Simultaneous discrimination learning: Stimulus interactions

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Although considerable attention has been given to interactions between events serving as the positive (S+) and negative (S-) stimuli in successive discriminations, there has been little study of similar interactions in simultaneous discriminations. We propose that in a simultaneous discrimination, given what is typically relatively little experience with the consequences of responding to the S-, some of the value of the S+ transfers to the S- with which it was paired. Furthermore, the mechanisms responsible for this transfer of value appear to be the higher order Pavlovian association between the S- and the S+, as well as within-event associations between them. Although in typical simultaneous discriminations, negative value does not appear to transfer from the S- to the S+, when adequate experience is provided with the S-, contrast typically develops, reducing the value of the S- (negative contrast) and enhancing the value of the S+ (positive contrast). This model of stimulus interactions has implications not only for simple simultaneous discrimination learning, but also for research using combinations of discriminations (e.g., transitive inference in animals and humans). This model may also have implications for a number of human social psychological phenomena.

Psychologists have been systematically studying instrumental discrimination learning in animals for almost 100 years (Hunter, 1914). In most cases, two stimuli are presented, and responses in the presence of one are reinforced (generally referred to as the S+ or S^D), whereas responses in the presence of the other are not (generally referred to as the S- or S^A). In the case of successive discriminations, each stimulus is presented individually, and the measure of discrimination learning is typically the ratio of responding to the S+ relative to total responding to both the S+ and the S- (often referred to as the discrimination ratio), whereas with simultaneous discriminations, both stimuli are presented together, a choice is made between them, and the measure of discrimination learning is generally the proportion or percentage of correct choices.

During the first half of the 20th century, discriminations were more typically studied with the simultaneous procedure (Kimble, 1961); however, in the last half of the century, studies involving successive discrimination learning have received much greater attention. Two important functional differences between simultaneous and successive discrimination have been noted by Kimble. First, in simultaneous discriminations, the relational characteristics of the stimuli may be easier to detect because the

stimuli can be directly compared. Thus, the interactions between the S+ and the S- in the two tasks may be different. Second, Kimble notes that in a simultaneous discrimination the learned behavior can be described as a choice between two responses, approach the S+ or approach the S-, whereas in a successive discrimination the learned behavior is more accurately described as responding or not responding to the presented stimulus (go/no-go). Thus, the experience with the two stimuli, especially the S-, may be different in the two tasks. Finally, simultaneous discriminations involve irrelevant spatial cues that are typically quite salient and may interfere with task acquisition.

STIMULUS INTERACTIONS

There are two forms of stimulus interactions that should be distinguished. The first is based on the properties of the stimuli themselves (the similarity between them). The second is based on the properties of the procedure (whether the stimuli are presented successively or simultaneously).

Stimulus Similarity Effects

The degree of physical similarity between the S+ and the S- during the acquisition of a discrimination has played an important role in theories of discrimination learning (see, e.g., Lawrence, 1955; Logan, 1966; Spence, 1937). By making certain assumptions—(1) that the excitatory strength of the S+ is greater than the inhibitory strength of the S-; (2) that the shape of the generalization gradient is concave downward; and (3) that the net effect can be represented by the algebraic summation of the two (i.e., excitation minus inhibition)—Spence was able to

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predict results that had been taken by others (e.g., Köhler, 1929) as evidence for relational learning by animals. For example, if following discrimination training between two stimuli that differ in some attribute (e.g., brightness), animals are given a choice between the training S+ and a novel stimulus removed from the S+ in the direction away from the S−, they will often prefer the novel stimulus over the training S+. This phenomenon, known as transposition, can be predicted from the summed absolute gradients of stimulus generalization (sometimes referred to as an elemental model of generalization), in which the maximum net excitation (i.e., the maximum value of the difference between excitation and inhibition) is displaced from the S+ in the direction away from the S−. When similar effects are found following successive discrimination training, it has been referred to as peak shift, because the peak rate of responding has shifted away from the S+, and by assessing the rate of responding to stimuli along the dimension defined by the difference between the S+ and the S−, one can determine the location of the peak (Hanson, 1959).

Spence's (1937) theory of discrimination learning is based on the absolute stimulus properties of the S+ and the S−, rather than on their relational role in the discrimination. According to Spence, if the discriminative stimuli selected as the S+ and S− are sufficiently different from each other, the excitatory and inhibitory generalization gradients will not overlap, and there should be no peak shift.

Functional Properties of the Successive and Simultaneous Discrimination Procedures

Although simultaneous and successive discrimination procedures are easy to distinguish, little attention has been paid to the functional differences in the results of training with these two procedures. Most of the research on discrimination learning that has been published in the past 50 years has used successive discrimination procedures, perhaps because it is simpler (only one stimulus is presented at a time) and, consequently, it is easier to interpret the meaning of the rate of responding to the discriminative stimuli. However, recent research using simultaneous discrimination procedures suggests that the stimulus interactions that occur with this procedure may be quite different from those that occur when discriminations are acquired by successive procedures. For this reason, before presenting the results of recent research investigating the stimulus interactions involved in the acquisition of simultaneous discriminations, it is important to summarize what is known about stimulus interactions involved in the acquisition of successive discriminations.

Successive discriminations. If pigeons are trained to peck at two stimuli presented successively (repeatedly, in random order) and reinforcement is withheld for responding to one of them, responding to the other stimulus (the stimulus associated with the unchanged schedule) gen-

erally increases. This phenomenon, first reported by Reynolds (1961), is known as positive behavioral contrast.

A number of accounts of behavioral contrast have been proposed (Williams, 1983). For example, Hinson and Staddon (1978) proposed that response competition in the poorer component of the discrimination is responsible for increased responding in the unchanged component. It is as if the responses not made to the S− are not eliminated but are suppressed and shifted to the S+. However, reduced responding in one component of a discrimination is not sufficient to produce contrast. For example, if responding in one component is reduced by replacing the contingent reinforcement with noncontingent reinforcement (Halliday & Boakes, 1971) or by reinforcement for the absence of responding (Reynolds, 1961), no evidence of contrast is found.

A second account of behavioral contrast attributes it to the decrease in the rate of reinforcement associated with the poorer schedule (Herrnstein, 1970). This hypothesis fits the intuitive notion of contrast—that it is a phenomenon that depends on the relative value of the two schedules of reinforcement. In the context of another, equally rich schedule, a rich schedule is not unusual, but in the context of a much poorer schedule, the same rich schedule appears better by comparison. More recently, however, Williams (1981) suggested that it may not be that the unchanged component is valued more in the context of the poorer component but, rather, that the increase in responding occurs in anticipation of the relative aversiveness of the upcoming poorer schedule. Animals act as if whatever reinforcers might be available during the richer schedule will soon become less available. In support of this hypothesis, Williams (1981) reported that contrast was found when the poorer schedule reliably preceded the richer schedule, but not when the richer schedule preceded the poorer schedule. Consistent with this interpretation of behavioral contrast, Williams (1992) has found that when two stimuli associated with the same schedule of reinforcement, Sa and Sb, are followed by either a stimulus of the same value or one of lesser value, respectively, the higher rate of responding to Sb than to Sa is positively correlated with a preference for Sa on Sa/Sb choice trials. Thus, pigeons peck more at Sb, but they prefer Sa. This result suggests that behavioral contrast is not an indication of the increase in value attributed to the S+ (in the context of an S−) but, rather, to the fact that the S+ soon might be replaced by the S− (i.e., things are likely to get worse soon).

Finally, Gamzu and Schwartz (1973) suggested that response rate to a stimulus is determined by two additive factors—first, the operant contingency of reinforcement associated with responding and, second, the Pavlovian relation of the stimulus to reinforcement. According to Gamzu and Schwartz, it is the Pavlovian relation that is affected by the introduction of the poorer schedule and that produces contrast. When the poorer schedule is introduced, it presumably makes the unchanged schedule a bet-

ter Pavlovian predictor of reinforcement than it was before, and it is those Pavlovian responses that add to the operant response to produce the contrast effect. This hypothesis appears to account best for the fact that contrast occurs under conditions that also typically result in auto-shaping (noncontingent key pecking produced by the pairing of keylight and food), but not under conditions that do not result in auto-shaping (e.g., stepping on a treadle for food; Hemmes, 1973).

