Discriminative stimuli that follow the absence of reinforcement are preferred by pigeons over those that follow reinforcement

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Clement, Feltus, Kaiser, and Zentall (2000) found that when pigeons have to work to obtain a discriminative stimulus that is followed by reinforcement, they prefer a discriminative stimulus that requires greater effort over one that requires less effort. The authors suggested that such a preference results from the greater change in hedonic value that occurs between the more aversive event and the onset of the stimulus that signals reinforcement, a contrast effect. It was hypothesized that any stimulus that follows a relatively more aversive event would be preferred over a stimulus that follows a relatively less aversive event. In the present experiment, the authors tested the counterintuitive prediction of that theory, that pigeons should prefer a discriminative stimulus that follows the absence of reinforcement over a discriminative stimulus that follows reinforcement. Results supported the theory.

The law of least effort suggests that organisms should prefer stimuli that predict less rather than more effort (Tolman, 1932). However, if those stimuli *follow* more rather than less effort, it is not obvious whether a preference between the stimuli should be found.

According to most traditional theories of learning (Hull, 1943; Skinner, 1938; Tolman 1932), stimulus preference should be affected by its consequences rather than by its antecedents. Thus, a preference should not be found between stimuli preceded by different amounts of effort. However, if effort becomes part of the context in which the stimulus appears (Bouton, 1993) or if backward associations form between the reinforcement and the effort that precedes it (Spetch, Wilke, & Pinel, 1981), then antecedent effort may affect preference in the same way as consequent effort, and stimuli that follow less effort should be preferred over those that follow greater effort. A third possibility is that the antecedent effort is judged in contrast to the conditioned reinforcing properties of the stimulus that follows. If this is the case, then stimuli that follow greater effort might be preferred over those that follow less effort.

Clement, Feltus, Kaiser, and Zentall (2000) tested these hypotheses. They trained pigeons with two simple simultaneous discriminations. On half of the trials, a single peck to an initial white stimulus was sufficient to obtain one of the discriminations (e.g., the pigeon was fed for choosing red but was not fed for choosing yellow). On the remaining trials, 20 pecks were required to the initial white stimulus to obtain the other discrimination (e.g., the

pigeon was fed for choosing green but was not fed for choosing blue). On test trials, when the pigeons were presented with a choice between the two positive, S+ stimuli, they showed a preference for the S+ that was preceded by greater effort during training (20 pecks) over the S+ associated with lesser effort (1 peck).

If such an effect were to be found in humans, it would likely be interpreted as an example of cognitive dissonance (Festinger, 1957). According to a cognitive dissonance account, expending additional effort to obtain an outcome should cause dissonance. Dissonance would result from having to expend greater effort on some trials when lesser effort was required on others. To reduce that dissonance, humans often judge the outcome that required greater effort to obtain to be more attractive than the one that required less effort to obtain.

Although cognitive dissonance theory has also been applied to the behavior of animals (Lawrence & Festinger, 1962), Clement et al. (2000) proposed a simpler mechanism to explain the preference for stimuli that follow greater effort. According to Clement et al., preference for stimuli that follow greater effort is produced by the contrast between the state of the animal immediately prior to presentation of the discriminative stimulus that signals reinforcement (at the end of the response requirement) and its state at the time that stimulus is presented. In this case, it is assumed that the animals are in a greater negative hedonic state at the end of the 20-peck requirement than at the end of the single-peck requirement. Thus, the relative change in hedonic state should be greater on high-effort trials and the value of the reward would be greater.

According to this model, any relatively aversive event that precedes the discriminative stimuli should lead to a preference for those stimuli over others that follow a less aversive event because the change in hedonic value or

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contrast should be greater following the relatively greater aversive event.

To test this hypothesis, DiGian, Friedrich, and Zentall (2004) manipulated the delay between the end of a common response requirement and the appearance of the discriminative stimuli. In support of the theory, they found that pigeons also prefer stimuli that follow longer delays over stimuli that follow shorter delays. In that study, during training, pigeons learned two simple simultaneous discriminations as in Clement et al. (2000). The first discrimination was preceded by a 6-sec delay whereas the second discrimination was presented immediately after the initial stimulus. When given a choice between the two S+ stimuli, as predicted, the pigeons showed a preference for the S+ that followed the delay over the S+ that followed no delay.

