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Within-event learning contributes to value transfer in simultaneous instrumental discriminations by pigeons

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Following simultaneous discrimination training with pigeons, in which responding to the S+ was reinforced on half of the trials and responding to the S− was never reinforced, we examined the effect on the S− of presenting the S+ by itself and the effect on the S+ of presenting the S− by itself (relative to an S− or an S+ for which there had been no single-stimulus presentations). For Group A+, responding to the S+ presented by itself was always reinforced, whereas for Group A−, such responding was extinguished. For Group B+, responding to the S− presented by itself was always reinforced, whereas for Group B−, responding was extinguished. Although both Group A+ and Group A− tended to avoid their associated S− (relative to a control S−), Group A+ avoided its associated S− less than did Group A−. In contrast, although for Group B+, presentation of the S− alone increased the pigeons' preference for its associated S+ (relative to a control S+), for Group B−, presentation of the S− alone had little effect on its preference for its associated S+. These results suggest that presentation of one stimulus from a simultaneous discrimination has two independent and sometimes opposite effects on the other discriminative stimulus. First, it reduces the strength of within-event conditioning between the S+ and the S−, and second, if the value of the singly presented stimulus has increased, some of its newly acquired value will transfer retroactively to the stimulus with which it was originally paired.

Recently, it has been demonstrated that when stimuli are presented in a simultaneous discrimination, the stimulus that is associated with reinforced responding (S+) transfers value to the stimulus that is associated with nonreinforced responding (S−; Dorrance, Kaiser, & Zentall, 1998; Zentall & Sherburne, 1994; Zentall, Sherburne, Roper, & Kraemer, 1996). This phenomenon, referred to as *value transfer*, was first described by Fersen, Wynne, Delius, and Staddon (1991), but direct support for value transfer theory was first reported by Zentall and Sherburne. Zentall and Sherburne trained pigeons to discriminate between two pairs of stimuli, A+B− and C±D−. When A and B were presented, responses to A were always reinforced, whereas responses to B were never reinforced. When C and D were presented, responses to C were reinforced on a random 50% of the trials, whereas responses to D were never reinforced. After training on these two discriminations, on test trials, the pigeons consistently chose B over D. According to value transfer theory, B was preferred because, although neither B nor D had acquired any direct value, A had more value to transfer to B than C had to transfer to D.

Zentall et al. (1996) suggested two possible Pavlovian conditioning mechanisms to explain the transfer of value from the S+ to the S−. The first involves a direct, but delayed, association between B− (conditioned stimulus [CS]) and food (unconditioned stimulus [US]). A direct B–US association is possible because, as acquisition progresses, on half of the trials, observing B is likely to be the first link in a chain (consisting of observing B, then observing A, then responding to A, and then getting fed). Thus, the pigeon is likely to observe B prior to getting fed, a procedure analogous to trace conditioning.

A second mechanism that could account for the transfer of value from S+ to S− involves a higher order association, in which the A+ and B− represent CS1 and CS2, respectively. During training, B− reliably predicts the occurrence of A+, which, in turn, predicts the US. According to this higher order conditioning account, there is an indirect association between B− and the US (food) through A+.

Zentall et al. (1996) reasoned that these direct and indirect mechanisms could be distinguished by devaluing A+ following training and then evaluating the choice of B−. If devaluation of A reduces the preference for B, this suggests that B must have acquired its association with the US through A. If devaluation does not reduce the preference for B, however, this suggests that the association between B and the US was direct. Zentall et al. first trained pigeons on the A+B− and C±D− pairs. Following an initial BD test to establish a baseline preference for B over D, A was devalued by extinguishing responses to it (Group A−). For comparison purposes, C was devalued for other pigeons (Group C−). When given a second BD test, the pigeons in Group A− no longer preferred B, whereas pigeons in Group C− continued to prefer B. These data suggest that when A lost value, it was no longer able to transfer as

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much value to B, and B was no longer preferred. When C lost value, however, it transferred even less value to D, so B was still strongly preferred. The results support the hypothesis that B is associated indirectly with reinforcement through its association with A and that the association occurs, perhaps, through a higher order association linking B to reinforcement.

If value transfer occurs through a higher order association, this implies that the association between the S+ and the S− is directional. That is, a change in the value of the S− should affect the S+ (because the S− is assumed to be a signal for the presence of the S+), but a change in the value of the S+ should not affect the S− (because the S+ should not signal the presence of the S−). Alternatively, the association between the S+ and the S− may be bidirectional. That is, the simultaneous presentation of the S+ and the S− in training may result in within-event conditioning between them. If this were true, one would expect that a change in the value of B could affect A, just as a change in the value of A affects B (Zentall et al., 1996).