Spence's (1937) elemental theory of discrimination learning cannot account for behavioral contrast, because the summation of excitatory and inhibitory gradients should always result in a net gradient that is somewhere between the two. However, Blough (1975) has suggested that an elemental model based on Rescorla and Wagner's (1972) conditioning model might account for both peak shift and contrast effects by giving different weights to the algebraic sum of associative strengths of the common and unique elements of the discriminative stimuli (see also Wills & Mackintosh, 1998).

Simultaneous discriminations. Recently, it has been suggested that stimulus interactions that occur during the acquisition of simultaneous discriminations might be quite different from those that develop in successive discriminations (Fersen, Wynne, Delius, & Staddon, 1991). Fersen et al. have suggested that in a simultaneous discrimination, some of the value associated with the S+ transfers (or generalizes) to the S- that is presented with it (an induction-like process). Furthermore, some of the negative value of the S- also may transfer to the S+. Although this notion of value transfer does not depend on the similarity between the S+ and the S- and thus differs from Spence's (1937) theory of stimulus generalization, one could view the spatial and temporal proximity of the two simultaneously presented stimuli as playing a role similar to the perceptual similarity of stimuli that look alike.

Fersen et al. (1991) proposed this view of stimulus interaction in simultaneous discriminations to account for their finding of transitive inference in pigeons. Evidence for transitive inference, as studied in humans, involves a verbal task in which two (or more) propositions are presented—for example, "If Alice is taller than Barbara, and Barbara is taller than Carol." Can participants then answer correctly the question "Who is taller, Alice or Carol?" To control for end point effects (i.e., the fact that Alice appears only in a sentence in which she is "taller than" but Carol never appears in a sentence in which she is "taller than"), the transitive inference task is usually expanded from three terms to five terms (by adding, e.g., "Carol is taller than Debby, and Debby is taller than Eva"). Transitive inference is then assessed using the second and fourth terms (i.e., by asking, "Who is taller, Barbara or Debby?"). One can create a nonverbal version of this task by substituting "is correct in the presence of" for "is taller than" (McGonigle & Chalmers, 1977), in which case the task reduces to four simultaneous discriminations that can be represented as A+B-

B+C-, C+D-, and D+E- (in which "+" and "-" represent the correct and the incorrect alternatives, respectively). Such a task can readily be acquired as a set of conditional discriminations (e.g., select B if it is presented with C, but not if it is presented with A). However, such learning could not account for performance with novel pairings (e.g., BD).

Fersen et al. (1991) trained pigeons on this task and found that on test trials, the pigeons preferred B over D. To account for this finding without resorting to inferential logic or to the development of a linear representation of the five terms, Fersen et al. suggested that differential value transfer might be involved. They reasoned that although the direct values associated with B and D in training were likely to be quite similar (because both stimuli had served as an S+ in one discrimination and as an S- in another discrimination), their indirect values were likely to be quite different, because A (to which responses were always reinforced) should have more value to transfer to B (in the A+B- discrimination) than C (which had served as both an S+ in the C+D- discrimination and an S- in the B+C- discrimination) should have to transfer to D (in the C+D- discrimination). Thus, according to Fersen et al., in a simultaneous discrimination, the value of an S- depends not only on its direct value (typically negative, acquired through nonreinforced responding), but also on the indirect positive value that it gains from the S+ with which it was presented. We will return to this interpretation of transitive inference later.

TESTS OF VALUE TRANSFER THEORY

If the notion of value transfer in a simultaneous discrimination is correct, it would suggest that stimulus interactions in simultaneous discriminations are opposite to the contrast effects typically found in successive discriminations. A direct test of value transfer in simultaneous discriminations was conducted by Zentall and Sherburne (1994). According to value transfer theory, in a simultaneous discrimination, the value of a negative stimulus should be directly proportional to the value of the positive stimulus with which it is presented. Zentall and Sherburne (Experiment 2) presented pigeons with two simultaneous discriminations involving distinctive hues. The value of the S+ stimuli was manipulated by varying the probability of reinforcement associated with responding to them. Thus, in one discrimination, A₁₀₀B₀, responses to A were reinforced on all trials, whereas responses to B were never reinforced. In the other discrimination, C₅₀D₀, responses to C were reinforced on 50% of the trials, whereas responses to D were never reinforced. According to value transfer theory, if pigeons are given a choice between the two S- stimuli, they should prefer B over D because more value should transfer from A to B than should transfer from C to D. In fact, the pigeons selected B over D on almost 80% of the test trials.

To ensure that the preference found could not be attributed to idiosyncratic preexperimental stimulus preferences, Zentall and Sherburne (1994) then gave the pigeons single-stimulus training with the B and D stimuli, and responding to either stimulus was reinforced on 50% of the trials. The purpose of the single-stimulus training was to equate response rates to those stimuli. The experiment was then repeated with the same discriminations, but the stimuli represented by A and C (as well as the stimuli represented by B and D) were interchanged. Thus, the positive stimulus to which responding was originally reinforced on all trials was now the positive stimulus to which responding was reinforced on half of the trials, and vice versa. Following this reversal training, a second BD test was given. Once again, B was preferred over D, and now the preference was over 90%. In another experiment (Zentall & Sherburne, 1994, Experiment 1), pigeons showed similar results when the training stimuli consisted of hues and shapes, but on test trials, whenever they were given a choice between a hue and a shape, they showed a bias to choose the shape. Despite this bias, however, the pigeons showed a significant (65%) preference for B over D.

GENERALITY OF THE VALUE TRANSFER EFFECT

Although evidence for value transfer was found with this discrete-trial simultaneous discrimination procedure, behavioral contrast effects are generally reported in the context of free-operant successive discriminations. There is a free-operant version of the simultaneous discrimination, however, known as a concurrent-schedules procedure. In this procedure, the pigeon is offered two schedules, each signaled by a distinctive stimulus, and the relative rate of responding is taken as a measure of preference (see Herrnstein, 1961). To examine schedule interactions in the concurrent-schedules procedure, Belke (1992) trained pigeons on two concurrent variable-interval schedules that differed in the density of programmed reinforcement. In one concurrent schedule, pigeons were offered a choice between a rich, variable-interval 20-sec schedule (VI20sec; on such a schedule, after a variable amount of time has passed that has a mean of 20 sec, the first response is reinforced) and a leaner VI40sec schedule. In the other concurrent schedule, the pigeons were offered a choice between the same lean VI40sec schedule (signaled by a different stimulus) and a still leaner VI80sec schedule. For comparison purposes, we can refer to these concurrent schedules as $A_{VI20}B_{VI40}$ and $C_{VI40}D_{VI80}$. On test trials, Belke assessed the schedule interactions by presenting the pigeons with a choice between the two nominally equal schedules, B_{VI40} and C_{VI40} , one from each concurrent schedule in training. Contrary to the prediction of value transfer theory, Belke found that the pigeons preferred the C_{VI40} schedule over the B_{VI40} schedule. Thus, C_{VI40} , which in training was presented in the context of the poorer D_{VI80} schedule, was preferred over B_{VI40} , which in training was presented in the context of the richer A_{VI20} schedule. In-

stead of value transfer, Belke found contrast (see also Gibbon, 1995).

The problem with the unambiguous interpretation of these findings is that the two schedules used in test served different roles in training. Because in training, B_{VI40} was the poorer of the two schedules in its concurrent discrimination, the pigeons should have learned to leave it for the better A_{VI20} schedule. On the other hand, because in training C_{VI40} was the better of the two schedules in its concurrent discrimination, the pigeons should have learned to stay with it, rather than leave it for the poorer D_{VI80} . According to this interpretation, these tendencies to leave or stay, acquired during training, could have produced Belke's results.

Zentall, Weaver, and Sherburne (1996) attempted to correct this problem by modifying the design to provide a better analogue of the Zentall and Sherburne (1994) study. To do this, they gave the pigeons a choice between two stimuli that not only had the same nominal value in training, but also served the same role in training (i.e., they were both the poorer schedule from each concurrent pair). Thus, Zentall, Weaver, and Sherburne trained pigeons on two concurrent schedules, $A_{VI20}B_{VI80}$ and $C_{VI40}D_{VI80}$, and then tested them with a choice between the two nominally equal schedules B_{VI80} and D_{VI80} . Under these conditions, consistent with value transfer theory, the pigeons showed a significant preference for B over D. Thus, with free-operant concurrent-schedule procedures, if the training stimuli associated with the poorer schedules are used in test, the results suggest that in training, value transfers from the better schedule to the poorer schedule.

