response rates were artificially suppressed on those trials, because the rats did not press for several seconds after sucrose was delivered. Neither the latency nor the percentage of trials with a response measures was affected in this manner. Those two measures were closely related throughout the experiment and led to identical conclusions. Because the percentage trials with a response measure was reported in previous studies (Holland, in press; Holland & Reeve, in press), I selected that index as the primary measure in the present experiments.

However, because in some conditions nearly every subject responded on every trial, it might be argued that the percentage trials with a response measure was relatively insensitive. Consequently, I supplemented the percentage trials with a response measure with latency data for the test sessions. At least compared with other unpublished data from this laboratory, the floor of the latency measure (well under 1 s) was not closely approached in the present experiments, suggesting that the latency measure provided an appropriate, more sensitive measure of strong response tendencies.

To provide simple indexes of discrimination performance during the discrimination training phases of these experiments, discrimination difference scores were calculated by subtracting the percentage of nonreinforced trials on which a response occurred from the percentage of reinforced trials on which a response occurred. In Experiment 1, for the discriminations that involved H, these scores were constructed from responding during H on C−H trials and on H-alone trials, and for the discriminations that involved N, they were constructed from responding during N on N and C−N trials. Analogous difference scores were constructed for the latency measure, except the latency on reinforced trials was subtracted from that on nonreinforced trials.

The measure of central tendency reported here is the median. Two-sided, distribution-free inferential statistics were used throughout, with the level of significance defined as .05.

Results

Except for the first few conditioning sessions, throughout the experiment the rats pressed during fewer than 10% of the pre-CS intervals. I do not discuss pre-CS responding further.

Discrimination training. The top two panels of Figure 1 show the acquisition of the ambiguous discrimination in Experiment 1. As in Holland and Reeve’s (in press) experiments, the subjects in Groups FP, FN, and PD acquired the positive component of the ambiguous discrimination (C→H+ vs. H−) more rapidly than the negative component (N+ vs. C→N−) discrimination: Over the first half of training, the
difference scores for the positive component were greater than those for the negative component, Wilcoxon $T(8) \leq 2.5$. Acquisition of both of those discriminations was poorer, $U(8, 8) \leq 11.5$, in Groups AMB+ and AMB−, which also received training with another ambiguous discrimination. That disadvantage is scarcely surprising when it is noted that rats in Groups AMB+ and AMB− received another visual cue (door light), which generalizes considerably with the panel and houselights, and another discrimination to solve. However, by the final 10 training sessions, ambiguous discrimination performance was reasonably comparable across training conditions.

The bottom panel of Figure 1 shows the acquisition of the discriminations that involved the P feature. Consistent with the acquisition data of Holland and Reeve (in press), within-groups comparisons of discrimination performances over the first half of training showed that the ambiguous discrimination was no more difficult than the feature positive discrimination, Group FP, $T(8) = 17$; or the feature negative discrimination, Group FN, $T(8) = 16$. Of course, it must be recognized that the cues used in these discriminations were not counterbalanced within the groups, and so discrimination procedure was confounded with cue identity. Thus, although the results of the acquisition phase of Experiment 1 are consistent with Holland and Reeve’s findings, they do not permit similarly strong claims about the relative ease of learning the ambiguous discrimination. A similar caution is provided by the performance of the rats in Groups AMB+ and AMB−: Performance on the second ambiguous discrimination (with Feature P and Target T) in those groups was poorer than performance on the feature positive or feature negative discriminations in Groups FP and FN, respectively, $U(8, 8) \leq 12.5$. However, it must be remembered that the subjects in Groups AMB+ and AMB− were also considerably slower at learning the primary ambiguous discrimination than the other groups. Consequently, it is probably also inappropriate to compare the rates of ambiguous and feature positive or feature negative discrimination learning between groups in this experiment.

In both Groups AMB+ and AMB−, the second ambiguous discrimination component that involved the D target (not shown in Figure 1) was more difficult than the component that involved the T target, $T(8) \leq 3.5$. On the final block of training trials, the median D+ versus P→D− difference score in Group AMB+ was 40.0, and the median P→D+ versus D− difference score in Group AMB− was 46.7.

**Testing.** The principal data of Experiment 1 were those from the test sessions. Performance on all of the originally trained discriminations was maintained throughout testing (Table 2).

The results of transfer test trials in Tests 1–4 are shown in Figure 2 (percentage trials with a response) and Figure 3 (latency). Both measures yielded the same patterns of data and supported the same conclusions. The top panels of Figures 2 and 3 show the results of Tests 1 and 4, which evaluated the effects of the ambiguous feature (C) on the transfer target (T) in the various groups. The feature C augmented responding to T (i.e., reduced the response latency and increased the percentage of trials on which a response occurred) in both Group FP, in which T had been trained as the target of a feature positive discrimination with P as a feature, $T(8) = 0$, and in Group AMB+, in which T had been trained within an ambiguous discrimination in which T had been reinforced after P, $T(8) = 0$. In addition (not shown in Figures 2 and 3), in Group AMB−, C facilitated responding to the D target, which had also been reinforced after P within an ambiguous

| Table 2 |

*Original Discrimination Performance During Test Sessions of Experiment 1*

<table>
<thead>
<tr>
<th>Trial type</th>
<th>FP</th>
<th>FN</th>
<th>PD</th>
<th>AMB+</th>
<th>AMB−</th>
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<tr>
<td></td>
<td>% trials with a response by group</td>
<td>Latency (s) by group</td>
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<td></td>
<td></td>
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<tr>
<td>C→H+</td>
<td>97.7</td>
<td>89.8</td>
<td>96.9</td>
<td>92.7</td>
<td>97.9</td>
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<tr>
<td>H−</td>
<td>14.0</td>
<td>2.4</td>
<td>13.3</td>
<td>28.2</td>
<td>38.8</td>
</tr>
<tr>
<td>N+</td>
<td>97.7</td>
<td>90.7</td>
<td>94.5</td>
<td>91.7</td>
<td>96.8</td>
</tr>
<tr>
<td>C→N−</td>
<td>32.8</td>
<td>16.3</td>
<td>27.4</td>
<td>31.3</td>
<td>34.6</td>
</tr>
<tr>
<td>P→T</td>
<td>100.0</td>
<td>3.2</td>
<td>95.8</td>
<td>92.7</td>
<td>47.9</td>
</tr>
<tr>
<td>T</td>
<td>2.4</td>
<td>93.0</td>
<td>88.3</td>
<td>7.3</td>
<td>99.0</td>
</tr>
<tr>
<td>P→D</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>36.9</td>
<td>74.8</td>
</tr>
<tr>
<td>D</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>79.8</td>
<td>27.1</td>
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<table>
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<th>Tests 2 &amp; 3</th>
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<tr>
<td>C→H+</td>
<td>97.3</td>
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<td>H−</td>
<td>8.9</td>
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<td>N+</td>
<td>96.4</td>
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<td>T</td>
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<tr>
<td>P→D</td>
<td>—</td>
</tr>
<tr>
<td>D</td>
<td>—</td>
</tr>
</tbody>
</table>

