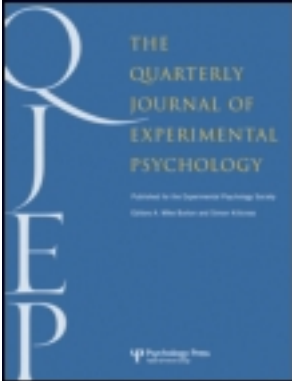


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### Occasion-setting training renders stimuli more similar: Acquired equivalence between the targets of feature-positive discriminations

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## **Occasion-setting Training Renders Stimuli More Similar: Acquired Equivalence between the Targets of Feature-positive Discriminations**

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In two experiments rats received training on two concurrent appetitive feature-positive discriminations. A preliminary test in Experiment 1 confirmed previous demonstrations of the transfer of occasion-setting properties—the feature from one of these discriminations was better able to facilitate responding to the occasion-set target CS from the second discrimination than to a control stimulus that had not been the subject of occasion-setting. The source of this transfer was investigated in a second phase of training, and in Experiment 2. In both experiments one of the occasion-set CSs was paired with food, and generalization of appetitive conditioned responding from this stimulus to the second occasion-set CS, and to a control cue, was examined. There was more generalization from the first occasion-set CS to the second CS that had also been occasion-set than to the control cue. This is taken as evidence that occasion-set CSs are rendered more similar as a result of their common training history. The implications of these findings for explaining transfer of occasion setting are discussed.

In a feature-positive occasion-setting discrimination a conditioned stimulus (CS) is reinforced in the presence of the feature, and non-reinforced in its absence. A number of accounts have been offered for the way in which the feature comes to acquire control over conditioned responding to the CS. These fall into two categories: in the first are those according to which the feature acts on the US representation, enhancing the ease with which it may be activated (e.g. Rescorla, 1985; see also Wagner & Brandon, 1989); in the second category are those accounts suggesting that the feature

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facilitates retrieval or use of the entire CS-US association (e.g. Bonardi, 1989; Bouton, 1990; Holland, 1983). These classes of theory make quite different predictions about the effect of the feature on a second CS: according to the first, the feature should show perfect transfer, whereas according to the second it should show none. Troublesome for both accounts, then, is the frequent observation that (at least in rat subjects—see e.g., Rescorla, 1985) when transfer does occur, not only is it frequently incomplete (e.g. Holland, 1986a, 1986b, 1989b), but also the extent to which it occurs depends critically on the way in which the transfer CS has been trained: more transfer is found if the transfer CS has also been the target of an occasion-setting discrimination (e.g. Holland, 1986a, 1986b, 1989a, 1989b; Wilson & Pearce, 1990).

Both classes of explanation can provide an account of why transfer might be incomplete. Theories explaining occasion setting as modulation of the US representation can appeal to generalization decrement. Presenting the feature along with a new, transfer CS could change the perception of the feature, thus attenuating its occasion-setting properties so that it will have less effect on the transfer CS. Alternatively, theories according to which the occasion setter acts on the entire CS-US association may appeal to stimulus generalization. Their prediction that the feature cannot transfer to a second CS is based on the assumption that that CS bears *no* physical similarity to the original CS—an assumption that is unlikely to be correct. But once it is permitted that the two CSs possess some elements in common, then the feature may have some effect on the transfer CS—although this is likely to be smaller than its effect on the original target.

However, even though incomplete transfer to a second CS may be accommodated, the fact that such transfer depends on the way that CS has been trained remains unaccounted for. To explain this observation, the US modulation accounts would have to assume that the type of training a CS has received dramatically influences the amount of generalization decrement it generates. Although this suggestion is not implausible, to accept it requires some arbitrary assumptions about generalization decrement. The second class of theories, according to which the occasion setter acts on the CS-US association, fares somewhat better. Their explanation of incomplete transfer in terms of stimulus generalization assumed that generalization between two stimuli is solely determined by their physical characteristics—but there is now quite substantial evidence to suggest that this assumption is incorrect, and that stimuli with a common training history may become effectively more similar. Enhanced generalization has been observed between stimuli that have been followed by a common consequent (e.g. Honey & Hall, 1989), preceded by a common antecedent (e.g. Bonardi, Rey, Richmond, & Hall, in press; Hall, Ray, & Bonardi, 1993), or simply preexposed (Honey, 1990). If this *acquired equivalence*

effect can also be mediated by a common history of occasion-setting training, so that two stimuli that have both been the targets of occasion-setting discriminations become more similar (cf. Lamarre & Holland, 1987; Wilson & Pearce, 1990), then this could explain why occasion setters transfer more readily to other occasion-set CSs. Independent evidence that this type of acquired equivalence occurs is clearly critical if such an account is to be sustained. The present experiments attempted to provide such evidence.