BY WHAT MECHANISM DOES VALUE TRANSFER?

The research described here suggests that the stimulus interactions that occur in a simultaneous discrimination are quite different from those that occur in a successive discrimination. The fact that in a simultaneous discrimination the S+ and the S- are presented at the same time suggests that the processes underlying the transfer of value may involve Pavlovian, stimulus-stimulus associations.

Higher Order Conditioning or Direct Conditioning?

The enhanced value of the S- could occur because of the development of either of two associations. First, acquisition of the simultaneous discrimination may encourage the direct Pavlovian association between the S- and the reinforcer, through a process analogous to trace conditioning. As the simultaneous discrimination is acquired, at the start of a trial, imagine that the pigeon is standing in front of one of the two response keys. On half of the trials, the S- will appear on that key, the pigeon will peck the other key, and reinforcement will appear. Although pecking the S+ for reinforcement is an instrumental behavior, a Pavlovian association may develop between the S- and reinforcement through trace conditioning (i.e.,

Table 1
Two Possible Bases for the Transfer of Value from the S+ to the S- in a Simultaneous Discrimination

(1) Direct conditioning:	CS ₂ (S-) —————→ US	CS ₁ (S+) —————→ US
(2) Higher order conditioning:	CS ₂ (S-) —————→ CS ₁ (S+) —————→ US	

Note—CS, conditioned stimulus; US, unconditioned stimulus; S+, positive stimulus in a simultaneous discrimination; S-, negative stimulus in a simultaneous discrimination.

observation of the S- is always followed, after a brief delay, by food, the unconditioned stimulus). A schematic diagram of this relation is identified as (1) in Table 1.

Alternatively, the S- could be associated with reinforcement indirectly through the S+, by means of Pavlovian higher order conditioning. According to this view, the S+ represents the primary conditioned stimulus (CS₁), which (when responded to) is followed by reinforcement. In this case, the S- is the higher order CS (CS₂), a stimulus that is paired with, or that signals, the presence of CS₁. Although the two CSs are presented simultaneously, on half of the trials it is likely that the S- (CS₂) will be seen first (see Wright & Sands, 1981). As the simultaneous discrimination is acquired, observation of the S- should signal the presence of the S+ on the other response key. A schematic diagram of this relation is identified as (2) in Table 1.

The distinction between the direct association of a secondary CS with the US and its association with the US as mediated through the primary CS has been suggested by Rescorla (1980). Rescorla proposed that one could distinguish between these two processes following conditioning by devaluing the hypothesized mediator (the CS₁; e.g., by extinguishing the CS₁-US association). If the CS₂ derived its association with the US through the CS₁, then following the devaluation of the CS₁, there should be little evidence for CS₂ conditioning. If, however, the CS₂ was directly associated with the US during conditioning, one still should find evidence of a CS₂-US association.

Zentall, Sherburne, Roper, and Kraemer (1996) tested these hypotheses with the design used by Zentall and Sherburne (1994). In Zentall, Sherburne, et al. (1996, Experiment 1), pigeons were first trained on two simultaneous discriminations (A₁₀₀B₀ and C₅₀D₀). Following a test to confirm that B was preferred over D, half of the pigeons received *devaluation* training with A (consisting of single-stimulus extinction trials), whereas the remaining pigeons received devaluation training with C (the control group). Immediately after devaluation training, a second BD test was administered. The design of this experiment is presented in Table 2. Zentall, Sherburne, et al. found that the pigeons that had experienced devaluation of A no longer preferred B over D, whereas those that had experienced devaluation of C showed a slightly enhanced preference for B (relative to the first test). Thus, it appears that the mechanism by which value transfers from the S+ to the S- in a simultaneous discrimination involves higher order

conditioning, in which the S+ serves as a mediator through which the S- is associated with reinforcement. If this interpretation of the data is correct, one should be able to manipulate the degree of transfer by manipulating the distance between the S+ and the S- (i.e., the distance between the response keys). The farther apart the stimuli, the smaller should be the effect of the value of the S+ on the S-.

Is the Association Between S- and S+ Unidirectional or Bidirectional?

If higher order conditioning is responsible for the transfer of value from S+ to S-, it suggests that the association is unidirectional (see Table 1). On the other hand, it also is possible that a backward association develops between the primary CS and the secondary CS. Rescorla and Durlach (1981) have proposed that when conditioning involves two CSs, not only are there associations formed between each of the CSs and the US, but also there are bidirectional, within-event associations that develop between the two CSs.

Zentall, Sherburne, et al. (1996, Experiment 2) tested for the presence of bidirectional, within-event S+S- associations by training with two simultaneous discriminations (as in Experiment 1) but then providing reinforced single-stimulus training with either the S- associated in training with the better S+ (100% reinforcement) or the S- associated in training with the poorer S+ (50% reinforcement). If the associations acquired during original training are unidirectional, giving additional value to the S- (the presumed CS₂) should have little effect on its S+. However, if those associations are bidirectional, giving added value to the S- should affect the pigeons' choice between the two S+ stimuli.

In Zentall, Sherburne, et al. (1996, Experiment 2), the two S+ stimuli in training had different values (A₁₀₀B₀ and C₅₀D₀), as they did in the earlier experiments, and giving value to either B or D (B₁₀₀ for half of the pigeons, D₁₀₀ for the remaining pigeons; see Table 3) had little effect on the preference for A and B. However, it may be that the large difference in direct value between A and C experienced during training prevented that manipulation from having a detectable effect on test trials. This potential bias was corrected in Zentall, Sherburne, et al. (Experiment 3) by training pigeons on two simultaneous dis-

Table 2
Design of Zentall, Sherburne, Roper, and Kraemer (1996, Experiment 1)

Question: If A mediates the association of B with reinforcement, will the devaluation of A interfere with that association and reduce the preference for B over D?

Group	Training	Test 1	Devaluation	Test 2
A-	A ₁₀₀ B ₀ and C ₅₀ D ₀	B > D	A ₀	B = D
C-	A ₁₀₀ B ₀ and C ₅₀ D ₀	B > D	C ₀	B > D

Note—The hues red, green, yellow, and blue served equally often as A, B, C, and D. The subscripts represent the percentage of reinforcement associated with responding to the stimulus in training.

Table 3
Design of Zentall, Sherburne, Roper, and Kraemer
(1996, Experiment 2)

Question: Will an increase in the value of B retroactively affect A resulting in a preference for A over C?

Group	Training	Test 1	Valuation	Test 2
B+	A ₁₀₀ B ₀ and C ₅₀ D ₀	A versus C	B ₁₀₀	A > C
D+	A ₁₀₀ B ₀ and C ₅₀ D ₀	A versus C	D ₁₀₀	A > C

Note—The hues red, green, yellow, and blue served equally often as A, B, C, and D. The subscripts represent the percentage of reinforcement associated with responding to the stimulus in training.

criminations in which the values of the two S+ stimuli (and the two S− stimuli) did not differ (A₅₀B₀ and C₅₀D₀; see Table 4). In Phase 2, differential value was associated with the two S− stimuli (B₁₀₀D₀), and the S+ stimuli then were tested for preference. Consistent with the hypothesis that bidirectional associations are established during simultaneous discrimination learning, when the pigeons were given an AC test, they showed a modest but significant preference for A.

For a second group, following original discrimination training (A₅₀B₀ and C₅₀D₀), the value of the two S+ stimuli was modified (A₁₀₀C₀) to confirm that such a manipulation would affect the preference for the S− stimuli. As was predicted, on test trials, the pigeons once again showed a significant preference for B over D.