*Note. Group designations and trial types are described in text. Only Groups AMB+ and AMB− received Trial Types P→D and D. C = clicker; D = door light; H = houselight; N = noise; P = panel light; and T = tone.*
Figure 2. Percentage of trials with a response in Test Sessions 1–4 in Experiment 1. ([top] Performance in Test Sessions 1 and 4, which assessed the powers of the ambiguous C feature. [center and bottom] Performance in Test Sessions 2 and 3, which assessed the P features' abilities to modulate the targets of the ambiguous discrimination. In all panels, unshaded bars represent performance during the second empty trace interval on feature-alone trials [during which a target cue would normally be presented], hatched bars represent performance during a target when it was preceded by the feature, and solid bars represent performance during a target cue when it was presented alone. The group names specify the nature of the additional discrimination in which T was trained [see Table 1].)

Figure 3. Latency to the first response during Test Sessions 1–4 in Experiment 1. ([top] Performance in Test Sessions 1 and 4, which assessed the powers of the ambiguous C feature. [center and bottom] Performance in Test Sessions 2 and 3, which assessed the P features' abilities to modulate the targets of the ambiguous discrimination. In all panels, unshaded bars represent performance during the second empty trace interval on feature-alone trials [during which a target cue would normally be presented], hatched bars represent performance during a target when it was preceded by the feature, and solid bars represent performance during a target cue when it was presented alone. The group names specify the nature of the additional discrimination in which T was trained [see Table 1].)

discrimination. The median percentage of C→D trials on which a response occurred during D was 85.5%, and the median latency of that responding was 2.51 s, compared with 27.1% and 4.24 s for responding to D alone, T(8) < 3.

Similarly, C suppressed responding to T (i.e., increased the response latency and reduced the percentage of trials on which
a response occurred) in both Group FN, in which T had been trained as a target of a feature negative discrimination, $T_s(8) \leq 1$, and in Group AMB-, in which T had been nonreinforced after P within an ambiguous discrimination, $T_s(8) \leq 1.5$. Furthermore, in Group AMB+, C suppressed responding to the D target, which had also been nonreinforced after P within an ambiguous discrimination, 38.4% and 3.01 s during D on C→D trials versus 79.8% and 2.18 s on D-alone trials, $T_s(8) \leq 1$. Thus, the ambiguous C feature effectively modulated responding to targets of other ambiguous, feature positive, and feature negative discriminations.

Conversely, C had no significant effect on responding to T in Group PD, in which T was involved in a pseudodiscrimination, $T_s(8) \geq 13$. Furthermore, the discrimination difference scores (C→T minus T for percentage trials with a response, and T minus C→T for latency) in that group were reliably smaller than those in any of the other groups, $U_s(8, 8) \leq 5$, indicating less transfer in that group than in any of the others.

The center and lower panels of Figures 2 and 3 show the results of Tests 2 and 3, which examined the effects of the P features trained in feature positive, feature negative, ambiguous, or pseudodiscrimination procedures on the targets trained in the ambiguous discrimination. The center panels show the effects of P on responding during the H target, which in training was reinforced only when it was preceded by C. Responding to H was enhanced by P only when P had been trained within a feature positive discrimination, Group FP, $T_s(8) = 0$, or another ambiguous discrimination, Groups AMB+ and AMB-, $T_s(8) = 0$. There was no evidence that a feature trained in either a pseudodiscrimination or a feature negative discrimination could enhance responding to a target that was trained within the positive component of an ambiguous discrimination: Responding on P→H trials did not differ significantly from responding on H trials in either Groups PD or FN, $T_s(8) \geq 8$. Between-groups analyses support these claims of differential transfer across conditions: The P→H versus H difference scores in Groups FP, AMB+, and AMB- each were reliably greater than those in Groups FN and PD, $U_s(8, 8) = 0$, which did not differ from each other.

Likewise, responding during the N target (bottom panels of Figures 2 and 3), which was reinforced only when it was not preceded by C, was reliably suppressed by the P feature only when P had been trained within a feature negative discrimination, Group FN, $T_s(8) = 0$, or another ambiguous discrimination, Group AMB+, $T_s(8) = 0$; Group AMB-, $T_s(8) \leq 1.5$. There was no evidence that a feature trained in either a pseudodiscrimination or a feature positive discrimination could suppress responding to a target that was trained within the negative component of an ambiguous discrimination (N). Responding on N trials did not differ significantly from responding on P→N trials in either Group FP or PD, $T_s(8) \geq 9.5$. Between-groups analyses support these claims of differential transfer across conditions. For both response measures, the N versus P→N difference scores in Groups FN, AMB+, and AMB- were each reliably greater than those in Group PD, $U_s(8, 8) \leq 13$, indicating greater transfer in those groups than in the pseudodiscrimination control. The differences in latencies in those three groups also were reliably greater than those in Group FP, $U_s(8, 8) \leq 12$, but the differences in percentage trials with a response were not, $U_s(8, 8) \geq 14$. Groups FP and PD did not differ reliably in their display of either difference measure.

Figure 4 shows the results of Test 5, which examined C's ability to modulate responding controlled by T after the level of that responding was manipulated. The pattern of transfer effects was the same as that seen in Tests 1 and 4, suggesting that transfer depended on the specific type of conditional discrimination training history of the target transfer, rather than the level of responding controlled by that target alone at the time of test. Even when all targets controlled intermediate levels of responding, which could potentially be either enhanced or suppressed by the influence of other cues, responding controlled by the targets of feature negative training could only be suppressed, not enhanced, by an ambiguous feature, and responding controlled by the targets of feature positive training could only be augmented, not suppressed, by an ambiguous feature.

First, C suppressed responding controlled by a previous target of a negative occasion setter in Groups FN and AMB-,
even when that target controlled relatively low levels of responding, \(T_s(8) \leq 3\). Second, \(C\) facilitated responding controlled by a previous target of a positive occasion setter in Groups FP and AMB+, even when that cue alone controlled substantial responding, \(T_s(8) \leq 2.5\). Third, \(C\) had no effect on responding to the target of the pseudodiscrimination in Group PD, \(T_s(8) = 13\). Between-groups comparisons showed transfer to be greater in Groups FP, FN, AMB+, and AMB− than in Group PD: The \(C\rightarrow T\) versus \(T\) difference scores were reliably smaller in Group PD than in either Groups FP or AMB+, \(U_s(8, 8) \leq 12.5\), and reliably larger than in either Groups FN or AMB−, \(U_s(8, 8) \leq 11\).