Equivalence was evaluated by making use of the idea that, if stimuli have become more similar, then generalization between them will be enhanced. The procedure used was similar to that used by Honey and Hall (1989). Subjects were given training with three CSs: X, Y, and Z. X and Y were the targets of feature-positive occasion-setting discriminations, whereas Z was simply reinforced and then extinguished. In a subsequent "revaluation" stage X was conditioned as a signal for food delivery, and then generalization of appetitive conditioned responding to Y and Z was examined. If occasion-set stimuli acquire equivalence, then the animals should respond more to Y than to Z in this test.

### EXPERIMENT 1

The experimental procedure used was similar to that described by Bonardi (e.g. 1990; cf. Wilson & Pearce, 1990). Each feature was the 3-min presentation of a visual stimulus, during which three 10-sec auditory CSs were presented and followed by the delivery of a food pellet. CSs occurred at the same rate in the absence of the feature, but these presentations were non-reinforced. Animals were given training on such two occasion-setting discriminations, with two CSs, X and Y, and two features, A and B; X was reinforced in the presence of A, and Y in the presence of B (see Table 1).

TABLE 1  
Design of Experiment 1

Stage 1		Stage 2		Revaluation	Test
A(X+)	X-	A(X+)	X-		
B(Y+)	Y-	B(Y+)	Y-	X+	Y versus Z
	Z+		Z-		

*Note:* "A(X+)" and "B(Y+)" denote reinforced presentations of X in the presence of A, and of Y in the presence of B, respectively. "X+" and "Z+" refer to reinforced presentations of X and Z in the absence of features; "X-", "Y-", and "Z-" denote non-reinforced presentations of X, Y, and Z in the absence of the features.

Then generalization between X and Y was examined in the following manner. After occasion-setting training neither X nor Y elicited much responding when presented alone, so that when, in a subsequent stage of training, X was paired with food, conditioned responding to this stimulus increased. Then X's similarity to Y was assessed by comparing generalized conditioned responding to Y with that to a third CS, Z, which during initial training had been consistently reinforced, and then extinguished until it supported the same low level of responding as Y. Y and Z were counter-balanced such that, on the basis of their physical properties, there would be no reason to anticipate differential generalization to these stimuli. But Z had never been the target of an occasion-setting discrimination; thus if a common history of occasion-setting training renders stimuli more similar, more generalization should be observed from X to Y than from X to Z.

One of the reasons for interest in equivalence between occasion-set CSs, as we mentioned above, was the possibility that it might explain why occasion setters often transfer more readily to occasion-set cues (e.g. Holland, 1986a, 1986b, 1989a, 1989b; Wilson & Pearce, 1990). It therefore seemed prudent to confirm that this result could be obtained in our occasion-setting preparation. Thus, before the revaluation stage, a test was administered in which the effects of feature A on responding to both Y and Z were examined; we expected to replicate the finding that A would have more effect on responding to the occasion-set Y than to Z. In addition, another transfer test was included to evaluate the completeness of this transfer: in this test the effect of the features on responding to their original target CSs and to the alternative occasion-set CSs was compared.

## Method

### *Subjects*

The subjects, 16 naive male hooded (Lister) rats with a mean *ad lib* weight of 337 g (range: 320–365 g), were housed in pairs. Before the start of training they were reduced to 80% of their *ad lib* weights, and were maintained at this level for the rest of the experiment by being fed a restricted amount of food at the end of each session.

### *Apparatus*

The apparatus consisted of four Campden Instruments operant chambers. Each of the boxes had three walls of sheet aluminium, a transparent plastic door as the fourth wall, and a white translucent ceiling. One wall, adjacent to the door, contained a recessed food tray to which 45-mg mixed-composition food pellets could be delivered. Access to this food tray was by means of a rectangular aperture 6 cm high  $\times$  5 cm wide. A transparent plastic flap of the same dimensions was attached by a hinge to the top of

the entrance to the food tray. Pushing this flap inwards from its vertical resting position allowed subjects to gain entry to the food tray. This movement actuated a microswitch, and each closing of this switch was recorded as a single response. The flap automatically returned to its resting position when the rat removed its snout from the food tray. Illumination was provided by a 2.8-W 15-V houselight, mounted centrally in the front wall; this light was always on except when the dark stimulus was presented. A light stimulus was provided by turning on a 30-W striplight (rated for 240 V but operated at 100 V) that was located above the ceiling. Two speakers were mounted on the back wall through which an 82-dB, 10-Hz clicker, an 82-dB 2-kHz tone, and an 84-dB white noise (Scale A) could be delivered from a Campden Instruments tone generator and white noise generator. The boxes were housed in sound- and light-attenuating shells; masking noise was provided by the operation of ventilating fans contained in these shells. The apparatus was controlled by BBC microcomputers programmed in a version of BASIC.

### *Procedure*

*Pretraining.* In the first three 30-min sessions the animals were trained to retrieve food pellets from the food tray. These pellets were delivered according to a variable time (VT) 60-sec schedule. Animals who failed to eat all the pellets that were delivered were given an extra session.