Further Tests of Within-Event Associations

Evidence for bidirectional associations between the S+ and the S− in a simultaneous discrimination suggests that within-event conditioning has occurred (Rescorla & Durlach, 1981). But within-event conditioning involving the S+ and the S− should be disrupted by the presentation of either stimulus in the absence of the other. Yet, all of the experiments described in Zentall, Sherburne, et al. (1996) involved just that. In Experiment 1, the single-stimulus presentation of one of the S+ stimuli not only should have devalued that stimulus, but also should have weakened the within-event association between that stimulus and the S− with which it was paired in Phase 1 (see Table 2). Thus, in Experiment 1, devaluation was confounded with the extinction of within-event conditioning.

In Experiment 2, the failure to find an effect on S+ preference (A vs. C) of the valuation of the S− (B₁₀₀ or D₁₀₀) may be due to the fact that such effects could have been eliminated by the concomitant weakening of within-event associations (see Table 3). Thus, once again, the weakening of within-event associations may have prevented the valuation of S− from affecting the S+ with which it was paired in training.

In Phase 2 of Experiment 3, for the group that experienced B₁₀₀D₀ training in Phase 2, the within-event associations should have been equally weakened, and whatever differential value was acquired could transfer to A. Similarly, for the second group in Experiment 3, the pre-

sensation of both of the S+ stimuli in the absence of the S− stimuli from Phase 1 should have weakened the within-event associations for both discriminations equally. Thus, whatever residual value was acquired by A and lost by C in the A₁₀₀C₀ discrimination could be seen on BD test trials (see Table 4). The results of all three experiments presented by Zentall, Sherburne, et al. (1996) are consistent with the view that within-event conditioning occurs during the acquisition of a simultaneous discrimination. In all cases, however, the evidence is indirect.

More direct evidence for the presence of within-event conditioning comes from research in which (1) in original training the two S+ stimuli are not differentially reinforced, (2) in Phase 2 training only a single stimulus from original training is presented, and (3) whether that stimulus is associated with reinforcement in Phase 2 or not is subject to experimental manipulation (Dorrance & Zentall, 1999). In this experiment, all the pigeons again were trained on two simultaneous discriminations (A₅₀B₀ and C₅₀D₀), as in Zentall, Sherburne, et al. (1996, Experiment 3). Thus, no preference should have been established during initial training. However, in Phase 2, only one stimulus was presented (either A or B), and responses to that single stimulus were reinforced for some pigeons (A₁₀₀ or B₁₀₀) or not reinforced for others (A₀ or B₀). Thus, there were four groups designated A+, A−, B+, and B− (see Table 5). The two groups that experienced stimulus A in Phase 2 were then given a BD preference test, whereas the two groups that experienced stimulus B in Phase 2 were given an AC preference test.

The results indicated that within-event conditioning had occurred in Phase 1, especially when Phase 2 training involved the S+ from original training. For both Groups A+ and A−, there was a strong preference for D over B. Thus, extinction of the within-event AB association greatly reduced the value transfer from A to B, even for group A+, for which A actually experienced an increase in value. The preference for D occurred because the transfer of value from C to D remained unaffected by single-stimulus presentations of A.

On the other hand, there was also an effect of the valence of A in Phase 2. Although both groups showed a significant preference for D over B on test trials, that preference was significantly stronger for group A− than it was

Table 4
Design of Zentall, Sherburne, Roper, and Kraemer
(1996, Experiment 3)

Question: Will an increase in the value of A and a decrease in the value of C retroactively result in a preference for B over D?

Group	Training	Phase 2	Test
A+C−	A ₅₀ B ₀ and C ₅₀ D ₀	A ₁₀₀ C ₀	B > D
B+D−	A ₅₀ B ₀ and C ₅₀ D ₀	B ₁₀₀ D ₀	A > C

Note—The hues, red, green, yellow, and blue served equally often as A, B, C, and D. The subscripts represent the percentage reinforcement associated with responding to the stimulus in training.

Table 5
Design of Dorrance and Zentall (1999)

Question: How will an increase or decrease in the value of the S+ or S- retroactively affect the stimulus with which it appeared in original training?

Group	Phase 1	Phase 2	Test
A+	A ₅₀ B ₀	A ₁₀₀	B < D
A-	A ₅₀ B ₀	A ₀	B << D
B+	A ₅₀ B ₀	B ₁₀₀	A > C
B-	A ₅₀ B ₀	B ₀	A = C

Note—The hues red, green, yellow, and blue served equally often as A, B, C, and D. The subscripts represent the percentage of reinforcement associated with responding to the stimulus in training.

for group A+. Thus, although the association between A and B was weakened by the single-stimulus presentations of A, in Group A+, some of the added value acquired by A apparently did transfer to B. When, as in this experiment, the two S+ stimuli were trained with similar value, single-stimulus presentations of one of those S+ stimuli (A) were sufficient to reverse the preference for its associated S- (B). In Experiment 1 of Zentall, Sherburne, et al. (1996), however, the value of A₁₀₀ in training was substantially greater than the value of C₅₀, and single-stimulus presentations of A were insufficient to reverse the preference for B.

The data from the two groups that experienced stimulus B in Phase 2 and were then given an AC preference test showed effects that were quite different. For group B+, there was a significant preference for A over C. Thus, unlike the large effect on B of presenting A by itself, for group B+ there was no apparent effect on A of presenting B by itself. If there was any effect at all, it was overwhelmed by the transfer of value from the now 100% reinforced B₁₀₀ to the 50% reinforced A₅₀.

For group B-, the pigeons were essentially indifferent on AC test trials. Thus, once again, there was no apparent effect on A of presenting B by itself, and in this case, because there was no change in the value of B from Phase 1 to Phase 2, A was unaffected.

Overall, the results of Zentall, Sherburne, et al. (1996) and Dorrance and Zentall (1999) suggest that there are bidirectional within-event associations that develop between S+ and S- in a simultaneous discrimination, but presentation of either stimulus by itself is not necessarily sufficient to disrupt that association. Instead, it appears that (1) positive value acquired following discrimination training can transfer to a stimulus that has less value at the time of test and (2) although single-stimulus presentation of the S+ from original discrimination training appears to weaken the association between the S+ and the S-, single-stimulus presentation of the S- from original discrimination training does not appear to weaken the association between the S- and the S+. Furthermore, in both cases, a change in the value of one of the stimuli following original discrimination training can affect the value of the other, a result that

not only supports value transfer theory but also indicates that value can transfer retroactively.

Value Transfer Versus Occasion Setting

The results of earlier research suggest that if the value of one discriminative stimulus is modified in the absence of the other, whether those trials occur following training (as in Zentall, Sherburne, et al., 1996) or during training (with single-stimulus trials interspersed among discrimination training trials), similar results should be found (i.e., the value that the S+ has to transfer to its associated S- is determined not only by its value in the context of the discrimination, but also by the value that it takes on when it appears by itself or with other stimuli). Thus, if A₅₀B₀ and C₅₀D₀ discrimination training trials are accompanied by single-stimulus A₁₀₀ and C₀ trials, one should find a preference for B over D on test trials. Although one could argue that single-stimulus A₁₀₀ trials should weaken the association between A and B, C₀ trials should have a corresponding effect on the association between C and D.

What is provocative about this design is that it presents conditions appropriate for the development of *occasion setters*. An occasion setter is a stimulus that signals the value of a discriminative stimulus but does not take on the value of that stimulus (Holland, 1983). Consider the role played by the S- stimuli in the mixed-trial design just described. Responding to A is sometimes associated with a high rate of reinforcement (100%; i.e., when it is presented alone) and is sometimes associated with a lower rate of reinforcement (50%; i.e., when it appears with B₀). Thus, B₀ should serve as a signal that the value of A is now lower than it would be if B₀ were not there. In Pavlovian terms, either the reduced value of A should be attributed to B₀ (see Rescorla & Wagner, 1972) and B should become a CS- or, if B becomes an occasion setter, it should not enter into association with A. In either case, the value of B should not improve with the addition of A₁₀₀ trials. Alternatively, if the value of B is determined by the overall (or average) value of A, then because the overall value of A is better than the overall value of C, B should be preferred over D.

A similar and perhaps even more convincing argument can be made for the effect of C₀ trials on the C₅₀D₀ dis-

Table 6
Design of the Experiments Presented in Dorrance, Kaiser, and Zentall (1998)

Question: Value transfer or occasion setting?