DiGian et al. (2004) also found that preference for the S+ that followed a delay required that the delay could be anticipated. When a common initial stimulus was followed by a delay on some trials but was followed by no delay on others, no discriminative stimulus preference was found. However, when the presence versus absence of the upcoming delay was differentially signaled so that the pigeon had to respond in the presence of a signal that the delay was coming, a significant preference was found for the S+ stimulus that followed the delay. DiGian et al. reasoned that in the case of the Clement et al. procedure, the added response requirement on high-effort trials served the same signaling function for the more aversive event (i.e., on high-effort trials, after the initial peck, the pigeon could anticipate having to make an additional 19 pecks to obtain the discriminative stimuli).

The purpose of the present experiment was to assess the generality of the contrast hypothesis by asking if the absence of reinforcement (in the context of the presence of reinforcement on other trials) can function as an aversive event comparable to greater effort or greater delay previously found to produce a preference for the discriminative stimuli that follow. Thus, if on some trials responses to an initial stimulus were reinforced and were then followed by a simple-simultaneous discrimination (e.g., A+B-), and on the remaining trials responses to the initial stimulus were not reinforced and were then followed by a different simple-simultaneous discrimination (e.g., C+D-), on test trials would C+ be preferred over A+?

The use of food and the absence of food as the differential hedonic events also allowed us to test the hypothesis that differences in the total duration of the trial may have been responsible for the preferences found by Clement et al. (2000) and by DiGian et al. (2004) because in both cases, stimuli presented on trials of a longer duration were preferred over stimuli presented on shorter duration trials. To control for the total duration of the trial, in the present experiment, the no-food event was of the same duration as the food event.

Because DiGian et al. (2004) had found a preference for the S+ stimulus that followed a delay only if the delay was signaled (i.e., could be anticipated), we conducted a preliminary experiment to test the generality of the effects

of an unsignaled aversive event, in this case the absence of food. Consistent with the results of DiGian et al., when pigeons pecked a white response key that on some trials was followed by food and then one pair of discriminative stimuli, and on other trials was followed by the absence of food and then the other pair of discriminative stimuli, when the pigeons were tested with a choice between the two S+ stimuli, they showed no consistent preference. Thus, in the present experiment, the food and no-food events were signaled.

The pigeons in the present experiment were trained on two simultaneous discriminations. One of the discriminations was preceded by a food event (i.e., 1.5-sec access to food), whereas the other was preceded by a no-food event (i.e., 1.5-sec in the absence of food). To ensure that the pigeons could anticipate the food and no-food events, the initial stimulus was an X stimulus on trials when the discriminative stimuli were preceded by food and the initial stimulus was an O stimulus when the discriminative stimuli were preceded by the absence of food. On test trials, the pigeons were given a choice between the two S+ stimuli or the two S- stimuli. Some of each of those choices were preceded by the X and food, others were preceded by the O and no food, and still others were not preceded by either pair of events (the two stimuli appeared at the start of the trial, immediately after the intertrial interval).

METHOD

Subjects

The subjects were 8 white Carneaux pigeons (*Columba livia*), 5–8 years of age and of unknown sex, obtained from the Palmetto Pigeon Plant (Sumter, SC). The pigeons had previously served in a matching-to-sample experiment involving red and green hues and vertical and horizontal lines. The pigeons were individually housed in a colony room maintained under a 12:12-h light:dark cycle. The animals were maintained at 80%–85% of their free-feeding weights for the duration of the experiment, but they had free access to water and grit in the home cage.

Apparatus

The experiment was conducted in a standard test chamber (BRS, LVE, Laurel, MD) that measured 33 cm high $\times$ 35 cm from response panel to back wall $\times$ 31 cm across the response panel. The response panel contained three horizontally aligned rectangular response keys (3.0 cm high $\times$ 2.5 cm wide, separated by 0.8 cm) each of which could be illuminated by a projector (Industrial Electronics Engineer, Model 10, Van Nuys, CA), mounted behind the key. The center key could be illuminated with either a white X or O on a black field. Each of the side keys could be illuminated with red, green, blue, and yellow stimulus fields (Kodak Wratten filters Nos. 26, 60, 38, and 9, respectively). Access to reinforcement was permitted through a horizontally centered 5.2 $\times$ 5.8 cm aperture in the response panel. Reinforcement (Purina Pro Grains) consisted of 1.5-sec access to the illuminated grain feeder. A houselight (GE 1820) provided general illumination during intertrial intervals. An exhaust fan mounted externally on the chamber masked extraneous sounds. All of the events in the chamber were controlled by a micro-computer located in an adjacent room.