*Stage 1.* During the first 16 sessions all animals received training on two occasion-setting discriminations, with X and A, and with Y and B. Thus animals received presentations of X in both the presence and the absence of A; presentations of X during A were reinforced with a single food pellet, whereas those in A's absence were non-reinforced. Y was reinforced in the presence of B, and non-reinforced in B's absence in exactly the same way. In addition, the animals also experienced reinforced presentations of Z. X was the tone for all animals; for half of them Y was the noise and Z the click, and for the remainder the converse was true. The illumination in the chambers was provided solely by the houselight, except during feature presentations; when the feature was dark, the houselight was turned off, whereas when the feature was light, the striplight was also turned on. For half of each of the two counterbalanced subgroups just referred to, A was the light and B the dark; the opposite was true for the remaining animals.

Each occasion-setting trial consisted of a 6-min period that was followed by a 3-min feature presentation. Presentations of the CS that was appropriate to that particular feature were programmed to occur at semi-random intervals throughout this 9-min trial, on an average of once per minute. This programming was arranged so that there were three 10-sec reinforced

presentations of the CS during the feature, and six non-reinforced presentations of the CS in the period preceding the feature; a further constraint was that each CS was preceded by a 10-sec pre-CS period. There were two trials for each occasion-setting discrimination per session; in addition, each session also contained one Z trial: this comprised a 6-min period during which there were six reinforced presentations of Z, also programmed to occur at semi-random intervals within the trial. This arrangement equated the number of reinforced presentations of X, Y, and Z. The different types of trial were presented in a semi-random order; there was no intertrial interval, but there was a 3-min period at both the start and end of each session during which no events were programmed to occur.

*Stage 2a.* Stage 2a was identical to Stage 1, except that all Z presentations were non-reinforced. This measure was designed to equate responding to Z with that to Y alone; six sessions were required to achieve this.

*Test 1.* In the first test session transfer of the features' occasion-setting power to occasion-set CSs was examined. In order to evaluate the completeness of this transfer, the effect of each feature on its original CS and on the other occasion-set CS was examined. There were four A trials and four B trials in this session, presented in the order A A B B. One A and one B trial contained the original CSs (X and Y, respectively); these constituted "same" (S) trials. In the remaining "different" (D) trials the transfer CSs (Y and X, respectively) were presented. The order of these two types of trial was counterbalanced so that half the animals received the sequence S D D S and the remainder D S S D. These two subgroups were counterbalanced across the physical identities of A and B, and of Y. No reinforcement was delivered during these trials, which were in other respects identical to those experienced during Stage 1 training.

*Stage 2b.* All animals then received two more reminder sessions of training identical to those given in Stage 2a.

*Test 2.* Subjects were then given a second test in which transfer of A's properties to the occasion-set and non-occasion-set transfer CSs (Y and Z respectively) was examined. This session consisted of four A trials, two with Y and two with Z; half the animals received these trials in the order Y Z Z Y and the remainder in the order Z Y Y Z; for half of each of these subgroups Y was the click and Z the noise, and for the remainder the converse was true. In other respects these test trials were identical to those from Test 1.



*Revaluation.* Subsequently all animals received 10 sessions of training in which X was paired with food, so that it would elicit conditioned responding in preparation for the generalization test. There were 12 presentations of X in each session, each of which was followed by the delivery of a food pellet. The intertrial interval (ITI) was variable, with a mean of 3 min; in addition there was a 3-min period at both the start and end of each session in which no events occurred.

*Test 3.* Finally, the animals were given a third test in which generalization from X to Y and to Z was examined. The single test session consisted of four presentations of Y and four of Z: half of the animals received these trials in the order Y Z Z Y Z Y Y Z, and the remainder Z Y Y Z Y Z Z Y; for half of each of these subgroups Y was the click and Z the noise, and for the remainder the converse was true. The ITI was, as in the revaluation stage, variable, with a mean of 3 min; no reinforcers were delivered in this session.

In both of the experiments reported here, each CS was preceded by a pre-CS period of the same duration as the CS. The rate of magazine entry was recorded separately during both CS presentations and the pre-CS periods. Conditioned responding to a particular CS was evaluated using a "corrected" score, produced by subtracting the pre-CS rate from the CS rate; corrected scores were calculated separately for CSs in the presence and absence of a particular feature. Finally, a significance level of  $p < 0.05$  was adopted in all the analyses that follow.

## Results and Discussion

*Stages 1 & 2a.* Training proceeded uneventfully: during Stage 1 the animals acquired the occasion-setting discriminations, responding to X during A and to Y during B, but to neither X nor Y alone; they continued to respond appropriately in Stage 2a (see Table 2). During Stage 1, animals also came to respond at a fairly high rate to Z (with a mean of 9.38 responses per minute [rpm] during the last two training sessions), but this was reduced by the extinction treatment in Stage 2a, until animals responded at approximately the same rate to Y (in the absence of B) and Z. The corrected scores and pre-CS response rates for the last two sessions of Stage 2a are shown in the top panel of Table 2.