Experiment	Training	Test
1	A ₁₀₀ , A ₅₀ B ₀ , C ₀ , C ₅₀ D ₀	B > D
2	A ₁₀₀ , A ₅₀ B ₀ , C ₂₅ , C ₅₀ D ₀	B > D
3	A ₁₀₀ , A ₁₀₀ B ₀ , C ₂₅ , C ₁₀₀ D ₀	B > D
4	A ₁₀₀ , A ₂₅ B ₀ , C ₂₅ , C ₂₅ D ₀	B > D

Note—The hues red, green, yellow, and blue served equally often as A, B, C, and D. The subscripts represent the percentage of reinforcement associated with responding to the stimulus in training.

crimination. In this case, the presence of D should signal that C has value that it would not otherwise have. Again, in Pavlovian terms, either the increased value of C that is signaled by D should be attributed to D, thus making it a CS+, or if D becomes an occasion setter, it should not enter into association with C. Again, in either case, the value of D should not decrease with the addition of C₀ trials. Alternatively, if the value of D is determined by the overall value of C, then because the overall value of C is worse than the overall value of A, once again, B should be preferred over D.

In four experiments, Dorrance, Kaiser, and Zentall (1998) found support for value transfer theory. In each case, the relative average value of the S+ (presented by itself, as well as in the context of the S-) predicted the preference for the S- on test trials (see Table 6). Furthermore, when the effects of increasing the value of the S+ (when it appeared by itself) were separated from the effects of decreasing the value of the S+ (when it appeared by itself), both effects were found to be reliable. Thus, although there is evidence that single-stimulus presentations of the S+ tend to weaken the association between the S+ and the S- in a simultaneous discrimination, if one controls for this effect by equating it for the two discriminations, the value that the S+ can transfer to the S- depends on a combination of its value when paired with the S-, together with its value in other contexts.

Aitken (1999) has recently argued that what appears to be value transfer in this and earlier studies actually results from differential inhibition that accrues to the two S- stimuli (see also Couvillon & Bitterman, 1992; Wynne, Fersen, & Staddon, 1992). The argument is that 100% reinforcement to A₁₀₀ in the A₁₀₀B₀ discrimination should lead to few choices of B, whereas partial reinforcement of responding to C₅₀ in the C₅₀D₀ discrimination should lead to more choices of D. If pigeons make more choices of D₀ than of B₀ in training, more inhibition should develop to D than to B, and on BD test trials, B should be preferred. This position is based on Aitken's observation that there is a positive correlation across experiments between responding to D in training and the preference for B over D on test trials.

Although the logic seems sound, there is evidence that is inconsistent with this interpretation. First, despite the different reinforcement histories associated with the two simultaneous discriminations, in virtually all of the value transfer experiments, the number of choices of the two S- stimuli did not differ significantly. In some cases, pigeons actually chose B more often than D in training (presumably because of preexperimental stimulus preferences), yet almost all of them also preferred B over D on test trials. Furthermore, in a similar analysis of the relation between reinforced and nonreinforced experiences with the S+ and S- stimuli in three experiments using a transitive inference design, Higa and Staddon (1993) concluded that reinforcement history with the discriminative stimuli did not predict the presence (or absence) of the transitive inference effect. Instead, they suggest that this

effect may depend on dynamic properties of training, such as the order in which the training pairs are acquired.

Second, if differential inhibition, produced by the difference in the number of choices to D and B in training, was responsible for the choice of B over D in test, there should be a positive within-experiment correlation between that difference in training and the preference in test (the larger the difference in the number of choices of D vs. B, the greater the preference should be for B). Instead, that correlation was generally negative (although not significantly so).

Perhaps the most convincing evidence against the differential inhibition account of value transfer comes from Zentall, Sherburne, et al. (1996, Experiment 3) and Dorrance and Zentall (1999), in which the S+ stimuli were given the same direct value in training (as were the S- stimuli) and the value transfer manipulation was introduced following discrimination training, so there should have been no possibility of differential inhibition. Yet, in both studies, strong evidence for value transfer was found.

Aitken (1999) also suggested that stimulus generalization may have played a role in the value transfer effects found because hues were used as the discriminative stimuli and, typically, the discriminations presented in training involved hues that were not as far apart spectrally as they might have been (e.g., red + yellow- and green + blue-). However, as was noted by Zentall, Dorrance, and Clement (1999), traditionally obtained generalization gradients, following single-stimulus training (rather than discrimination training, which typically produces steeper gradients), indicate that there is virtually no responding to test stimuli that are as spectrally far apart as the hues used in the present value transfer research. Furthermore, in experiments in which there was complete counterbalancing of the hues, not only was value transfer found, but the condition in which the strongest value transfer effect was found (97% choice of B over D) was the condition in which the within-discrimination hues were selected to be spectrally farthest apart (i.e., red vs. green and yellow vs. blue; see Zentall et al., 1999). Certainly, if stimulus generalization played a role in these experiments, we should have seen some evidence of it in this experiment. Nonetheless, future research should more directly test Aitken's hypotheses and either assess the effects of differential inhibition and generalization or control for them.

NEGATIVE VALUE TRANSFER?

Although Fersen et al. (1991) discussed value transfer in a simultaneous discrimination solely in terms of the transfer of some of the positive value of the S+ to the S-, it is also possible that some of the negative value of the S- could transfer to the S+. In other words, the presence of the S- may reduce the positive value of the S+.

Traditionally, it has been more difficult to assess inhibitory processes than excitatory processes because, by its nature, inhibition must be assessed on an excitatory baseline (see Hearst, Besley, & Farthing, 1970). In the case

Table 7
Design of Experiments Described in
Clement, Weaver, Sherburne, and Zentall (1998)

Question: Does negative value transfer?

Experiment	Training	Test
Preliminary	$A_{100}B_0, C_{100}D_{50}$	$A = C$
1	$A_{75}B_0, C_{75}, B_0$	$A > C$
2	$A_{75}B_0, C_{75}D_{25}, B_0, D_{25}$	$A > C$

Note—The hues red, green, yellow, and blue served equally often as A, B, C, and D. The subscripts represent the percentage of reinforcement associated with responding to the stimulus in training.

of simultaneous discriminations, the assessment is made even more difficult, because the total experience that the animal has with the S— is generally more limited than in a successive discrimination. In a simultaneous discrimination, it is sufficient for the tendency to respond to the S+ to be clearly greater than the tendency to respond to the S— for a high level of discrimination performance to be found. In a successive discrimination, however, the tendency to respond to the S— must be near zero for a high level of discrimination performance to be found. Furthermore, in the case of a successive discrimination, responses to the S— have only minimal negative consequence (a few wasted responses), whereas in a simultaneous discrimination, the consequence of an incorrect choice is typically a lost reinforcement. As a result, simultaneous discriminations are generally acquired rapidly, and experience with the S— is limited.

A preliminary experiment exploring the possibility of negative value transfer was reported by Clement, Weaver, Sherburne, and Zentall (1998). The design of this experiment (see Table 7) was the mirror image of the design used by Zentall and Sherburne (1994). The idea was to train pigeons on two simultaneous discriminations in which the direct reinforcement value of the two S+ stimuli was equal and the value of the S— stimuli was varied ($A_{100}B_0$ and $C_{100}D_{50}$). Following training, when the pigeons were given AC test trials, no preference was found. However, given the limited experience that the pigeons had with the two S— stimuli (the discriminations were acquired very quickly, with an average of only 13.3 choices of each S— during acquisition, and those choices were typically made early in acquisition), it was not clear that this provided a reasonable test of the transfer of negative value. Compare this limited experience with the more than 200 choices (on average) of each S+ during acquisition.