Procedure

Training. Each trial began with the onset of an initial stimulus, either the X or the O on the center response key. Five pecks to the initial stimulus terminated its presentation. The X stimulus was al-

ways followed by 1.5-sec access to food, whereas the O stimulus was followed by 1.5 sec of darkness. Access to food was followed by the $S^+_{Food} S^-_{Food}$ discrimination. The no-food event was followed by the $S^+_{NoFood} S^-_{NoFood}$ discrimination. A schematic representation of the training events appears in Figure 1.

For half of the birds, the red hue served as the S^+ and the yellow hue as the S^- following the presentation of food, whereas for the remaining birds, the green hue served as the S^+ and the blue hue as the S^- following the presentation of food. The $S^+_{NoFood} S^-_{NoFood}$ discrimination followed the no-food event with the green hue serving as the S^+ and the blue hue serving as the S^- for half of the birds, and the red hue serving as the S^+ and the yellow hue as the S^- for the remaining birds. Choice of the S^+_{Food} and S^+_{NoFood} were reinforced on 100% of the trials, whereas choice of either the S^-_{Food} or S^-_{NoFood} was never reinforced.

Testing. There were six different types of test trials. A schematic representation of the testing trials appears in Figure 2. Half of these trials involved a choice between the two S^+ stimuli used in training; the other half of the trials involved a choice between the two S^- stimuli. One third of the test trials began with the onset of an X on the center response key, and another third of the test trials began with the onset of an O on the center key. Five pecks to these stimuli terminated their presentation and were followed by their respective food or no-food event, as in training. The food or no-food event was followed by the presentation of either the two S^+ stimuli (half of those trials) or the two S^- stimuli (the remaining trials). The remaining one-third of the test trials began with the onset of the two S^+ stimuli (half of the trials) or the two S^- stimuli (the remaining trials) without any preceding initial event. Each of the six test trial types was presented 8 times during the single test session, and all choices were randomly reinforced on 50% of the trials. No training trials were presented during the test session.

RESULTS

Training

The pigeons acquired the two simultaneous hue discriminations ($S^+_{Food} S^-_{Food}$ and $S^+_{NoFood} S^-_{NoFood}$) at about the same rate. The mean sessions to 90% correct was 2.75 for the $S^+_{Food} S^-_{Food}$ discrimination and 3.25 for the $S^+_{NoFood} S^-_{NoFood}$ discrimination [$t(7) = 1.41$, $p > .05$]. On the last training session, all pigeons were

performing both simultaneous discriminations at 100% correct.

Testing

On the $S^+_{Food} S^+_{NoFood}$ test trials, pooled over test conditions, pigeons chose the S^+_{NoFood} stimulus on 66.7% of the trials. A t test performed on these preference scores indicated that the difference was significant [$t(7) = 2.83$, $p < .05$]. On the $S^-_{Food} S^-_{NoFood}$ test trials, pooled over test conditions, pigeons chose the S^-_{NoFood} stimulus on 57.8% of the trials. A t test indicated that this difference was not significant [$t(7) < 1$]. The test-trial results are shown in Figure 3.

Evaluation of the $S^+_{Food} S^+_{NoFood}$ test trials according to which initial event preceded presentation of the test pair, using a one-way repeated measures analysis of variance (ANOVA), indicated that there was a significant effect of prior event [$F(2,14) = 6.57$, $p < .01$]. The pigeons were significantly more likely to choose the S^+_{NoFood} over the S^+_{Food} when the trial began with the no-food event (81.2%) than when it began with a initial food event (53.1%) [$t(7) = 4.02$, $p < .01$]. However, the choice of the S^+_{NoFood} on trials with no initial event (65.6%) was not significantly different from choice of the S^+_{NoFood} on either initial food event trials (53.1%) [$t(7) = 1.37$, $p > .05$] or initial no-food event trials (81.2%) [$t(7) = 2.24$, $p > .05$].

Evaluation of the effect of the initial event on choice between the S^-_{Food} and S^-_{NoFood} , using a one-way repeated measures ANOVA, indicated that the effect was not statistically significant ($F < 1$).