*Test 1.* The results from Test 1 are shown in Figure 1. It is clear that subjects continued to perform accurately on the occasion-setting discriminations during the extinction test, and that the features' occasion-setting powers transferred perfectly to the occasion-set transfer CS. This is evident from the fact that response rates to X and Y were higher when the feature

TABLE 2  
Response Rates<sup>a</sup> in the Last Two-session Block of Stages 2a  
and 2b of Experiment 1

Measure	X	A(X)	Y	B(Y)	Z
<i>Stage 2a</i>					
Corrected	0.51	4.15	0.78	6.68	0.78
Pre-CS	0.63	6.19	0.42	4.88	0.91
<i>Stage 2b</i>					
Corrected	0.17	5.94	1.26	6.62	2.07
Pre-CS	0.66	3.72	0.94	4.66	0.56

<sup>a</sup>Response rates are given in rpm.

Note: "A(X)" and "B(Y)" refer to response rates evoked by presentations of X in the presence of A, and of Y in the presence of B, respectively. "X", "Y", and "Z" refer to the corresponding rates for presentations of X, Y, and Z in the absence of the features. The rows marked "Corrected" refer to the response rates during each type of CS after subtraction of the rate in the appropriate pre-CS period; the pre-CS rates appear in the rows marked "Pre-CS". (Pre-CS response rates for A(X) and B(Y) refer to responding during A and B alone, respectively.)

was present than when it was absent, and that this difference was, if anything, larger on different (D) trials than on same (S) trials. The results of an analysis of variance (ANOVA) with feature (present or absent) and trial type (S or D) as factors revealed a significant effect of feature,  $F(1, 15) = 11.69$ , that did not interact with trial type,  $F < 1$ . The main effect of trial type was not significant,  $F < 1$ . Thus the features were

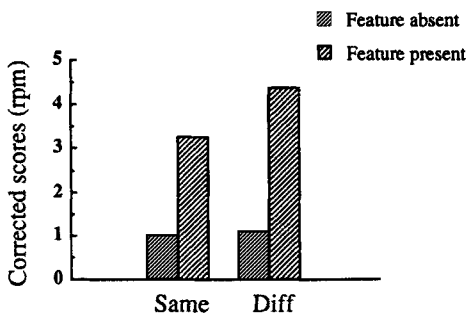


FIG. 1. Mean corrected response rates (rpm) to X and Y in the presence and absence of the features, in the first test session of Experiment 1: during Same trials each CS was presented in the feature with which it had been trained, whereas in Diff (different) trials CSs were presented in the alternative feature.

equally effective on D and S trials. The pre-CS response rates were, for S and D trials, respectively, 2.94 and 1.69 rpm during the feature and 0.28 and 0.09 rpm in the feature's absence. ANOVA revealed a main effect of feature,  $F(1, 15) = 31.53$ , and of trial type,  $F(1, 15) = 4.75$ . The interaction between these two factors was not significant,  $F(1, 15) = 1.62$ .

*Stage 2b.* The corrected and pre-CS response rates from the two sessions of Stage 2b are shown in the bottom panel of Table 2. Occasion-setting discrimination performance was maintained, and the extinction treatment was apparently successful in equating responding to Y and Z. It was critical that response rates to Y and Z were the same, so that differential generalization to these stimuli could be reliably estimated in the final test. Accordingly, an ANOVA was performed on these data, which revealed, as anticipated, that the response rates to these two stimuli did not differ,  $F(1, 15) = 1.33$ ; nor did the corresponding pre-CS rates,  $F(1, 15) = 1.99$ .

*Test 2.* Test 2 compared transfer of occasion setting to occasion-set and non-occasion-set CSs, by looking at the effect of A on responding to Y and Z. The results are shown in Figure 2, and it is clear that we succeeded in replicating the differential transfer effect: although, as in Test 1, A elevated responding to the occasion-set Y quite substantially, it had virtually no effect on Z. This impression was supported by the results of an ANOVA with feature (present or absent) and CS (Y or Z) as factors, that revealed a significant effect of feature,  $F(1, 15) = 11.67$ , of CS,  $F(1, 15) = 6.44$ , and a significant interaction between these two factors,  $F(1, 15) = 5.72$ . A Newman-Keuls test revealed that the feature had a significant effect on responding to Y but not to Z. Thus here, as in other preparations, occasion setters transfer more readily to CSs that have been occasion set than to those that have not.

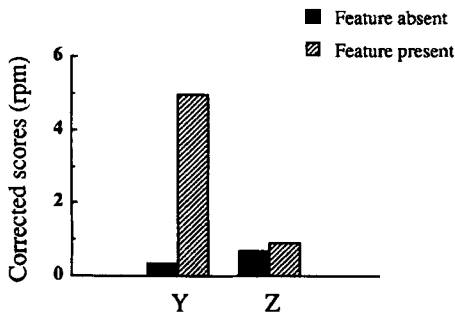


FIG. 2. Mean corrected response rates (rpm) to Y and Z in the presence and absence of feature A, in the second test session of Experiment 1.