**Discussion**

These data have several implications. First, it is unlikely that the rats used a simple configural strategy to solve the ambiguous discriminations: Discrimination performance readily transferred to other target cues, but that transfer depended on the training history of the target, rather than its physical identity or the level of responding it controlled (this point is considered further in the General Discussion section). Instead, an occasion setting strategy seems more likely: Elsewhere (e.g., Holland, 1989a), I have reported similar training-dependence of transfer of Pavlovian occasion setting.

Second, the ambiguous discrimination procedure gave its feature (\(F\)) both positive and negative occasion setting properties: \(C\) facilitated responding to the \(T\) target in Group FP and suppressed responding to the \(T\) target in Group FN (top panels of Figures 2 and 3).

Third, the ambiguous discrimination procedure apparently endowed its targets (\(H\) and \(N\)) with the same properties as possessed by the targets of positive and negative occasion setters, respectively. In Group FP, the \(H\) target was an acceptable target for the \(P\) feature from a serial feature positive discrimination, and in Group FN the \(N\) target was an acceptable target for the \(P\) feature from a serial feature negative discrimination (center and bottom panels of Figures 2 and 3).

Fourth, occasion setting training apparently endowed both the occasion setter and its target or targets with special properties. Both the features and the targets had to be trained within one of the discriminations to modulate responding to a target or to serve as a target of modulation, respectively. In Group PD, in which the feature and target were trained within a pseudodiscrimination, the feature did not modulate responding to either target of an ambiguous discrimination, and responding evoked by the target of the pseudodiscrimination was not modulated by the feature from an ambiguous discrimination. Thus, the transfer of occasion setting to targets of occasion setters cannot be attributed solely to special properties of either the target (see also Davidson & Rescorla, 1986; Rescorla, 1985) or the feature alone.

Fifth, both the occasion setter (feature) and target within these serial discriminations seem to be coded with respect to whether they were involved in positive or negative discriminations. In Group FP, the \(P\) feature (trained within a serial feature positive discrimination) only enhanced responding. And in Group FN, the \(P\) feature (trained within a serial feature negative discrimination) only suppressed responding, even to otherwise acceptable targets of transfer (see center and bottom panels of Figures 2 and 3). Analogously, although the ambiguous \(C\) feature had both facilitatory and suppressive powers, its effects on responding to \(T\) were unidirectional in Groups FP and FN (see the top panels of Figures 2 and 3 and both panels of Figure 4). Likewise, within the ambiguous discriminations, responding to the \(H\) target was only facilitated, and responding to the \(N\) target was only suppressed by the various occasion setting features, regardless of the level of responding controlled by those targets at the time of test. Even the ambiguous features had only unidirectional effects on individual targets from another ambiguous discrimination (see the top panels of Figures 2 and 3 and Figure 4).

**Experiment 2**

Experiment 2 was similar to Experiment 1, except that the cues were arranged simultaneously, rather than serially, during the compounds and the roles of the tone and door light targets were not counterbalanced in the group that received two ambiguous discriminations (Group AMB). If, as Holland and Reeve (in press) suggested, simultaneous ambiguous discriminations are solved with a configural process distinct from occasion setting, then patterns of transfer quite different from those observed in Experiment 1 would be anticipated. To the extent that the various transfer compounds were perceptually distinct from the training compounds, no transfer to new compounds would be expected, regardless of the training history of the transfer targets (Holland, 1989a).

**Method**

**Subjects and apparatus.** The subjects were 16 male and 16 female albino rats, bred in a psychology department facility from Charles River stock. They were experimentally naive and about 240 days old at the beginning of the experiment. They were maintained as in Experiment 1. Four male and 4 female rats were randomly assigned to each of the four groups in Experiment 2.

**Procedure.** The rats were first trained to eat from the food cup and press the lever in a single 60-min session. Throughout that session, the rats received a 0.3-ml delivery of 0.2 M sucrose for each lever press, and during the first 40 min, sucrose deliveries occurred on a VT 2-min schedule. The next 8 sessions were designed to establish discriminative control by the cues to be reinforced later in training (except for their durations, the cues used in this experiment were identical to those used in Experiment 1). In each of the first 2 of these sessions, each lever press during a noise cue (\(N\)) was reinforced. The first session was 60 min long and included thirty 30-s \(N\) presentations. The second session was 90 min long and included thirty 15-s \(N\) presentations; all subsequent stimulus presentations were 15 s long in this and later phases of the experiment. The next 6 sessions were all 90 min long and, in all groups, included 20 \(N\) presentations and 20 presentations of a clicker + houselight cue (\(CH\)). In addition, there were 20 presentations of a panel light + tone compound (\(PT\)) in Group FP, 20 tone (\(T\)) presentations in Group FN, 10 \(PT\) and 10 \(T\) presentations in Group PD, and 10 \(PT\) presentations and 10 door light (\(D\)) presentations in Group AMB. Each lever press during any of the cues was reinforced, but presses in the absence of these cues had no scheduled consequence.

Next, the subjects received discrimination training. Table 1 shows an outline of the remaining procedures of Experiment 2. In each 90-
in all four groups. In each session, the rats in Group FP received 10 reinforced PT+ presentations and 10 nonreinforced T− presentations; the rats in Group FN received 5 reinforced T+ presentations, 5 nonreinforced T− presentations, 5 reinforced PT+, and 5 nonreinforced PT− presentations; and the rats in Group AMB received 10 reinforced PT+ presentations, 10 nonreinforced T− presentations, 10 reinforced D+ presentations, and 10 nonreinforced panel light + door light (DP−) presentations. Group AMB received 40 discrimination training sessions, and the other three groups received 25 discrimination training sessions.

Finally, all rats received four identical 90-min test sessions. In each of Test Sessions 1 and 4, the rats received eight presentations of each of the kinds of trials they received in discrimination training, plus eight nonreinforced presentations of the clicker alone (C) and eight nonreinforced presentations of a clicker + tone compound (CT). Group AMB also received eight nonreinforced presentations of a clicker + door light (CD) compound. In each of Test Sessions 2 and 3, the rats received eight presentations of each of the kinds of trials they received in discrimination training, plus eight nonreinforced presentations of the panel light alone (P), eight nonreinforced presentations of the panel light + noise compound (PN), and eight nonreinforced presentations of a panel light + houselight (PH) compound.