To provide a better estimate of the effect that a well-experienced S— might have on the S+ with which it is paired, Clement et al. (1998, Experiment 1) made several changes in the design of the preliminary experiment (see Table 7). First, because it is not clear what effect partial reinforcement of responding to the S— might have on its associated S+ (D_{50} might either transfer positive value to C_{100} or draw value away from C_{100}), the $C_{100}D_{50}$ discrimination trials used in the preliminary experiment were replaced with single-stimulus C_{100} trials. Second, the prob-

ability of reinforcement associated with the two S+ stimuli was reduced from 1.00 to .75. This change was made to avoid the possibility of a performance ceiling on AC test trials. More specifically, pigeons given a choice between two stimuli that are both associated with reinforcement on 100% of the trials may respond to the first stimulus observed. Third, because errors could be made on $A_{75}B_0$ trials, but not on single-stimulus C_{75} trials, a correction procedure was used to ensure that the pigeons would experience the same number of reinforcements for responding to A_{75} as C_{75} . Finally, to ensure adequate exposure to the consequences of responding on B_0 trials, single-stimulus presentations of B_0 were included during training. Thus, training consisted of discrimination trials involving $A_{75}B_0$ and single-stimulus trials involving C_{75} and B_0 . If negative value transfers from B to A as the result of training, pigeons should prefer C over A on test trials. Instead, Clement et al. found a strong (71%) preference for A over C. The results of this experiment suggest that the presence of an S— actually enhances the S+ with which it is paired.

The rationale for deleting D from the C+D— discrimination was to avoid the problem of predicting the effect on C of giving some value to D. But given the finding that A was preferred over C, it is possible that single-stimulus presentations of C introduced an artifact—namely, A appeared in the context of a choice in both training and test, whereas C appeared in the context of choice only in test. Thus, on test trials, the novelty of the choice context for C may have biased the pigeons to choose A.

In Experiment 2, Clement et al. (1998) corrected this problem by replacing single-stimulus presentations of C with a CD discrimination in which D had direct value greater than zero and the pigeons experienced single-stimulus presentations of the two S— stimuli ($A_{75}B_0, C_{75}D_{25}, B_0, D_{25}$; see Table 7). Once again, following acquisition, the pigeons were given a choice between A and C, and once again they preferred A. Thus, the preference for A in the first experiment did not depend on the absence of choice trials involving C in training.

The results of these experiments suggest that in a simultaneous discrimination, whereas positive value transfers to the negative stimulus, negative value does not transfer to the positive stimulus. (When pigeons were trained with $A_{100}B_0$ and $C_{100}D_{50}$ and tested with B vs. D, no preference was found.) In fact, if adequate experience is provided with the negative stimulus, it results in contrast, enhancing the value of the positive stimulus with which it was paired.

Although single-stimulus presentations of the S— stimuli did appear to produce contrast in the simultaneous discriminations, one could argue that those single-stimulus presentations effectively converted the simultaneous discriminations into successive discriminations (i.e., $A_{75}, C_{75}, B_0, D_{25}$). But if single-stimulus training with the S— stimuli converted the simultaneous discriminations into successive discriminations, it is not clear why *differential* contrast would occur. That is, were it not for the $A_{75}B_0$ and

$C_{75}D_{25}$ associations developed during training, it is not clear why B should be contrasted with A, rather than with both A and C, and why D should be contrasted with C, rather than with both A and C. Thus, nonreinforced experience with B (as well as D) should have had the same effect on C as on A.

The presence of single-stimulus trials appears to be necessary to produce the contrast effect found by Clement et al. (1998). Is it possible that the inclusion of single-stimulus trials among discrimination trials will generally convert the relation between S+ and S- from value transfer to contrast—even in a positive value transfer design? Clearly, single-stimulus trials are not sufficient to produce contrast, because Dorrance et al. (1998) found value transfer when single-stimulus presentations of the S+ stimuli were included in training. However, in each of the experiments reported by Dorrance et al., the value of at least one of the S+ stimuli changed when it was presented as a single stimulus. However, for contrast to occur, it may be sufficient to have single-stimulus presentations of the S+ stimuli and for the value of those S+ stimuli to be the same as they are in the context of the simultaneous discrimination. Clement et al. included a positive value transfer group in their Experiment 2 and added single-stimulus presentations of the S+ stimuli in training ($A_{100}B_0$, $C_{50}D_0$, A_{100} , C_{50}). Consistent with value transfer theory, on BD test trials, the pigeons preferred B over D on 70% of the trials. Thus, single-stimulus presentations of the S+ stimulus from the simultaneous discrimination are not sufficient to convert value transfer to contrast. However, single-stimulus presentations of the S- may result in contrast.

Recall that in the positive value transfer design, the value of the S+ is varied, and its effect on the S- stimulus is assessed on test trials. Thus, one could argue that the single-stimulus presentation of the S- test stimuli should reduce or eliminate the effect of the S+ on the S- with which it is paired. That is, whatever value is attributed to the S- on the basis of its association with its S+ should be reduced by direct experience with the S- when presented by itself. Clement and Zentall (2000, Experiment 1) tested this hypothesis in a design similar to that used by Zentall and Sherburne (1994). Pigeons were trained on two simul-

taneous discriminations, with choice of one S+ reinforced on 100% of the trials and choice of the other S+ reinforced on 50% of the trials (see Table 8). Single-stimulus presentations of the two S- stimuli were also included. To ensure that the pigeons had similar direct experience with both S- stimuli, the stimuli were each given a small value, sufficient to maintain responding on single-stimulus trials. Furthermore, that small value was also nominally given to the S- stimuli when they appeared in the simultaneous discriminations ($A_{100}B_{12.5}$, $C_{50}D_{12.5}$, $B_{12.5}D_{12.5}$). Surprisingly, when the pigeons were given BD test trials, they showed a strong preference for D. Furthermore, in a follow-up within-subjects experiment, Clement and Zentall (Experiment 2) demonstrated that if there was little experience with the S- during original training, value transferred from S+ to S- but when training was continued and single-stimulus S- trials were included, contrast resulted (see Table 8). Thus, when pigeons that had just shown value transfer were given adequate exposure to the S- stimuli, they reversed their preference and showed negative contrast.

SUMMARY

The research presented here suggests that in a typical simultaneous discrimination, some of the value acquired by the S+ will transfer to the S- with which it was paired. However, under these conditions, the value of the S- appears to have little effect on the S+ with which it was paired. For an S- to affect the S+ with which it was paired, sufficient experience with the consequences of responding to the S- must be provided. Under these conditions, contrast (both positive and negative) appears to occur between the two discriminative stimuli. Furthermore, simultaneous discrimination training appears to result in the development of within-event associations that are weakened by single-stimulus presentations of the S+, but probably not by single-stimulus presentations of the S-.

Although these findings do not follow directly from theories of induction and contrast, they do have a certain intuitive appeal. In a typical simultaneous discrimination in which there is relatively little experience with the S-, it seems reasonable for the S- to take on some of the value of the S+ with which it was paired and for the S+ to be relatively unaffected by the S-. However, if greater experience is provided with the S-, relational or comparative aspects of the discriminative stimuli may be emphasized, and contrast should result.

Some interesting questions remain. That the S- preference on test trials can be reversed by providing the animal with single-stimulus experience with the S- in training suggests that one could track the shift in preference from one S- to the other by manipulating the amount of single-stimulus experience provided. Furthermore, it is not clear whether single-stimulus experience with the S- is necessary or whether experience with the S- in the context of the S+ would be sufficient to produce the shift in pref-

Table 8
Design of the Experiments Presented
in Clement and Zentall (2000)

Question: What is the effect of single-stimulus S- training on transfer of value from S+ to S-?

Experiment	Training	Test
1	$A_{100}B_{12.5}$, $C_{50}D_{12.5}$, $B_{12.5}$, $D_{12.5}$	$B < D$
2		
Phase 1	$A_{100}B_{12.5}$, $C_{50}D_{12.5}$, A_{100} , C_{50}	$B > D$
Phase 2	$A_{100}B_{12.5}$, $C_{50}D_{12.5}$, $B_{12.5}$, $D_{12.5}$	$B < D$

Note—The hues red, green, yellow, and blue served equally often as A, B, C, and D. The subscripts represent the percentage of reinforcement associated with responding to the stimulus in training.

erence. For example, if the simultaneous discrimination were made more difficult (the hues used in all of the experiments described were relatively easy to discriminate), there would be more experience with the consequences of choice of the S[−]. Would such experience be sufficient to produce contrast, or would it merely increase generalization between the S⁺ and the S[−], leading to greater value transfer?