The pre-CS response rates during this session were, for Y and Z trials, respectively, 1.31 and 2.06 rpm in the presence of the feature, and 0.41 and 0.10 rpm in its absence. An ANOVA performed on these scores revealed a significant main effect of feature,  $F(1, 15) = 7.56$ , but no other effects or interactions were significant, largest  $F(1, 15) = 1.21$ .

*Revaluation.* Response rates to X increased during this stage; during the last two sessions the mean corrected rate of responding to X was 9.12 rpm, and the corresponding pre-CS rate was 0.76 rpm.

*Test 3.* Figure 3 shows response rates to Y and Z in the test. It is clear that there was substantial generalization to Y, but rather less to Z. An ANOVA performed on these data with stimulus (Y or Z) as a factor confirmed that responding to Y was significantly greater than responding to Z,  $F(1, 15) = 23.21$ . The pre-CS rates for the two stimuli in the test (0.38 and 1.50 rpm for Y and Z, respectively) did not differ,  $F(1, 15) = 3.46$ . Thus, in accordance with our prediction, it appeared that generalization occurred more readily between X and Y, the two stimuli that had both been the targets of occasion-setting discriminations.

These data are, then, consistent with the idea that occasion-setting training can mediate acquired equivalence. As well as being of intrinsic interest, this observation could potentially explain the results of the second test, which replicated the frequent finding that occasion setters, although readily transferring their properties to occasion-set transfer CSs, are relatively ineffectual with CSs that have simply been trained and extinguished. The results of the generalization test are consistent with the idea that the differential transfer of occasion setting observed in Test 2 could be a product of differential stimulus generalization among the target CSs.

However, before accepting this interpretation, at least one other explanation of the generalization test results should be considered. Although every attempt was made to equate levels of responding to Y and

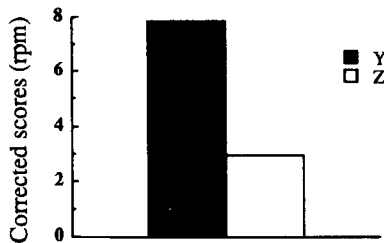


FIG. 3. Mean corrected response rates (rpm) to Y and Z in the final test session of Experiment 1.

Z before the generalization test, it is difficult to be certain that this was completely effective. It is therefore still possible that Y's reinforcement history as an occasion-set CS ensured that animals responded more to this stimulus—not because of acquired equivalence, but because Y's training endowed it with more associative strength than Z. Although this difference was presumably obscured by a floor effect at the end of training, it might have been revealed when responding to Y and Z was boosted by generalization from X. Experiment 2 was designed to rule out this alternative interpretation.

### EXPERIMENT 2

The design of Experiment 2 was similar to that of Experiment 1: animals were trained on two occasion-setting discriminations with target CSs X and Y, and also received training with W and Z, cues that were reinforced and then extinguished (see Table 3). Again, this training was followed first by a revaluation stage in which responding to X was manipulated, and second by a test in which generalization to Y and to Z was examined. The present experiment differed, however, in the nature of the revaluation stage. In this phase the animals were divided into two groups and given training with both X and W: in Group OS the occasion-set cue X was reinforced and W was extinguished, whereas in Group C W was reinforced and X was extinguished.

If the occasion-set cues X and Y become equivalent, there will be enhanced generalization between these two stimuli; generalization from

TABLE 3  
Design of Experiment 2

<i>Group</i>	<i>Stage 1</i>		<i>Stage 2</i>		<i>Revaluation</i>		<i>Test</i>
OS	A(X+)	X-	A(X+)	X-	X+	W-	Y versus Z
	B(Y+)	Y-	B(Y+)	Y-			
	Z+	Z-	W+	W-			
C	A(X+)	X-	A(X+)	X-	W+	X-	Y versus Z
	B(Y+)	Y-	B(Y+)	Y-			
	Z+	Z-	W+	W-			

*Note:* "A(X+)" and "B(Y+)" denote reinforced presentations of X in the presence of A, and of Y in the presence of B, respectively. "X+", "Z+", and "W+" refer to reinforced presentations of X, Z, and W in the absence of the features; "X-", "Y-", "W-", and "Z-" denote non-reinforced presentations of X, Y, W, and Z in the absence of the features.

the trained and extinguished cue W will, on the other hand, be the same to Y and to Z, being determined solely by the real common elements that these stimuli share. In Group OS, X was reinforced during reevaluation; thus if this stimulus generalizes especially well to Y, this should produce more responding to Y than to Z at test. In Group C, on the other hand, X was non-reinforced during reevaluation; again, if this extinction treatment generalizes differentially to Y, then animals in this group should respond less to Y than to Z at test. An appeal to the differential associative strengths of occasion-set and of trained and extinguished CSs would be unable to explain this pattern of results—this account is constrained to predict more responding to Y than to Z in both groups. A final departure from Experiment 1 was that the tests for transfer of occasion setting were omitted.