Results

Discrimination training. Consistent with previous findings with feature positive and feature negative discriminations (e.g., Holland, 1989c) in all groups of subjects, acquisition of the primary, CH+, H−, N+, CN−, ambiguous discrimination proceeded more rapidly than the acquisition of the comparable serial discrimination in Experiment 1 (compare Figures 1 and 5). However, because of minor differences in the pretraining procedures of the two experiments, a direct comparison of acquisition rates may be inappropriate.

In all four groups, performance on the discrimination involving the H target (reinforced in compound with the C feature, top panel of Figure 5) was superior to performance on the discrimination involving the N target (nonreinforced in compound with C, center panel of Figure 5), $T(8) < 3$. There were no reliable differences among the various groups’ performances on these discriminations. Similarly, acquisition of the discriminations involving the T target (bottom panel of Figure 5) did not differ among Groups FP, FN, and AMB. However, acquisition of the D+ versus DP− discrimination ("D" discrimination, bottom panel of Figure 4) was very slow in Group AMB (probably because the bright, diffuse door light masked the dimmer, more localized panel light on DP− trials), necessitating the extended training of that group.

Testing. Because many subjects responded on 100% of certain types of test trials in all four test sessions, in this section, latencies to the first response are presented as well as the percentages of trials on which a response occurred.

Performance on the original discriminations remained intact throughout testing in all groups. Table 3 shows the percentages of trials on which a response occurred and response latencies for the various original discrimination cues during the test sessions.

The top panels of Figure 6 show the transfer test results of the first and fourth test sessions, which examined the effects
of the ambiguously trained C feature on responding to the T (or D) targets, which were trained within various other discriminations. As in Experiment 1, C had no effect on responding to the T target trained within a pseudodiscrimination, Group PD, $T(8) = 114$. However, unlike in Experiment 1, C exhibited no transfer to any of the targets, regardless of their training history. C did not facilitate responding to the T target of a feature positive discrimination, Group FP, $T(4) = 4$, four ties for percentage trials, and $T(8) = 4$ for latency, or suppress responding to the target of a feature negative discrimination, Group FN, $T(6) = 9.5$, two ties for percentage trials, and $T(8) = 11$ for latency, or to the D target of Group AMB, $T(8) =

Table 3

<table>
<thead>
<tr>
<th>Trial type</th>
<th>% trials with a response by group</th>
<th>Latency (s) by group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FP</td>
<td>FN</td>
</tr>
<tr>
<td>Tests 1 &amp; 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH+</td>
<td>97.6</td>
<td>89.9</td>
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<tr>
<td>H-</td>
<td>14.0</td>
<td>2.4</td>
</tr>
<tr>
<td>N+</td>
<td>97.6</td>
<td>90.6</td>
</tr>
<tr>
<td>CN-</td>
<td>32.8</td>
<td>6.2</td>
</tr>
<tr>
<td>PT</td>
<td>100.0</td>
<td>3.2</td>
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<td>T</td>
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<td>92.9</td>
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<td>—</td>
</tr>
<tr>
<td>D</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Tests 2 &amp; 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH+</td>
<td>97.3</td>
<td>98.2</td>
</tr>
<tr>
<td>H-</td>
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<tr>
<td>N+</td>
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<td>90.2</td>
</tr>
<tr>
<td>CN-</td>
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<td>11.6</td>
</tr>
<tr>
<td>PT</td>
<td>98.4</td>
<td>9.9</td>
</tr>
<tr>
<td>T</td>
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<td>96.4</td>
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<tr>
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<td>—</td>
<td>—</td>
</tr>
<tr>
<td>AMB</td>
<td>—</td>
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</tr>
</tbody>
</table>

Note. Group designations and trial types are described in text. Only Group AMB received Trial Types PD and D. C = clicker; D = door light; H = houselight; N = noise; P = panel light; and T = tone.

Figure 6. Percentage of trials with a response (left) and latency to the first response (right) in Test Sessions 1-4 in Experiment 2. (Top) Performance in Sessions 1 and 4, which assessed the powers of the ambiguous C feature to modulate responding to the T target or the D target [bars labeled D]. (Bottom) Performance in Sessions 2 and 3, which assessed the P features' abilities to modulate responding to the N target of the ambiguous discrimination. The group names specify the nature of the additional discrimination in which the T [and/or D] target was trained (see Table 1.)
17 for percentage trials, and $T(8) = 14$ for latency. Although in Group AMB the percentage of trials with a response was greater on CT compound trials than on T-alone trials, $T(8) = 2$, that responding can be attributed entirely to responding controlled by C alone: Responding during CT did not differ from that during C alone, $T(6) = 10.5$, two ties for percentage trials, and $T(7) = 11$, one tie for latency. The pattern of data shown in the top panels of Figure 6 is consistent with the rats' use of configural cues to solve the ambiguous discriminations and is very different from the pattern observed with serial compound training in Experiment 1 (see the top panels of Figures 2 and 3).

The bottom panels of Figure 6 show the results of Tests 2 and 3, which examined the effects of the P feature on responding to the reinforced N target of the ambiguous discrimination. In Group FN, P suppressed responding to N, $T(8) = 0$, as would be anticipated if the simultaneous feature negative training procedure (N+, PN–) had established P as a simple inhibitor (Holland, in press). P had no such suppressive effects in any of the other groups, and the suppressive effects of P were significantly larger in Group FN than in any other group: The N minus PN difference scores were greater in that group than in any of the others, $Us(8, 8) < 3$.

There was no evidence that P enhanced responding to H in any group, $T(8) \geq 15$ (in all groups, responding was observed on less than 20% of the PH and H trials, with latencies greater than 4 s). However, it is likely that the panel light (P) was masked by the bright houselight (H) target in this test, just as it was probably masked in acquisition by the door light in Group AMB. Thus, these data are probably uninformative and so are not presented here in detail.

**Discussion**

The lack of transfer in this experiment contrasts with the pattern of transfer observed in Experiment 1, which used serial compounds of these same cues. On the whole, I believe that the differential pattern of transfer between the experiments suggests that these serial and simultaneous ambiguous discriminations were solved in different fashions, as in the case of Pavlovian feature positive (Holland, 1989a) and feature negative discrimination training (Holland, 1989c).

This claim should be interpreted somewhat cautiously because some of the instances of failure of transfer in Experiment 2 are less informative than those in Experiment 1. For example, as I noted earlier, the effects of the P feature on responding to the H target in Tests 2 and 3 were uninterpretable, because the bright houselight may have masked the dimmer panel light cue. It might also be argued that the compound of clicker and tone in Tests 1 and 4 may have been subject to similar problems: Perhaps one of the cues effectively masked the other. Indeed, such a claim could be made about any simultaneous compound.