In their third experiment, Zentall et al. (1996) first trained pigeons with two discriminations involving similar reinforcement histories, A±B− and C±D−. Then, half of the subjects were trained with an A+C− discrimination. Thus, for these pigeons, the value of A was increased, and the value of C was decreased. A second BD test was then given. As predicted by both the higher order conditioning and the within-event conditioning accounts, this group chose B over D. They did so, apparently, because B was associated with the now higher valued A. For the remaining subjects, B+D− training followed original A±B−, C±D− training, and the test involved A versus C. Thus, for these pigeons, the value of B was increased, whereas the value of D was not. According to the within-event conditioning account, this group should choose A over C because of its association with the newly valued B, whereas according to the higher order conditioning account, there should be no differential preference for A over C, because a change in the value of B should not affect A. Consistent with the within-event conditioning hypothesis, a preference for A over C was found. Thus, following simultaneous discrimination training, an association appears to develop between the S+ and the S−, and that association appears to be bidirectional.

Rescorla and Durlach (1981) have demonstrated within-event learning with a variety of Pavlovian procedures, including an autoshaping procedure with pigeons, using visual, appetitive stimuli similar to those used in value transfer experiments. In one experiment, pigeons were trained with three intermixed trial types: presentation of a white key followed by food and presentations of two compound stimuli, neither of which was followed by food. Each compound stimulus was composed of a hue (blue or yellow) projected onto the top half of a response key and a set of black and white lines (vertical or horizontal orientation) projected onto the bottom half of the response key. After training, the pigeons received discrimination training with only the line orientations. During this phase, one of the line orientations was followed by food, whereas the other was not. The pigeons were then tested for responding to the hues. Rescorla and Durlach found that responding was higher to the hue that had previously been paired with the reinforced lines than to the hue that had previously been paired with the nonreinforced lines.

Although within-event learning has typically been invoked to describe associations that develop between elements of a compound CS during Pavlovian conditioning (Rescorla & Durlach, 1981), similar associations may also develop during instrumental discrimination learning. Thus, it is possible that, in addition to their instrumental properties, the S+ and the S− of a simultaneous discrimination may be considered to be two components of a compound conditioned stimulus.

An important prediction of a within-event learning account is that any separate presentation of either element of the compound stimulus should tend to undermine within-event learning, because this should weaken the association that developed between the two stimuli. If within-event learning is the mechanism underlying value transfer, presentations of A by itself, whether those presentations are associated with reinforcement or not, should reduce the pigeons' preference for B over D. Similarly, presentation of B by itself should also weaken the association between A and B.

In the case of Zentall et al. (1996, Experiment 3), following acquisition of the original discriminations (A±B−, C±D−), the stimuli were presented in a context different from training (either A+C− or B+D−). Although that experience should have weakened the within-event conditioning established during original training, it would be expected to have had a similar effect on both simultaneous discriminations, and, thus, its effects on the test stimuli (B vs. D and A vs. C) should have been comparable.

In the case of the devaluation of A following A+B−, C±D− training (Zentall et al., 1996, Experiment 1), it was assumed that the devaluation of A led to a reduction in the preference for B, because B could then serve as a signal for a less valued stimulus, A. However, it is possible that presentations of A alone were sufficient to weaken the within-event association between A and B, resulting in a decreased preference for B on BD test trials. In that experiment, the decreased value of A presented by itself was confounded with the weakening of the association between A and B resulting from those same single-stimulus presentations of A.

The present experiment was designed to assess whether the value associated with the separately presented stimulus (i.e., A+ vs. A− and B+ vs. B−) affects the stimulus with which it was originally paired, independently of the effect of the single-stimulus presentation per se.

METHOD

Subjects

The subjects were 16 experimentally naive White Carneaux pigeons, 5–8 years old, and of undetermined sex, maintained at 80% of their free-feeding weights. The pigeons were housed in individual cages in a room maintained on a 12:12-h light:dark cycle, and they had free access to water and grit.

Apparatus

The test chamber contained a pigeon compartment measuring 37 cm high, 34 cm across the response panel, and 30 cm from the response panel to the back wall. Mounted on the response panel were three square pecking keys measuring 2.5 cm wide and 2.5 cm high. The pecking keys were mounted side by side, 0.5 cm apart, with their bottom edges 24 cm above the wire mesh floor. The stimuli were projected only on the left and right response keys.