An alternative means of giving the pigeons experience with the S[−] stimuli would be to use a procedure developed by Findley (1958), in which a single stimulus is presented (either the S⁺ or the S[−]) and the pigeon can choose to stay with that stimulus or change it to the other stimulus by pecking a second (change-over) key. Whether such a procedure would yield results similar to those following simultaneous discrimination training is not clear, but it would provide a relatively easy way to manipulate exposure to the S[−] stimuli.

IMPLICATIONS FOR OTHER RESEARCH INVOLVING SIMULTANEOUS DISCRIMINATIONS

Value transfer theory was proposed by Fersen et al. (1991) to account for a variety of transitive inference effects that have been reported with animals (Davis, 1992; Gillan, 1981; McGonigle & Chalmers, 1977; Steirn, Weaver, & Zentall, 1995). Recall that, following training with four simultaneous discriminations (A₁₀₀B₀, B₁₀₀C₀, C₁₀₀D₀, D₁₀₀E₀) animals given a choice between B and D typically prefer B and that such results have been taken as evidence for the development of a transitive inference. Fersen et al. suggested, however, that B may have been preferred over D because A had more value to transfer to B (responses to A were always reinforced) than C had to transfer to D (responses to C sometimes were reinforced and sometimes were not reinforced).

Although the positive value transfer research presented here (Zentall & Sherburne, 1994; Zentall, Sherburne, et al., 1996) suggests that value can transfer from an S⁺ to its associated S[−], as Fersen et al. (1991) predicted, there is also evidence that when differential value transfer is controlled, transitive inference effects can still be found (Weaver, Steirn, & Zentall, 1997). Weaver et al. trained pigeons on a modified version of the transitive inference task, in which the simultaneous discriminations can be represented as A₅₀B₀, B₁₀₀C₅₀, C₅₀D₀, and D₁₀₀E₅₀. Notice two characteristics about this series. First, the relations among the five terms should be sufficient to define a transitive relation (i.e., A is better than B, B is better than C, C is better than D, and D is better than E). Second, the values of A, C, and E all should be the same, because responses to them are always reinforced on 50% of the trials. Thus, the value that A has to transfer to B should be the same as the value that C has to transfer to D, and B should not be preferred over D. However, it is also possible that in a simultaneous discrimination, negative

value could transfer from the S[−] to the S⁺. But because the relative negative value that E can take from D should be the same as the relative negative value that C can take from B, again, according to Fersen et al., B should not be preferred over D. Weaver et al. found, however, that pigeons trained with this procedure did in fact show a significant preference for B over D. They concluded that although value does appear to transfer from the S⁺ to the S[−] in a simultaneous discrimination and that such transfer may contribute to the transitive inference effect that has been found in many studies, the transitive inference effect is probably multiply determined and some other mechanism is necessary to account for the effect found.

The more recent contrast research described here suggests what that mechanism might be. Recall that no evidence for negative value transfer was found. In fact, when there was sufficient experience with the S[−] stimulus in a simultaneous discrimination, contrast was found. In transitive inference training, there are no single-stimulus presentations of the S[−] stimuli, but there is extensive experience with the dual role played by each of the interior S[−] stimuli (B, C, and D). Thus, unlike a simple simultaneous discrimination, in which animals quickly learn to avoid responding to the S[−], there is considerable experience with nonreinforced responding to these S[−] stimuli, because those stimuli are at other times associated with reinforcement.

Although Weaver et al. (1997) controlled for both differential positive and negative value transfer, they did not control for differential contrast. The source of contrast for B would be C, and the pigeons would have had considerable experience with the consequences of responding to C, because it had served as both an S[−] in the B₁₀₀C₅₀ discrimination and an S⁺ in the C₅₀D₀ discrimination. Similarly, the source of contrast with D would be E, but because E appeared only in the D₁₀₀E₅₀ discrimination, it is less likely that the pigeons would have had as much experience with the consequences of responding to E as they had had with the consequences of responding to C. Thus, it is possible that the preference for B over D resulted from the extra value given to B by C (positive contrast), in the absence of corresponding contrast between D and E.

One could test this hypothesis by repeating the experiment conducted by Weaver et al. (1997) and including an additional simultaneous discrimination (E₅₀F₀). Learning to respond to E in the context of this E₅₀F₀ discrimination should encourage more responding to E in the D₁₀₀E₅₀ discrimination, and additional responding to E in the D₁₀₀E₅₀ discrimination should result in contrast between E and D, comparable with that produced between C and B. If differential contrast is responsible for the transitive inference effect, pigeons trained with this procedure should not prefer B over D. Alternatively, if pigeons can learn the relations among the training stimuli or are able to establish a linear representation of the stimuli, a continued preference for B over D should be found.

VALUE TRANSFER IN HUMANS

The value transfer effect found with pigeons appears to be a product of several basic learning principles—higher order conditioning (Zentall, Sherburne, et al., 1996) and a backward association between the S+ and the S− (Dorrance & Zentall, 1999). To what extent would similar processes control simultaneous discrimination learning in humans? If humans were trained on two simultaneous discriminations that differed in the value of responding to the two S+ stimuli ($A_{100}B_0$ and $C_{50}D_0$), they too might show a preference for B over D.

One might expect that humans would be less influenced by such Pavlovian processes, because the direct experience that humans would have with the consequences of responding to each of the four stimuli should be more likely to control choice on test trials (i.e., responses to B and D never would have been reinforced, so there would be no basis for choosing between them).

In a preliminary experiment (described in Lonon & Zentall, 1999), human participants were trained, as were the pigeons, with different probabilities of reinforcement associated with the choice of each of the positive stimuli ($A_{100}B_0$, $C_{50}D_0$), but many of the participants appeared unable to acquire the $C_{50}D_0$ discrimination. During the postexperiment debriefing, a number of the participants indicated that when they chose C and did not receive feedback that they were correct, they assumed that they would have been correct had they chosen D. Remarkably, for many of them, the fact that they were never correct for choosing D did not convince them that this hypothesis was incorrect. Thus, these participants interpreted the feedback that they received to mean that the discrimination was not a $C_{50}D_0$ discrimination but, rather, was closer to a $C_{50}D_{30}$ discrimination. For this reason, it was decided to change the manipulation from probability of reinforcement to magnitude of reinforcement. To emphasize the differences in value between the two S+ stimuli, responses to A were rewarded with 1,000 points, whereas responses to C were rewarded with 100 points. Responses to B and D were rewarded with 0 points.

When Lonon and Zentall (1999, Experiment 1) trained human participants on two simultaneous discriminations, $A_{1,000}B_0$ and $C_{100}D_0$, and then gave them a choice between the two S− stimuli, consistent with value transfer theory, almost 70% of the participants chose B over D. When asked about their choice, some of the participants indicated that they chose the negative stimulus that “went with” the better positive stimulus. Other participants reported that they had no idea why they chose B.

Lonon and Zentall (1999, Experiment 2) went on to ask whether value would transfer retroactively, the way it does with pigeons. Humans were trained with two simultaneous discriminations, $A_{100}B_0$ and $C_{100}D_0$, in which A and C were nondifferentially reinforced. They were then trained to discriminate between the two S+ stimuli, $A_{1,000}C_0$, with the value of A improving from 100 to 1,000

points and the value of C declining from 100 to 0 points. Following acquisition of this new discrimination, when given a BD preference test, again, consistent with value transfer theory, 78% of the participants chose B over D. Thus, just as with pigeons, value appears to transfer retroactively from a newly improved S+ to the S− with which it was originally paired.

Finally, Lonon and Zentall (1999, Experiment 3) asked whether humans form bidirectional associations between the S+ and the S− in a simultaneous discrimination that would allow a newly improved S− to transfer value back to an originally better, but now relatively poorer, S+. Again, humans were trained on two simultaneous discriminations, $A_{100}B_0$ and $C_{100}D_0$. Then the two S− stimuli were presented in a simultaneous discrimination, $B_{1,000}D_0$, with the value of B improving to 1,000 points but the value of D remaining at 0 points. Following acquisition of this new discrimination, when given an AC preference test, the participants did not show a preference for A over C. In fact, they showed a small, nonsignificant preference for C over A. Apparently, unlike pigeons, humans do not seem to show a bidirectional retroactive transfer of value. The implication of this difference in finding is not clear, but it may be attributable to differences in procedure, rather than to differences in underlying mechanism.