However, I believe most of the examples of failure of transfer observed in this experiment do not reflect simple masking effects. First, I have used compounds of these same cues (including clicker + tone) in several previous investigations (e.g., Holland, 1989a, 1989c, in press; Holland & Reeve, in press) and found little evidence for such masking effects:

After simple conditioning procedures, the responses to these compounds closely reflect responding to their constituent elements. Second, several of the test compounds in Experiment 2 involved cues of different modalities, which are unlikely to have interacted extensively. For example, in Tests 2 and 3, there was no evidence that an ambiguous panel light feature would inhibit responding controlled by the noise target of another ambiguous discrimination. Similarly, in Tests 1 and 4, there was no evidence that an ambiguous clicker feature would inhibit responding controlled by the door light feature of another ambiguous discrimination. It is worth pointing out that this failure to observe transfer between ambiguous discriminations is the principal finding of Experiment 2, and this finding seems less susceptible to masking interpretations, because of the involvement of cues from different modalities.

**Experiment 3**

The results of Experiments 1 and 2 indicate that the rats solved the serial and simultaneous discriminations in different manners. Experiment 3 examined further the mechanisms of solution of serial ambiguous discriminations. It considered first whether the feature's modulatory power is affected by increases or decreases in that feature's direct control over responding. After $T \rightarrow H^+, H^-, T \rightarrow N^-, N^+$ serial ambiguous discrimination training, responding during the trace intervals after $T$, in the absence of $H$ or $N$, was either reinforced or nonreinforced. Finally, T's ability to modulate responding during $H$ and $N$ was reassessed.

Holland (1989b, in press) found that positive occasion setting powers of a feature from serial feature positive or positive-patterning discriminations survived extensive nonreinforced exposure to that feature alone, even though simple conditioned responding directly elicited by that feature extinguished. Similarly, after serial feature negative training, the feature's negative occasion setting powers survived reinforced feature presentations that were sufficient to establish simple excitation to that cue and eliminate simple conditioned inhibition (Holland, 1989c, in press). Rescorla (e.g., 1985) found similar effects with pigeon subjects. Thus, in Experiment 3, retention of T's ability to modulate responding to $H$ and $N$, after responding controlled by T alone was explicitly reinforced or nonreinforced, would be indicative of occasion setting similar to that observed in previous experiments with serial feature positive and feature negative discriminations, both Pavlovian (Holland, 1989b, 1989c) and operant (Holland, in press).

Experiment 3 also addressed the involvement of response coding processes in the acquisition and transfer of serial ambiguous discrimination performance. For example, suppose, as Urciuoli and Honig (1980) suggested, that the true conditional cue in a discrimination such as $T \rightarrow H^+, H^-$ is not T itself, but the response pattern controlled by T. The rats might learn to respond to "$H$, given a previous response," and to withhold responding to "$H$, given no previous response." With this solution strategy, the observation of transfer of occasion setting powers to targets of other occasion setters would be anticipated, because all occasion setters would be functionally interchangeable by virtue of their con-
trolling similar patterns of responding. Furthermore, no transfer to targets that had not been trained within serial discriminations would be anticipated, because reinforcement for responding during those cues had never been made conditional on a prior response level.

Within this view, the posttraining modification of the response pattern controlled by T in Experiment 3 would be expected to alter responding to the H and N targets by removing the normal discriminative cues for responding or not responding to those cues. As a further test of this view, Experiment 3 also examined the effects on responding to the H and N targets of a test feature that controlled response patterns similar to those controlled by T, but that had not been trained as an occasion setter. If the response level controlled by T were the critical cue for modulating discrimination control by H or N, then any cue that engendered comparable response levels should also modulate responding to H and N. It is notable that Wilson and Pearce (1989) found that a cue trained separately from their ambiguous discrimination modulated responding to the various targets in the same manner as the explicitly trained ambiguous feature did.

Finally, in an attempt to further specify the nature of training necessary to make a cue an acceptable target of occasion setting in these procedures, Experiment 3 also examined T's ability to modulate responding controlled by a target that was partially reinforced. Several investigators (e.g., Bouton & Swartzentruber, 1986; Holland, 1986; Wilson & Pearce, 1990) have failed to observe transfer to such a cue in other situations thought to involve occasion setting phenomena.

Method

Subjects and apparatus. The subjects were 24 male albino rats, bred in a psychology department facility from Charles River stock. They were experimentally naive and about 120 days old at the beginning of the experiment. They were maintained as in Experiments 1 and 2.

Procedure. The rats were trained to eat from the food cup and press the lever in two 60-min sessions. In the first session, the rats received a 0.3-ml delivery of 0.2 M sucrose for each lever press, and during the first 40 min, sucrose deliveries occurred on a VT 2-min schedule. The second session was similar, except no response-independent reinforcers were delivered. The next five sessions were designed to establish discriminative control by the cues to be reinforced in later phases of training. In each of the first three of these 60-min sessions, each lever press during a 15-s illumination of the door light (D), noise (N), or 15-s clicker (C) stimulus was reinforced. Each session included 30 D and 30 C presentations, randomly intermixed.

The next two sessions each included 30 T-H+ compound presentations and 30 N+ trials. T-H+ trials comprised a 5-s 1500-Hz tone, followed, after a 5-s empty trace interval, by a 5-s illumination of the houselight, during which each lever press was reinforced. N+ trials consisted of 5-s presentations of the white noise, during which each lever press was reinforced.

Next, all rats received training on the ambiguous discrimination. Table 4 gives an outline of the remaining procedures of Experiment 3. In each of forty 60-min sessions, there were 15 each of 4 kinds of trials. T-H+ and N+ trials were identical to those in the previous sessions. T-N— trials comprised a 5-s tone followed, after a 5-s empty trace interval, by a 5-s noise presentation; and H— trials comprised a 5-s illumination of the houselight. Reinforcement was not available on T—N— or H— trials.

After training on the ambiguous discrimination, 20 sessions of training with the transfer targets were administered. In the first of these 60-min sessions, the rats received twenty 5-s presentations of the door light, during which each response was reinforced (D+); twenty nonreinforced presentations of the door light (D—); and twenty presentations of a 5-s clicker, followed by two empty 5-s trace intervals (C—0+). Each response during the second of these empty intervals (corresponding to the time of target presentation on serial compound trials) was reinforced. In each of the next 4 sessions, there were 12 of each of these 3 kinds of trials, plus 6 of each of the 4 kinds of ambiguous, discrimination-training trials. In each of the remaining 15 sessions, there were 6 of each reinforced trial type and 12 of each nonreinforced trial type.