Located behind each pecking key was a 12-stimulus, in-line projector with 28-V, 0.1-A lamps that projected four hues, red (R), yellow (Y), blue (B), and green (G), produced by Kodak Wratten filters (numbers 26, 9, 38a, and 60, respectively).

Midway between the bottom of the pecking keys and the floor was the opening to a rear-mounted grain feeder that provided reinforcement. A houselight that was located 5 cm above the center response key provided chamber illumination. The chamber was connected to a computer in an adjacent room, which controlled the experimental procedure. A white noise generator and a fan provided background masking noise.

Procedure

Pretraining. The subjects were first trained to eat from the grain feeder, and they were then shaped to keypeck. Each trial began with one of the four stimuli—R, Y, B, and G—presented randomly on either the left or the right response key. The subjects were shaped by the method of successive approximations to peck once at each lit key in order to obtain reinforcement. A single peck to the stimulus turned it off, and reinforcement was available for 2.5 sec. After a 10-sec intertrial interval (ITI), the next trial began. Each session consisted of 24 trials. Once pecking was established to all four stimuli on the left and right, the number of responses required for reinforcement was increased gradually from one to five (fixed ratio [FR] 5). Pretraining was complete when the subjects completed two sessions of FR5 to each stimulus.

Discrimination training. Discrimination training began the day after pretraining was completed. The four pretraining stimuli were divided into two pairs, red/yellow and blue/green. Each trial began with the presentation of one pair of stimuli—one stimulus on the left key, the other on the right key. The first peck made to either stimulus defined the choice and turned off the other stimulus. The pigeon was then required to peck four more times to the chosen stimulus in order to end the trial. For the stimulus pair A±B−, five pecks to A led to reinforcement on a random 50% of the trials, whereas five pecks to B led directly to the 10-sec ITI. For the stimulus pair C±D−, five pecks to C led to reinforcement on a random 50% of the trials, whereas five pecks to D led directly to the ITI. Over subjects, each stimulus served equally often as A, B, C, and D. The AB and CD trials occurred in random order. Each session consisted of 96 trials. As each subject reached a criterion of 90% correct on both of the discriminations for two consecutive sessions, it was transferred to Phase 2 on the following day.

Single-stimulus training. Single-stimulus training consisted of one 96-trial session. Eight pigeons each were randomly assigned to Groups A and B. In Phase 2, all the pigeons in Group A received single presentations of Stimulus A. For 4 pigeons, responses to A were always reinforced (Group A+). For these pigeons, trials consisted of presentations of A alone for 6 sec, and the first response after 6 sec was reinforced (fixed interval [FI] 6 sec), followed by a 10-sec ITI. For the remaining 4 pigeons in Group A, responses to A were not reinforced (Group A−). For these pigeons, trials consisted of presentations of A alone for 6 sec, followed by the ITI.

All the pigeons in Group B received single presentations of Stimulus B. For 4 pigeons, responses to B were reinforced on an FI 6-sec schedule (Group B+); for the remaining 4 pigeons, B was presented for 6 sec, and responses to B were not reinforced (Group B−). The design of the experiment is presented in Table 1.

Test. The test was conducted immediately following Phase 2 training. For Groups A+ and A−, it involved one session consisting of 32 B versus D test trials. For Groups B+ and B−, it involved one session consisting of 32 A versus C test trials. Each test stimulus appeared equally often on the left and the right response keys. Reinforcement occurred on half of the trials, regardless of choice (FR5).

RESULTS

The mean number of sessions to criterion for pigeons in training was 3.94 ($SE = 0.25$). The rate of acquisition did not differ significantly among the four groups ($F < 1$).

Groups A+ and A−

For Group A+, the mean percent choice of D in test was 80.7 ($SE = 7.7$). For Group A−, the mean percent choice of D was 89.2 ($SE = 2.0$; see the left panel of Figure 1). The results of a t test indicated that, overall, the performance of these pigeons differed significantly from chance [$t(7) = 8.65, p < .001$].