IMPLICATIONS FOR TRANSITIVE INFERENCE RESEARCH WITH HUMANS

Successful performance of the verbal form of the transitive inference task has been taken as an indication of a relatively high level of cognitive development—specifically, providing evidence of the ability to seriate and coordinate propositions (Piaget, 1928). Thus, in Piaget's view, the ability to perform correctly on a transitive inference task represents the functional use of logic.

Evidence that primates appear to make transitive inferences (Gillan, 1981; McGonigle & Chalmers, 1977) may have been taken as evidence of their logical capacities, but certainly the fact that such effects can be found in rats (Davis, 1992) and pigeons (Fersen et al., 1991; Steirn et al., 1995) suggests that alternative accounts should be considered. Fersen et al.'s suggestion that value transfer might account for transitive inference performance was instrumental in initiating the research program described here (see also Couvillon & Bitterman, 1992; Wynne, 1995).

The finding of value transfer and contrast in simultaneous discrimination learning in animals, together with similar findings of value transfer in humans, suggest not only that Fersen et al. (1991) were largely correct in their predictions, but also that these processes may have considerable generality. If value transfer and contrast play a role in the finding of transitive inference in animals, they may also play a role in findings of transitive inference in research with humans. In cases such as transitive inference, in which a phenomenon might be multiply determined, it is difficult to experimentally separate the logi-

cal, cognitive components from the more basic conditioning components, but recent research suggests a promising approach (Greene, Spellman, Dusek, Eichenbaum, & Levy, 2001). Using a nonverbal form of the transitive inference task, analogous to that used with animals, Greene et al. found that human adults performed successfully whether or not they were told that performance of the task required making an inference based on the premise pairs. Furthermore, when uninformed participants were later questioned about their awareness of the task structure, few of those who showed successful performance were aware of the task's relational structure. The authors concluded that relational learning does not require conscious processes, much less logical reasoning. This view is quite different from the interpretation of successful performance of the transitive inference task proposed by Piaget (1952) as evidence for the logical understanding of logical inferences.

IMPLICATIONS FOR BROADER ISSUES IN HUMAN BEHAVIOR

The conditioning processes responsible for value transfer and contrast may also play a role in social evaluation and other supposedly complex social psychological phenomena. Although such involvement is clearly speculative at this time, the apparent similarities between value transfer and several social phenomena suggest that they may share common underlying mechanisms.

Acquired Stimulus Value

Through conditioning, patriotic and religious symbols have long been known to arouse human emotions. Although those who find their emotions triggered by such symbols are not typically aware of the processes by which such learning has occurred, they are generally aware of those things that the symbol represents. Thus, conscious, cognitive processes are likely to be involved as well. There is evidence, however, that such conscious processes are not always involved in changes in value that come about through simple conditioning processes. It has long been part of advertising folklore to present products in contexts judged to be attractive, and such manipulations do appear to affect judgments of value. Smith and Engel (1968), for example, reported that participants who saw a new car advertisement that included a young woman model rated the car as better designed, faster, more appealing, and more expensive looking than did participants who saw the same advertisement without the model. Furthermore, and of particular interest in the present context, the participants generally indicated that although they were aware of the model, they did not believe that the presence of the model affected their perception of the car (Cialdini, 1988).

Similar results were reported by Gorn (1982), who showed participants video advertisements for writing implements (pens) presented with musical backgrounds that the participants had rated prior to test. Gorn found that sig-

nificantly more of the participants selected pens that were paired with "liked" music than with "disliked" music. Thus, some of the value of the preferred music appears to have transferred to the pen with which it was paired.

A related finding was reported by Neely (1982). In this study, participants first learned about election results. Three candidates were assigned different values: strong (i.e., won 16 elections and lost 4), medium (i.e., won 10 elections and lost 10), and weak (i.e., won only 4 elections and lost 16). These candidates were then paired with three new candidates who had all won and lost 10 elections. The only differences among the three novel candidates was the value of the candidate with which each was paired. Remarkably, the participants ranked the novel candidates paired with the strongest candidates as strongest and those paired with the weakest candidates as weakest. Thus, the likelihood that the new candidates would win appeared to be based on the strength (or value) of the candidate with which the new candidates were paired, rather than in contrast to these candidates (see also Heit, Price, & Bower, 1994). If the animal research presented earlier is relevant to this finding, it would suggest that in the case of the new candidates, not enough was known about them to induce critical comparisons. Instead, they were judged "by the company they were in." If value transfer theory is appropriately attributed to this finding, it should be possible to reverse the finding by providing participants with further information about the new candidates. Thus, the purpose of this exercise in finding analogous phenomena is not just to identify hypothetical examples of value transfer in humans, but also to suggest ways to test those hypotheses. Furthermore, the analogy between value transfer and social judgment will be of value only if it can be shown that it makes verifiable predictions when appropriate variables are manipulated.

Basking in Reflected Glory

Another social psychological phenomenon in which value transfer may be involved has been referred to as "basking in the reflected glory of others" (or BIRGing; see Cialdini et al., 1976). BIRGing occurs when attempts are made to enhance one's self-presentation by promoting one's association with famous or highly valued individuals. For example, a person might proffer that she comes from the same town as a famous singer. Presumably, she believes that she gains value from their common association (see also Tesser's, 1988, reflection effect).

Clearly, BIRGing involves processes that are more complex than those described in the preceding section, because the relatively less valued object (the S-) in this case is the self. Although it can be assumed that one knows a lot about one's self, one can also assume that in the context described, the person that one is trying to impress does not. Thus, the speaker is hoping that value will transfer from the known famous singer to himself or herself. An interesting prediction that follows from the results of value transfer research is that if one asked a person who

engaged in BIRGing to evaluate himself or herself, conditions that should encourage comparison, contrast would result (relative to someone who had not previously invoked the name of a famous person).

The Mere Ownership Effect

A phenomenon that may be related to BIRGing is known as the "mere ownership effect" (Beggan, 1992). The mere ownership effect occurs when an object that is given to a participant (ownership) is rated as more desirable than the same object when participants are just asked to rate it (nonownership). Ownership can be viewed as an acquired association between an object and a person (its owner), and in this case, it must be assumed that the owner has more value and thus serves as the S+. Thus, the association between the object and the person may allow value to transfer from the self to the previously relatively neutral object.

In most of the effects described with humans, one could view the training experience as an example of Pavlovian conditioning, because there is no explicit discrimination training provided. However, with the exception of the explicit training procedure used by Lonon and Zentall (1999), in all of the remaining procedures used with humans, it is assumed that the participants are responding on the basis of the explicitly identified S+ and that they clearly discriminate between it and the presumed S-. In fact, when participants are asked, they typically deny that their choice was influenced by the Pavlovian pairing (see Smith & Engel, 1968). On the other hand, we have argued earlier that despite discrimination training, Pavlovian processes (i.e., higher order conditioning and within-event conditioning) are likely to be involved in the acquisition of simultaneous discriminations. Thus, in the case of simultaneous discriminations, it may not be possible to distinguish between Pavlovian processes and instrumental choice.

CONCLUSION

The interactions between the S+ and S- in a simple simultaneous discrimination are not necessarily simple. Whether the S+ transfers value to the S- depends on how much experience an animal has had with the S-, as well as on the amount of experience that it had with the S+ outside of the context of the simultaneous discrimination. Identification of the mechanisms involved in simultaneous discrimination learning is important not only to develop a more complete theoretical account of these learning processes, but also because simultaneous discriminations are involved in more complex learning phenomena, such as transitive inference. Furthermore, the stimulus interactions that occur during simultaneous discrimination learning may be involved in a number of human social psychological phenomena, such as social attribution and evaluation.

The purpose of identifying these human social value analogies to value transfer is not to trivialize or explain

away complex social cognitive phenomena in associative learning terms but, rather, to suggest that certain components of these complex phenomena may be under the control of more basic conditioning processes. To the extent that these basic processes can be demonstrated and separated from the more complex social cognitive processes, a more complete understanding of them may be achieved. Furthermore, if analogous processes are involved in these (and perhaps other) social psychological phenomena, it suggests that it may be possible to eliminate or even reverse the effects of the experimental manipulation by providing additional experience with (or information about) the target of the manipulation (i.e., the presumed S-).

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