Then the subjects were randomly assigned to three groups of 8 rats each, and four 60-min sessions designed to manipulate that simple associative strength of the ambiguous T feature were given. In each experiment, the rats in all three groups received 5 D+, 5 D—, and 10 C—0+ trials, to maintain responding to those cues. In addition, in each session, the rats in Group T+ received 40 presentations of the 5-s tone, followed by two 5-s empty intervals; each lever press during the second empty interval (when the targets would normally have occurred) was reinforced. The rats in Group T— received the same tone presentations, but reinforcement was not available on those trials. The rats in Group 0 received no tone presentations during this phase.

Table 4
Outline of Procedures in Experiment 3

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<tr>
<th>Group</th>
<th>Discrimination</th>
<th>Target</th>
<th>T posttrain</th>
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<th>Tests 2 &amp; 3</th>
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<td>C—D—, D—, C—0—</td>
</tr>
</tbody>
</table>

Note. A plus (+) indicates that lever presses during that cue were reinforced, a minus (—) indicates that lever presses were not reinforced, and an arrow (→) indicates a serial compound in which two 5-s cues were separated by a 5-s empty trace interval. C = clicker; D = door light; H = houselight; N = noise; T = tone; and 0 = no event.
Finally, four test sessions were given. Sessions 1 and 4 tested T's ability to modulate responding to each of its two original targets, H and N, and to the partially reinforced D cue. In each of those 60-min sessions, there were 6 presentations each of 10 kinds of trials. Seven of those kinds of trials were test trials, during which no reinforcement was available. On T→H, T→N, T→D, and T→0 trials, the 5-s tone was followed, after a 5-s empty trace interval, by a 5-s houselight, noise, door light, or empty interval, respectively. Five-second presentations of the houselight, noise, and door light alone comprised H, N, and D trials, respectively. Finally, reinforced T→H+, N+, and D+ trials similar to those in the previous phase were given to maintain responding and minimize generalization decrement from training sessions.

Test Sessions 2 and 3 examined the ability of the consistently reinforced clicker cue (C) to modulate responding during the various target cues. In each of those 66-min sessions, there were 6 presentations each of 11 trial types. H, N, D, T→H+, N+, and D+ trials were similar to those in Test Sessions 1 and 4. C→H, C→N, C→D, and C→0 trials were similar to the serial compound trials of Sessions 1 and 4, except that the 5-s tone was replaced by the 5-s clicker. Finally, there were also reinforced C→0+ trials, in which responding was reinforced during the second empty 5-s trace interval after the clicker.

**Results**

**Discrimination training.** By the end of ambiguous discrimination training, all 24 rats responded more during the target cues on the two kinds of reinforced trials than on the two kinds of nonreinforced trials, T(24) = 0. Over the last five sessions of that phase, the rats responded during the targets on medians of 98.6% of T→H+ trials, 59.2% of H− trials, 98.3% of N+ trials, and 68.1% of T→N− trials. A response occurred during 19.7% of the 5-s pre-CS intervals; I have no explanation for why this rate was so much higher than in Experiments 1 and 2.

**Target training.** Subsequent introduction of D+ and C→0+ trials in the target training phase disrupted the T→H+, H− discrimination (as noted in Experiment 2, D and H generalized to each other considerably). By the last five sessions of the target training phase, although all 24 rats responded more on N+ trials than on T→N− trials, only 19 of the rats responded more on T→H+ trials than on H− trials. Both of these differences were reliable, however, T(24) = 0 and 31, respectively. Over these sessions, the rats responded during the targets on medians of 99.3% of T→H+ trials, 83.4% of H− trials, 98.3% of N+ trials, and 70.8% of T→N− trials. The rats also responded on 94.0% of D trials and during 79.1% of the reinforced empty intervals after C presentations. Despite the availability of reinforcement during this trace interval, a response occurred on only 17.9% of the pre-CS intervals over the five final sessions of this phase, no more than at the end of ambiguous discrimination training.

**T postraining.** Over the course of the T postraining phase, the percentage of trials on which a response occurred during the second empty 5-s interval after T increased from 42.5% in the first session to 81.3% in the last session in Group T+. T(8) = 0, and decreased from 33.8% to 15.0% in Group T−, T(7) = 0 (one tie).

**Testing.** Most of the subjects in all three groups responded at least once on all of the compound trials in the test sessions. Consequently, the percentage trials with a response measure was too insensitive to be useful. Instead, I report the latency data, as in Experiments 1 and 2, and also a measure of response rate, which was made possible by the inclusion of nonreinforced test presentations of the previously reinforced cues (see the Data analysis section of Experiment 1). Neither the latency nor the response measures were near their ceiling levels, and both proved to be sensitive across the ranges obtained.

Figure 7 shows the results of Tests 1 and 4 (combined), which examined the powers of the original ambiguous T feature. Consider first the effects of postraining reinforcement or nonreinforcement of responding controlled by T on performance of the original T→H+, H− discrimination (top panels); that discrimination was maintained in all three groups, T(8) ≤ 3.5. Although responding during the second 5-s empty trace interval after T was significantly stronger (shorter latency and higher rate) in Group T+ than in Group 0, Us(8, 8) ≤ 13, and stronger in Group 0 than in Group T, Us(8, 8) = 1, the T→H-versus-H difference scores did not differ reliably among the groups, Us ≥ 21. Even the numerically (but unreliably) greater responding on compound trials in Group T+ may be attributed simply to T’s greater response tendency in that group. Thus, the positive-component discrimination was unaffected by extinction or conditioning of the feature cue.

Although the N+, T→N− discrimination was maintained in all three groups, T(8) ≤ 3, the effects of conditioning or extinction of the T feature (center panels of Figure 7) were less clear. With the latency measure, there were no reliable differences in discriminative responding between the groups, Us(8, 8) ≥ 22. Conversely, with the rate measure, both reinforcement and nonreinforcement of T had decremental effects on performance on the negative T→N−, N+ discrimination: The T→N-versus-N difference scores were reliably greater in Group 0 than in either Group T+, U(8, 8) = 9.5, or Group T−, U(8, 8) = 11.5. Although a greater response on T→N trials in Group T+ might be attributable to the greater T-evoked responding in Group T+, the higher level of responding on T→N trials in Group T− is not explainable that way. However, the slight loss of T’s control of nonresponding after its nonreinforcement is consistent with conditioned suppression data of Holland and Gory (1986), who found a similar reduction in negative occasion setting as a consequence of extended nonreinforcement of a feature after serial feature negative training. Alternately, it might be argued that the rate of responding controlled by T was a significant part of the functional occasion setter for nonresponding to N, and deviations in either direction reduced T’s control.