## Method

### *Subjects and Apparatus*

The subjects, 16 naive male hooded (Lister) rats with a mean *ad lib* weight of 425 g (range 388–463 g), were housed in pairs and maintained exactly as in Experiment 1. The stimuli were an 80-dB, 2-kHz tone, an 80-dB, 10-Hz click, an 80-dB white noise, and an 80-dB 4-kHz tone pulsed at 1 Hz. All other aspects of the apparatus were identical to those in the previous experiments.

### *Procedure*

All aspects of the procedure that are not specified were identical to those of Experiment 1.

*Stage 1.* After magazine training all animals received 20 sessions of training; these were identical to those from Stage 1 of Experiment 1, except that each session included an additional trial during which W was continuously reinforced in exactly the same way as Z. For half the animals X was the steady tone and W the pulsed tone, and for the remainder this arrangement was reversed; for half of each of these two subgroups A was the light and B the dark, and for the remainder the converse was true; finally, for half of each of these four subgroups Y was the click and Z was the noise, and for the remainder Y was the noise and Z the click. Acquisition of conditioned responding proceeded slowly during these sessions, so an additional four sessions were administered, which were identical to those preceding them except that all reinforcers were increased from one pellet to two; this larger reinforcer was retained for the remainder of the experiment.

*Stage 2.* The six sessions of Stage 2 were identical to the final four sessions of Stage 1, except that Z and W were now non-reinforced.

*Revaluation.* At this point the animals were divided into two groups, and given Pavlovian discrimination training, with 12 S+ and 6 S- trials per session. For group OS, X was the S+ and W the S-; for Group C this arrangement was reversed. For half of each group the S+ was the steady tone and the S- the pulsed tone, and for the remainder the converse was true; for half the animals in each of these four subgroups Y was the click and Z the noise, and for the remainder Y was the noise and Z the click; finally, for half of the animals in each of these eight subgroups A was the light and B the dark, and for the remainder the opposite was true. There were 16 sessions in this stage, all other aspects of which were identical to those of the revaluation stage of Experiment 1.

*Test.* Finally, the animals were given four test sessions, each comprising four presentations of Y and four of Z. In the first and third of these all animals received the stimulus sequence click (C) noise (N) N C N C C N; in the second and fourth they received the same sequence in reverse.

## Results and Discussion

*Stages 1 & 2.* In Stage 1 the animals acquired the two occasion-setting discriminations and also came to respond at fairly high rates to W and Z: the rates of responding in the last two sessions of this stage were 4.81 and 6.41 rpm for W and Z, respectively; the corresponding pre-CS rates were 2.35 and 2.38 rpm.

The corrected scores and pre-CS rates during the last two sessions of Stage 2 are shown in the top and bottom panels of Table 4, respectively. It can be seen that the animals continued to perform accurately on the occasion-setting discriminations, and that extinction reduced responding to both W and Z. By the end of this stage response rates to Y and Z were approximately equal in both groups, permitting a meaningful estimate of differential generalization to these two stimuli to be obtained in the final test. This impression was confirmed by the results of an ANOVA with group (OS or C) and stimulus (Y or Z) as factors, which found that response rates to Y and Z did not differ, all  $F_s < 1$ . Pre-CS response rates were, however, for some reason higher to Y than to Z: an ANOVA parallel to the previous one revealed a significant main effect of stimulus,  $F(1, 14) = 4.78$ ; the effect of group and the interaction were not significant,  $F_s < 1$ . Nevertheless, it is unlikely that this difference was obscuring a real difference between Y and Z: an analysis on the uncorrected CS rates also revealed no significant effects or interactions, largest  $F(1, 14) = 1.67$ . There was thus no hint of a difference between the two groups in responding to Y and Z.

*Revaluation.* Animals learned to discriminate appropriately by the end of this stage: response rates in the final two sessions of this stage were, for Group OS, 7.03 and 1.12 rpm to the S+ and S-, respectively; the corres-

TABLE 4  
Response Rates<sup>a</sup> in the Last Two-session Block of Stage 2  
of Experiment 2

Group	X	A(X)	Y	B(Y)	Z	W
<i>Corrected scores</i>						
OS	0.72	4.63	1.41	5.44	1.38	1.63
C	0.88	6.37	1.57	6.12	1.06	0.31
<i>Pre-CS rates</i>						
OS	0.28	3.75	0.59	3.81	0.25	0.75
C	0.34	3.88	0.81	1.63	0.19	0.63

<sup>a</sup>Response rates are given in rpm.