An examination of the data from Groups A+ and A− suggests that the color of the test stimuli may have had an effect on choice. Although each of the colors served equally often as A, B, C, and D, it was decided to take out color pair as a factor in the analysis of the group data. A two-way mixed group (A+ vs. A−) × BD color pair (whether test pair was YG vs. RB) analysis of variance was performed on the test data for these groups. The analysis indicated that the choice of D over B was significantly greater for Group A− than for Group A+ [$F(1,4) = 10.7, p < .05$], and the effect of BD color pair was significant [$F(1,4) = 18.88, p < .05$]. The effect of color pair can be attributed to the fact that, when B and D were red and blue, D was chosen significantly more often (91.0%, $SE = 2.4$) than when B and D were green and yellow (79.2%, $SE = 6.8$). This type of color pair bias is consistent with the results of Zentall and Edwards (1984), which suggested that, for pigeons, these yellow and green stimuli are somewhat less discriminable from each other than are these red and blue stimuli. Thus, in the present experiment, when B and D were yellow and green, the preference may have been somewhat smaller, because these stimuli were less discriminable to the pigeons. Because stimulus color was counterbalanced over the four stimulus

Table 1
Design of the Experiment

Group	Phase 1	Phase 2	Test
A+	A±B−, C±D−	A+	BD
A−	A±B−, C±D−	A−	BD
B+	A±B−, C±D−	B+	AC
B−	A±B−, C±D−	B−	AC

Note—A plus (+) sign following a letter indicates that responses to that stimulus were reinforced, a minus (−) sign following a letter indicates that responses to that stimulus were not reinforced, and a plus/minus (±) sign indicates that responses to that stimulus were reinforced on a random 50% of the trials.

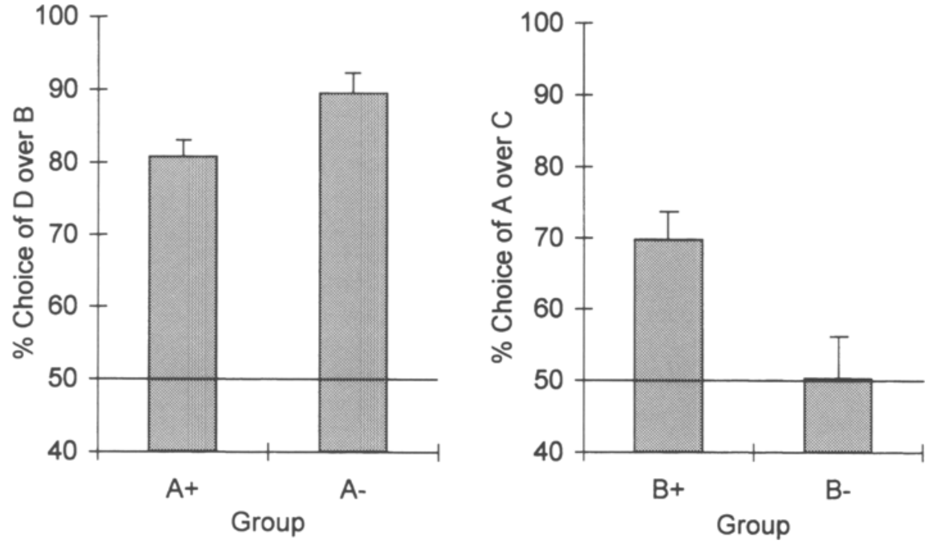

Figure 1. Left panel: The mean percent choice of D over B in test for Groups A+ and A−. Right panel: The mean percent choice of A over C in test for Groups B+ and B−. The error bars represent the standard error of the mean for each group.

events (A, B, C, and D), however, color preferences, per se, cannot account for the results.

Groups B+ and B−

For Group B+, the mean percent choice of A over C was 68.8 (SE = 4.9). For Group B−, the mean percent choice of A over C was 50.2 (SE = 6.3; see the right panel of Figure 1).

The results of a dependent t test indicated that the overall choice of A over C did not differ significantly from chance [$t(7) = 1.87, p > .05$]. However, the choice of A for Group B+ did differ significantly from chance [$t(3) = 3.82, p < .05$]. Furthermore, Group B+ chose A significantly more often than did Group B− [$t(6) = 2.32, p < .05$].

DISCUSSION

The results of the BD test demonstrated that subjects in both the A+ and the A− groups preferred D over B. This finding supports the hypothesis that, in a simultaneous discrimination, presenting the S+ by itself in a separate phase (whether responses are reinforced or not) disrupts the transfer of value from S+ to S−. By presenting A by itself, the AB association was apparently weakened, relative to the CD association, which remained intact. Thus, more value could transfer from C to D than from A to B.

The results of the BD test also demonstrated that whether responses to A were reinforced or not did make a difference. Pigeons in Group A+ chose D over B to a lesser extent than did pigeons in Group A−. This result suggests that changing the value of A during single-stimulus training, apart from weakening the AB association, differentially affected the choice of B, depending on whether responses to A were reinforced or extinguished. Thus, it appears that, although single-stimulus presentations of A weakened the association between A and B, they did so only partially, and B continued to serve as a signal for A, so that, when the value of A was changed, responding to B was affected accordingly.