DISCUSSION

The results of the present experiment indicate that pigeons prefer an S^+ stimulus that is preceded by a no-food event over an S^+ stimulus that is preceded by a food event. These results are consistent with the model pro-

Figure 1. Food and no-food training trial types. Each trial type was presented on half of the trials. Location of the S^+ (left or right) and S^- was counterbalanced over trials.

Figure 2. Testing trial types. Testing involved choice between the two S+ stimuli (half of the trials) and the two S- stimuli (the remaining trials). On one-third of the test trials, food was the initial event (top panel). On another third of the test trials, no food was the initial event (middle panel). On the remaining trials, there was no initial event (bottom panel). Each of the six test trial types was presented equally often. Location of the S+ (left or right) and S- was counterbalanced over trials.

posed by Clement et al. (2000). According to that model, animals should prefer stimuli that follow a relatively more aversive event over stimuli that follow a relatively less aversive event because after a more aversive event, the change (improvement) in hedonic state is greater at the onset of a stimulus that signals reinforcement. According to their model, any stimulus associated with reinforcement that is preceded by an event that puts the animal in a more aversive state should lead to a preference for that stimulus. The prediction was based on the results of an experiment in which the effort that preceded the presentation of discriminative stimuli was manipulated, and it was supported by recent research that has shown that a predictable delay can have an effect similar to that of greater effort. The present research has extended that finding to the presence versus the absence of food as a prior event.

In addition, in the present experiment, on no-food-event test trials, the pigeons showed a greater preference for the S+ stimulus that in training had been preceded by the no-food event than they did on food-event test trials. That is, it appears that in training the initial event served in part as a conditional cue. This occurred in spite of the fact that correct choice of the discriminative stimulus did not depend on the nature of the initial event. That is, the discriminations could have been acquired without having to learn anything about the initial event that preceded it.

In light of the effect of the initial event on test trials, it can be argued that the initial event provided a context in which the two simultaneous discriminations were acquired (see, e.g., Ross & Holland, 1981). It should be noted, however, that this context effect cannot account for the overall preference for the S+ stimulus that in train-

Figure 3. Percentage choice of the discriminative stimuli that followed the no-food event in training for the two S+ stimuli and the two S- stimuli as a function of the initial event (no food, food, or no event) during testing.

ing was preceded by the no-food event. Instead, it appears that, in addition to the overall preference for the S+ stimulus that in training was preceded by the no-food event, the no-food event (but not the food event or no event) on test trials increased the preference for the S+ stimulus that followed it in training.

A similar effect was reported by DiGian et al. (2004). Preference for the S+ stimulus that, during training, was preceded by a delay was greater when, on test trials, it was preceded by a delay than when it was preceded by no delay. Similar context effects have not been reported in other experiments, however (see Clement et al., 2000; Clement & Zentall, 2002). In those experiments, the prior event on test trials had no effect on the S+ stimulus preference. Thus, the conditions under which such context effects are found need to be examined further.

The results of the present experiment also suggest that the preference for the S+ stimulus that follows a relatively aversive event does not depend on those trials being of a longer duration in training than trials involving the other S+ stimulus. In the present experiment, all trials were of equal duration.

In the present experiment, although the pigeons showed some preference for the S- stimulus that in training followed the no-food event (see Figure 3), the difference was not statistically significant. When Clement et al. (2000) reported a preference for the S- stimulus that in training followed the high-effort response, over the S- that in training followed the low-effort response, they attributed the preference to the greater transfer of value from the higher valued S+ to its associated S- (Zentall & Sherburne, 1994). Why we did not observe a similar effect in the present study is not clear. However, other research involving this manipulation of the relative aversiveness

of a prior event has also found an effect on the relative preference for the S+ stimulus that followed the relatively more aversive event, but no significant preference for the S- stimulus that followed the relatively more aversive event (Clement & Zentall, 2002; DiGian et al., 2004). Furthermore, it should be noted that the value transfer effect described by Zentall and Sherburne (1994) involved S+ stimuli that had different histories of reinforcement. Zentall and Sherburne found that, when pigeons were trained with two simultaneous discriminations in which one S+ was associated with a higher probability of reinforcement than the other, on test trials involving the two S- stimuli, there was a preference for the S- stimulus that in training was associated with S+ stimulus of greater value. Recall that in the present research, the two S+ stimuli had comparable histories of reinforcement, and the difference in value between them arose indirectly, through their association with the differentially aversive prior events (greater effort, greater delay, or the absence of food). Thus, in the present research, because the differential value associated with the S+ stimuli was indirect and thus, of a smaller magnitude, there may have been less differential value associated with the S+ stimuli to transfer to their associated S- stimuli.