Note: "A(X)" and "B(Y)" refer to response rates evoked by presentations of X in the presence of A, and of Y in the presence of B, respectively. "X", "Y", "Z", and "W" refer to the corresponding rates for presentations of X, Y, Z, and W in the absence of the features. The section marked "Corrected" refers to the response rates during each type of CS after subtraction of the rate in the appropriate pre-CS period; the pre-CS rates appear in the section marked "Pre-CS". (Pre-CS response rates for A(X) and B(Y) refer to responding during A and B alone, respectively.)

ponding rates for Group C were 12.10 and 0.52 rpm. An ANOVA with group (OS or C) and stimulus (S+ or S-) as factors revealed a significant main effect of stimulus,  $F(1, 14) = 29.80$ ; nothing else was significant, largest  $F(1, 14) = 3.20$ . The pre-CS rates during these sessions were, for Group OS, 0.57 and 0.50 rpm for S+ and S-, respectively; the corresponding rates for Group C were 0.47 and 1.07 rpm. An ANOVA parallel to that performed on the corrected scores revealed no significant effects or interactions, largest  $F(1, 14) = 2.55$ .

*Test.* In the test the predicted result for Group OS was the same as in Experiment 1: as the occasion-set X was reinforced during the revaluation stage, at test animals should respond more to the occasion-set Y than to Z. In Group C the prediction was the opposite: during revaluation W was reinforced and X extinguished; thus, although there should be some generalization from W to both Y and Z, extinction of the occasion-set X should generalize differentially to Y, thus producing less responding to Y than to Z.

Table 5 shows response rates to Y and Z in Group OS and Group C in the test. The scores are pooled into two-session blocks. The data proved to support the predictions outlined above. In the first block subjects in Group OS replicated the results of Experiment 1 by responding more to



TABLE 5  
Corrected Response Rates<sup>a</sup> in the Two Two-session Blocks of the Test Stage in Experiment 2

Group	Block 1:	Y	Z	Block 2:	Y	Z
OS		6.38	5.63		2.00	3.50
C		3.00	5.88		1.38	0.63

<sup>a</sup>Response rates are given in rpm.

Note: "Y" and "Z" refer to group mean response rates evoked by presentations of Y and Z during the test phase of Experiment 2. Mean response rates for the first two sessions are shown on the left, and those for the second two on the right.

Y than to Z, whereas Group C showed the opposite pattern of results, responding more to Z than to Y; indeed, this effect was larger than that shown in Group OS. In the second block this pattern of responding appeared to reverse in both groups; however, the differences in this second block proved not to be significant. For the statistical analysis, the stimulus for which more responding was predicted in each group (Y in Group OS and Z in Group C) was designated the S+, and the other stimulus the S-. An ANOVA performed on these data with stimulus (S+ versus S-), group (OS or C), and session block as factors revealed a significant main effect of block,  $F(1, 14) = 24.03$ , and a significant Block  $\times$  Stimulus interaction,  $F(1, 14) = 8.65$ , which did not interact with group,  $F < 1$ . No other effects or interactions were significant,  $F_s < 1$ . A Newman-Keuls test was used to examine the significant interaction further, and revealed that responding to the S+ stimulus was significantly higher than to the S- stimulus on the first block, but that they did not differ on the second. The pre-CS response rates for these sessions were, for Group OS for Y and Z, respectively, 0.29 and 0.00 rpm in the first block, and 0.38 and 0.29 rpm in the second. The corresponding rates for Group C were 0.56 and 0.29 rpm in the first block, and 0.47 and 0.56 rpm in the second. An ANOVA parallel to that conducted on the corrected scores revealed no significant effects or interactions, largest  $F(1, 14) = 1.47$ .

The results of the present experiment confirm those of Experiment 1 in demonstrating increased similarity between stimuli that have been trained as the targets of occasion-setting discriminations. In Experiment 1 this involved demonstrating more responding to the occasion-set CS in the generalization test, a result potentially explicable in terms of preexisting differences in the associative strength of the test stimuli: occasion-setting training might leave a stimulus with more strength than the conditioning and extinction procedure used for the control test stimulus. The results of

the present experiment are not explicable in this way, however, because although Group OS responded more to the occasion-set CS, Group C showed the opposite pattern of behaviour.

Although they are entirely consistent with the hypothesis that generalization is enhanced between the occasion-set stimuli, X and Y, another interpretation of these data is possible. In particular it might be argued that their common training history establishes equivalence between the trained and extinguished stimuli, Z and W. If so, the resulting differential generalization between Z and W could explain the pattern of results obtained. Animals in Group C experienced reinforcement of W and so, according to this account, should respond more to Z than to Y at test, whereas Group OS, having experienced non-reinforcement of W, would show less responding to Z than to Y. It is not possible to tell from this experiment whether the test results are the product of enhanced generalization between X and Y, or between W and Z. Indeed, both types of equivalence could be operating. However, the results of Experiment 1 clearly may not be explained in terms of equivalence between trained and extinguished cues—there was only one such cue in that experiment. Perhaps the most parsimonious account of the present results is that they are, at least in part, the product of equivalence among the targets of occasion-setting discriminations.