The data from Groups A+ and A− appear, on the surface, to be inconsistent with the results of Zentall et al.'s Experiment 3 (1996). Although presentation of A+ (by itself) in the present experiment resulted in a reduced preference for B over D (relative to chance), Zentall et al. found that presentation of A+C− resulted in an increased preference for B over D. This discrepancy can be accounted for by the symmetrical weakening of AB and CD associations in the Zentall et al. experiment as compared with the unilateral weakening of the AB association in the present experiment. Thus, when both AB and CD associations are weakened, the preference for B is determined by the differential value acquired by A and C during single-stimulus training. When only the AB association is weakened, however, the transfer of value from A to B is reduced, but that reduction is partially mitigated by the increased value of A (in Group A+), or it is exacerbated by the decreased value of A (in Group A−).

The results of the AC test were consistent with those of the BD test. For Group B−, although extinguishing responses to B did not lead to a preference for A, as might be expected, the value of B did not change from discrimination training to single-stimulus training. Thus, it is possible that the AB association will not be disrupted unless the stimulus presented alone changes in value.

Another possible explanation for the failure of B− presentations to result in a preference for A is that negative value may not transfer from an S− to an S+; therefore, weakening the AB association by presenting B alone may have little effect on A. On the other hand, the data from Group B+ suggest that some of B's newly acquired value did transfer to A. Thus, reinforcing responses to B by itself led to a significant choice of A, whereas extinguishing responses to B by itself appeared to have little effect on A. The significant preference for A by pigeons in Group B+ may have occurred because separate presentation of B may have weakened the AB association, attenuating the transfer of negative value from B to A. Recent evidence suggests, however, that negative value does not transfer from an S− to an S+ (Clement, Weaver, Sherburne, & Zentall, 1998). Apparently, in a simultaneous discrimination, the presence of an S− does not diminish the value of its associated S+. However, reinforced presentations of B by itself may have allowed some positive value to transfer from the newly greater valued B (100% reinforcement) back to the less valued A (50% reinforcement).

What is clear from the results of the present experiment and from those of Zentall et al. (1996) is that changing the value of either the S+ or the S− can retroactively affect the value of the stimulus with which it previously was paired. Furthermore, subsequent manipulation of the value of the S+ appears to have a more consistent effect on the S− than subsequent manipulation of the value of the S− has on the S+. This result suggests that the association that develops between the S+ and the S− may not be symmetrical. Clearly, an association develops between the two stimuli, but the S+ retains more excitatory value than the S−, whereas the S− retains its role as a signal for the S+.

Rescorla and Durlach (1981) described an account of within-event conditioning that is consistent with the present results. According to their account, a representation of a compound stimulus is formed as a single unit, rather than as representations of the single components. Because each of the single elements is perceptually similar to the compound as a whole, the presentation of one element alone can activate the memory of the compound. In other words, the animals may fail to discriminate between the memory of the single element and the memory of the compound. Furthermore, if the singly presented element of the compound stimulus is altered, a memory of the compound is activated, and conditioning to the entire unit may result.

The results of the present experiment are also consistent with those of Rescorla (1983). Using an autoshaping procedure with pigeons, Rescorla examined the effect of presenting one element of a previously trained compound on the remaining (unpresented) element. In Experiment 1 of his study, pigeons were initially exposed to reinforced presentations of two compound stimuli, AB and CD. In Phase 2, either A or C was presented in the absence of reinforcement, and then responding to B or D was measured. Rescorla found, consistent with the notion of within-event conditioning, that responding to the element that had previously been paired with the extinguished element was significantly less than responding to the element that had previously been paired with the unextinguished element. Furthermore, reinforcement of one of the elements of the compound also resulted in decreased responding to the other element (Rescorla, 1983, Experiment 2).

Previous research has shown evidence for value transfer between stimuli in a simultaneous discrimination. Research has also shown that subsequent manipulation of one of the stimuli can retroactively affect the stimulus with which it had been previously paired. The results of the present experiment confirm the role of within-event conditioning in this transfer of value. Furthermore, the results of the present experiment demonstrate that, despite the weakening of the within-event association that results from presentation of a stimulus in isolation, following discrimination training, a change in the value of a singly presented stimulus can retroactively result in the transfer of value from that stimulus to the stimulus with which it was originally paired. Thus, within-event conditioning and value transfer between S+ and S− appear to function independently in the acquisition of simultaneous discriminations.

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