We have interpreted the results of the present experiment, as well as previous results, in terms of contrast effects. However, delay reduction theory (Fantino & Abarca, 1985) may also be able to account for many of these results. According to delay reduction theory, stimuli will be preferred if they signal a reduction in the delay to reinforcement. In the present procedure, although the discriminative stimuli signaled the same delay to reinforcement, Fantino and Abarca proposed that it is the relative delay to reinforcement that must be considered. To see

how delay reduction theory can predict the results of Clement et al. (2000) and DiGian et al. (2004), one must consider the ability of the discriminative stimuli to predict reinforcement relative to the total duration of the trial. Thus, a stimulus that predicts a given delay to reinforcement will be a better predictor of that reinforcer on a trial of a longer duration, because the duration of the stimulus represents a smaller proportion of that trial than when it occurs on a trial of a shorter duration. If more pecks are required, or if a delay precedes the discriminative stimuli, it would make the trial longer and, thus, the discriminative stimuli would be better predictors of reinforcement.

In the present experiment, trial duration was similar on food and no-food trials, so, as noted earlier, differences in trial duration could not be responsible for the preferences found. However, if one considers the prior food event as a reinforcer, then the time between reinforcers was shorter on food-event trials (generally it was merely the time to choose the S+ stimulus on that trial) than on no-food trials (the time between S+ choices on successive trials) and thus, according to delay-reduction theory, a preference for the stimuli that follow the no-food event would be expected.

Although this form of delay reduction theory can account for the results of several experiments, it has difficulty accounting for the results of a series of experiments reported by Clement and Zentall (2002). In these experiments, the discriminative stimuli did not appear on the same trials as the differential effort (Clement & Zentall, 2002, Experiment 1) or differential probability of reinforcement (Clement & Zentall, Experiments 2 and 3). Thus, one initial stimulus predicted whether a large number of responses would be required (half of the trials) or a simultaneous discrimination would be presented (the remaining trials), whereas a different initial stimulus predicted whether a single response would be required (half of the trials) or a different simultaneous discrimination would be presented (the remaining trials). Consistent with the results of Clement et al. (2000), Clement and Zentall (Experiment 1) found that the pigeons preferred the S+ associated with the initial stimulus that on other trials was followed by the high-response requirement. In this case, trials involving either of the two simultaneous discriminations were of the same duration as was the inter-reinforcement interval. Only the high- and low-response requirement trials differed in their duration. Thus, in these experiments, a preference for the S+ that on other trials was associated with high-effort (or the absence of reinforcement) cannot be accounted for by delay reduction theory.

Delay reduction theory also has difficulty accounting for the failure to observe an effect of prior reinforcement in Experiment 1 of DiGian et al. (2004). In this experiment, in which the presence versus the absence of a delay following a response to the initial stimulus was manipulated, a common initial event was used. DiGian et al. found that when the delay could not be anticipated, a significant preference between the two S+ stimuli was not found. According to delay reduction theory, it is not clear why

anticipation of the occurrence of the prior event should be needed for the event to have an effect on the preference for the S+ that follows. Thus, the contrast theory proposed by Clement et al. (2000) provides a more complete account of the results of all of these experiments than does the delay reduction hypothesis.

Development of the contrast model proposed to account for the present findings, as well as those of Clement et al. (2000), Clement and Zentall (2002), and DiGian et al. (2004), was prompted by analogous findings in the human literature (Aronson & Mills, 1959). Such findings with humans typically have been explained in terms of Festinger's theory of cognitive dissonance (Festinger, 1957), a theory that proposed that individuals are motivated to resolve the dissonance provided by discrepancies between their beliefs and their behavior. When it comes to similar findings in pigeons, however, it is likely that a simpler account is more appropriate. Contrast effects may also be involved though, when humans attribute greater value to rewards for which they have had to work harder. That is, it may be that contrast also plays a role in humans when effects are found for which cognitive dissonance has been proposed as the primary explanation.

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