## GENERAL DISCUSSION

The present experiments provide evidence that acquired equivalence is established among the targets of occasion-setting discriminations, and thus extend the range of procedures known to produce such equivalence. This observation raises a number of questions; the first of these concerns how the effect might be mediated. In order to answer this, it is necessary to consider in more detail what mechanism might underlie acquired equivalence. One suggestion, made by Honey and Hall (1989), is that a stimulus representation may be regarded as a set of elements, each of which corresponds to a physical attribute of the stimulus. The more common elements two stimuli share, the more similar they are. Moreover, a stimulus that has, say, been conditioned as a signal for food could be regarded as having elements added to its representation: it now has the properties of eliciting a conditioned response, and of activating a representation of food, for example. Thus if two stimuli have been trained in the same manner, common elements will be added to their representations, and their effective similarity will be increased.

Within this framework the question arises as to what might constitute the added common elements that are endowed by occasion-setting training. There are a number of possible candidates. Having been associated with

food clearly cannot be one, as the conditioned and extinguished CSs have also had such a reinforcement history; nevertheless, some aspect of the food reinforcement schedule might be important. For example, occasion-set CSs, unlike simple CSs, are effectively on a partial reinforcement schedule that might engender considerable frustration, and this could possibly constitute the common element that occasion-set CSs share with each other but that the simple CSs lack (but see, e.g., Wilson & Pearce, 1990). A second possible candidate is the feature itself. On a large number of their presentations the occasion-set CSs in the present experiment were accompanied by feature stimuli that, although nominally different, had several common characteristics—they were both visual stimuli of the same relatively long duration, for example. If the CSs become associated with their respective features, and these features share common elements, then this might be sufficient to generate an equivalence effect (e.g. Honey & Hall, 1991).

Whichever of these possible mechanisms proves to be correct, the present findings may have implications for accounts of transfer of occasion setting. If there is, as these results suggest, enhanced generalization among occasion-set CSs, then this could be responsible for the enhanced transfer of occasion setting that is frequently observed to occasion-set CSs. Of course, one cannot be certain on the basis of the present results that this is the correct explanation for such transfer effects; but they do make the possibility distinctly more plausible. And this, in turn, could have wider implications for theories of occasion-setter action. As we have seen, a number of findings from transfer experiments have necessitated a departure from the very simplest accounts of occasion-setter function. For example, when Holland discovered that transfer to occasion-set CSs was superior to that seen with other stimulus types, he suggested that occasion-set CSs enter a higher memory system, and that stimuli represented in this memory system are more susceptible to transfer (e.g. Holland 1989; Lamarre & Holland, 1987). However, the present findings suggest that such an account might be redundant, and that these differential transfer effects might be explicable within the framework of the older and rather simpler proposal that occasion setters act on the CS-US association.

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### La facilitation augmente la similarité entre stimuli: équivalence acquise entre les cibles de discriminations à caractéristiques positives ("feature positive")

Lors de deux expériences, des rats ont été entraînés à deux discriminations "feature positive" concurrentes à renforcement appétitif. Un test préliminaire lors de l'expérience 1 a permis de confirmer le transfert de propriétés facilitatrices—la caractéristique (feature) d'une des discriminations facilite plus les réponses au SC cible facilité de la seconde discrimination, qu'à un stimulus de contrôle qui n'a pas été facilité. L'origine de ce transfert a été explorée lors d'une seconde phase de l'entraînement, et pendant l'expérience 2. Dans chacune de ces expériences, l'un

des SC facilités a été associé à la nourriture et on a ensuite examiné la généralisation des réponses conditionnées à ce stimulus vers le second SC facilité, et vers un stimulus contrôle. La généralisation du premier SC facilité vers le second SC qui lui aussi a été facilité est plus importante que celle observée vers le stimulus contrôle. Ceci tend à prouver que les SC facilités deviennent plus semblables à cause de leur histoire expérimentale commune. Le texte discute l'implication de ces données pour l'explication du transfert de la facilitation.

### **El entrenamiento de facilitación vuelve a los estímulos más similares entre sí: Equivalencia adquirida entre los estímulos diana de discriminaciones de rasgo positivo**

En cada uno de los experimentos, unas ratas fueron entrenadas en dos discriminaciones concurrentes de rasgo positivo con refuerzo apetitivo. Una prueba preliminar realizada en el Experimento 1 confirmó demostraciones anteriores de la transferencia de un estímulo facilitador manifestó mayor poder facilitador de la respuesta a un EC que a su vez había sido facilitado en un otra discriminación que a un estímulo de control que no había sido empleado en procedimientos de facilitación. En una fase posterior de entrenamiento y en el Experimento 2 se analizó el origen de esta transferencia. En ambos casos uno de los ECs facilitados fue emparejado con comida y se analizó la generalización de una respuesta condicionada apetitiva de este estímulo a un segundo EC facilitado y a una clave de control, observándose mayor generalización del primer EC facilitado al segundo EC, antes también facilitado, que a la clave de control. Este resultado puede considerarse como una prueba de que los ECs facilitados se vuelven más semejantes entre sí a consecuencia de una parecida historia de entrenamiento. Se comentan las implicaciones de estos resultados para la explicación de la transferencia de la facilitación.