Next, consider T’s ability to modulate responding controlled by the partially reinforced D cue (bottom panels). There was no evidence of transfer of T’s ability to either facilitate or suppress responding to the partially reinforced D target. The latencies of responding to D on T→D trials did not differ significantly from those on D-alone trials in any group, T(8, 8) ≥ 12. Although the response rates during D on T→D− trials were greater than responding during D alone in both Groups 0 and T+, that greater responding is attributable to responding controlled by T alone: T→D− responding did not differ from responding during the equivalent interval after T alone in either group, Us ≥ 24.
Finally, consider the ability of the consistently reinforced C cue to substitute for T as an occasion setter for responding to the various target cues (Figure 8). In contrast to the effects of the original occasion setter, T (which enhanced responding to H, suppressed responding to N, and had no effect on responding to the partially reinforced D), C increased the rates, $T_s(24) < 29$, and decreased the latencies, $T_s(24) < 46.5$, of responding to all three of the test targets. Thus, it is more likely that C's effects were limited to simple summation of its response tendencies with those of the target cues. It is worth noting that these effects contrast with those found by Wilson and Pearce (1990): They found that a separately trained cue had the same effects on responding during the targets of an ambiguous discrimination as the ambiguous feature itself. The source of this discrepancy is unclear, although Wilson and Pearce suggested that their ambiguous and separately trained cues may have generalized to each other considerably.

**General Discussion**

Rats learned serial ambiguous discriminations ($X\rightarrow A^+, A^-, B^+, X\rightarrow B^-$) by acquiring both positive and negative occasion setting functions to the $X$ feature. At the least, $X$ possessed many properties in common with features trained in serial feature positive or serial feature negative discriminations alone. First, there was mutual transfer between features from the ambiguous and feature positive–feature negative discriminations. The ambiguous feature suppressed responding to the target of a feature negative discrimination...
and facilitated responding to the target of a feature positive discrimination. Similarly, the feature from a feature negative discrimination suppressed responding to the comparable B target from the ambiguous discrimination, and the feature from a feature positive discrimination facilitated responding to the A target.

Second, for this transfer to occur, the feature and target both had to have been trained within serial discriminations. Neither the feature from a serial pseudodiscrimination nor a consistently reinforced cue with similar temporal relations with food as the ambiguous feature had any modulatory powers. Furthermore, neither responding in the presence of the target from a serial pseudodiscrimination nor responding during a partially reinforced cue was modulated by ambiguous features. Third, an ambiguous feature's positive occasion setting powers were unaffected by nonreinforced presentation of that feature alone, and postraining counterconditioning of the feature to establish it as a discriminative stimulus for reinforcement of lever pressing did not eliminate the feature's ability to serve as negative occasion setter for responding controlled by another cue.

It might be argued that the rats solved the ambiguous discrimination by a combination of unidirectional occasion setting and simple conditioning strategies, rather than by acquiring bidirectional modulatory power to the ambiguous feature. For example, the rats might acquire both simple inhibition and positive occasion setting, or simple excitation and negative occasion setting to the feature. However, the dependence of transfer on the nature of target training in Experiments 1 and 3 and the effects of postraining counterconditioning and extinction in Experiment 3 seem inconsistent with this possibility.

It is unlikely that simple stimulus generalization between the various features or targets was an important contributor to the transfer effects obtained in these experiments. First, transfer to physically identical target cues varied dramatically as a function of the training history of those cues. Second, the patterns of transfer differed substantially depending on the temporal arrangement of the cues in training (compare the results of Experiments 1 and 2). It is not clear why transfer based on simple physical similarity among the stimulus elements would vary as a function of either of these variables.

Third, in most cases the transfer and original discrimination cues were selected to be of different stimulus modalities, and hence substantial generalization between them was unlikely. In Experiment 1, the feature from the ambiguous discrimination was auditory, and the feature from the other transfer discrimination was visual, but substantial transfer was observed. Similarly, in that experiment, the targets of the positive component (C→H+, H−) of the ambiguous discrimination and the targets of the transfer discriminations were of different modalities. And, in Group AMB− of Experiment 1, the targets of the transfer discrimination and the negative component (C−→N−, N+) of the ambiguous discriminations were of different modalities; nevertheless, substantial transfer was observed.

Indeed, comparison of the test performances of Groups AMB+ and AMB− suggests that transfer was largely independent of the similarity of the original and transfer target stimuli. In Group AMB−, the targets of the positive components of the two ambiguous discriminations were both visual, and the targets of the negative components were both auditory. Conversely, in Group AMB+, the targets of comparable components of the two ambiguous discriminations were of different modalities. Figures 2 and 3 reveal no evidence of greater transfer in Group AMB− than in Group AMB+.

The contrasting patterns of transfer observed in Experiments 1 and 2 argue against a simple configural account for the acquisition of the serial ambiguous discrimination, that rats simply acquired tendencies to respond to a unitary X→A+ cue and to withhold responding to a unitary X→B− cue. That view would incorrectly anticipate minimal transfer when X was combined with new targets and that the transfer would depend on the physical similarity of the resultant transfer compound to the training compounds, rather than on the training history of the transfer targets. Furthermore, given the intuition that rats are more likely to perceptually group or configure, the elements of a simultaneous compound than the elements of a serial compound, one would expect configural processes to be most revealed when simul-

![Figure 8. Latency to first response (left) and response rate (right) during Test Sessions 2 and 3 of Experiment 3, combined across groups. (Open bars represent responding during the second empty trace interval after the consistently reinforced C cue on C-alone presentations, hatched bars represent responding during the various target cues when they were preceded by C, and solid bars represent responding during the target cues on target-alone trials. Table 4 gives the training associated with each of the cues.)](image-url)
taneous compounds are used. Indeed, in Experiment 2, in which simultaneous compound cues were used, little transfer was observed.

All in all, the data presented here indicate that the feature cue within a serial ambiguous discrimination acquired both positive and negative occasion setting powers. This bidirectional modulatory power is inconsistent with the view that occasion setters act generally on a representation of the reinforcer (e.g., Rescorla, 1985). Nevertheless, the successful transfer to stimuli that had themselves served as targets of occasion setters shows that the ambiguous feature's action is not so specific as to be limited to a particular stimulus–reinforcer relation (e.g., Holland, 1983).

Similar training-specific transfer after serial feature positive and feature negative discrimination training led Holland (e.g., Holland, 1989c) to propose that as a consequence of their participation in serial conditional discriminations, events came to be represented in two relatively separate memory systems: one involved in simple excitatory and inhibitory associations, and another involved in conditional, occasion setting functions. Transfer of control among cues involved in conditional discriminations would occur as readily within that latter system as transfer of simple conditioning would occur among those events in the former system. This casually framed view was consistent with a variety of transfer data from experiments involving multiple features, targets, and reinforcers.

Nevertheless, the multiple memory system view as described by Holland (1989c) does not embrace the present transfer data. Within that view, it was sufficient for an event simply to be represented as a target in the "conditional" system for it to be a suitable target for modulation by other occasion setters. However, transfer was more specific in these experiments: Adequate targets of positive occasion setting were not adequate targets for negative occasion setting and vice versa. Indeed, the solution of the ambiguous discrimination itself demands that positive and negative relations must be specifically coded in the conditional system.

Even more damaging to that view are the observations that cues that are simply trained and extinguished may also serve as adequate targets of positive occasion setters after either serial feature positive (Holland, in press) or serial ambiguous (Holland & Reeve, in press) discriminations in this conditioning preparation (but not in a related Pavlovian procedure: e.g., Holland, 1989a). Trained and extinguished cues have been found to be suitable targets of transfer in other conditioning preparations as well (e.g., Bouton & Swartzentruber, 1986; Rescorla, 1985).

The character of Holland's (1989c) suggestion could be salvaged by arguing that the operations of training and extinction establish a cue as a target of reinforcement-context occasion setters or by claiming that the prerequisite for representation in the conditional system is merely the establishment of independent excitatory and inhibitory associations to a cue. However, it is not at all clear why these conditions would be met by training and extinction, but not, say, by partial reinforcement. At this point, it adds little to speak of multiple memory systems when the rules for entry to each system are not easily specified and the nature of event coding within each system is still unclear.

However, the notion may remain a useful heuristic for subsequent research.

Other accounts for acquisition and transfer effects in conditional discriminations also fare poorly with the present data. For example, Wilson and Pearce (1989, 1990) have shown that an account based on Pearce's (1987) generalization theory of compound conditioning phenomena successfully predicts a number of acquisition and transfer phenomena within feature positive and feature negative discriminations. Essentially, that theory claims that pairings of a compound conditioned stimulus with a reinforcer results in a single association between the reinforcer and a representative of the entire compound. The individual elements of that compound cue evoke responding only to the extent of generalization between those elements and the compound. So, in an ambiguous discrimination of the form $X_A^+$, $A^-$, $X_B^-$, $B^+$, for example, excitation accrues directly only to the $X_A$ and $B$ cues. Because of generalization between the compounds and between the compounds and their elements, initially, the nonreinforced $X_B^-$ and $A^-$ cues will also elicit responding. But because those cues are not reinforced in the presence of that generalized excitation, $X_B$ and $A$ will acquire inhibitory tendencies strong enough to counter the generalized excitatory tendencies, until the discrimination is solved.

A series of computer simulations based on the equations presented by Pearce (1987) verified that Pearce's model indeed predicts that rats will acquire the various discriminations required in the present experiments. Consider the results of Groups $AMB^+$ in Experiment 1, for example. Those subjects received training with two separate serial ambiguous discriminations: $C^+\rightarrow H^+$, $H^-$, $C^-\rightarrow N^-$, $N^+$ and $P^+\rightarrow T^+$, $T^-$, $P^-\rightarrow D^-$, $D^+$. The simulations showed that both discriminations would be acquired, within a very broad range of values (but not all values) chosen for the saliences of the individual elements and their similarities with each other. Furthermore, within a broad range of values, the observed mutual transfer was anticipated: The $C^+\rightarrow T$ and $P^+\rightarrow H$ compounds would show more strength than $T$ and $H$ alone, and the $C^-\rightarrow D$ and $P^-\rightarrow N$ compounds would show less responding than $D$ alone.

However, at least in its present form, Pearce's (1987) model cannot deal with several aspects of the transfer phenomena found in the present experiments. For example, consider again the performances of Groups $AMB^+$ and $AMB^-$ in Experiment 1. Although Pearce's model correctly predicts that in Group $AMB^+$, $C$ will enhance responding to $T$ and suppress it to $D$, and $P$ will enhance responding to $H$ and suppress it to $N$, it also predicts that responding to $C^-\rightarrow D$ and $P^-\rightarrow N$ (the compounds of features with the transfer targets of the negative components of the other ambiguous discrimination) will be greater than responding to $C^-\rightarrow T$ and $P^-\rightarrow H$ (the compounds of features with the targets from the positive components). This prediction follows from the model's method for calculating the similarity between compounds and between compounds and their elements and was confirmed over a wide range of parameter values with a series of computer simulations. Nevertheless, in Experiment 1, the compounds of both the $T$ and $C$ features with the transfer targets from the negative components of the other ambiguous discrimination evoked less responding than their compounds with the targets from the positive components. In Group $AMB^+$, in which the
targets of the negative components were D and N, responding occurred on 38.4% of C→D trials and 69.9% of P→N trials versus 58.0% of C→T trials and 92.1% of P→H trials, T(8) = 0. Similarly, in Group AMB=, in which the targets of the negative components were T and N, responding occurred on 75.0% of C→T trials and 61.2% of P→N trials versus 85.5% of C→D trials, T(8) = 4, p ≤ 0.1, and 82.9% of P→H trials, T(8) = 3 (data are taken from Figure 2 and the Results section of Experiment 1).

Similarly, within a broad range of parameter values, the model incorrectly predicts that in transfer tests, the feature of Experiment 1). It might be argued, for example, that even a simple operant discrimination involves stimulus control similar to that involved in Pavlovian occasion setting, because the stimulus sets the occasion for responding based on the response-reinforcer relation. A simple operant stimulus may be functionally like a feature in a Pavlovian positive patterning (X→A+, A−, X−) discrimination: Responses (A) are reinforced (+) in the presence of the Stimulus (X), but reinforcement is not delivered in the presence of X unless A occurs, and A is not reinforced unless X is present. Indeed, some recent data suggest that Pavlovian occasion setters have much in common with operant discriminative stimuli: Davidson, Aparicio, and Rescorla (1988) found that a cue trained as an operand stimulus effectively set the occasion for responding to a cue that had been trained as a target in Pavlovian occasion setting, and a cue trained as a Pavlovian occasion setter effectively controlled an operand that was trained with a different stimulus.

Consequently, it could easily be claimed that even the target cues in the present experiments were themselves occasion setters of sorts. The further arrangement of stimulus relations known to generate Pavlovian occasion setting might be analogous to arranging "higher order" occasion setting in Pavlovian conditioning procedures (e.g., Arnold, Grahame, & Miller, 1991; see also Sidman, 1986). Thus, it is valuable to note that variations in the temporal and predictive relations among the elements of compound discriminative stimuli and the availability of reinforcement seemed to alter the nature of operand discrimination control in the same manner as similar variations among CSs and USs alter the nature of Pavlovian stimulus control (see the present experiments; Holland, in press; Holland & Reeve, in press).

References


