Second-Order Contrast Based on the Expectation of Effort and Reinforcement

Tricia S. Clement and Thomas R. Zentall
University of Kentucky

Pigeons prefer signals for reinforcement that require greater effort (or time) to obtain over those that require less effort to obtain (T. S. Clement, J. Feltus, D. H. Kaiser, & T. R. Zentall, 2000). Preference was attributed to contrast (or to the relatively greater improvement in conditions) produced by the appearance of the signal when it was preceded by greater effort. In Experiment 1, the authors of the present study demonstrated that the expectation of greater effort was sufficient to produce such a preference (a second-order contrast effect). In Experiments 2 and 3, low versus high probability of reinforcement was substituted for high versus low effort, respectively, with similar results. In Experiment 3, the authors found that the stimulus preference could be attributed to positive contrast (when the discriminative stimuli represented an improvement in the probability of reinforcement) and perhaps also negative contrast (when the discriminative stimuli represented reduction in the probability of reinforcement).

In a recent experiment, Clement, Feltus, Kaiser, and Zentall (2000) manipulated the number of responses required to obtain a simultaneous discrimination. On some trials, one response (FR1) was required to obtain a simultaneous hue discrimination ($S^{+}_{\text{Low Effort}} - S^{-}_{\text{Low Effort}}$); on other trials, 20 responses (FR20) were required to obtain a different simultaneous hue discrimination ($S^{+}_{\text{High Effort}} - S^{-}_{\text{High Effort}}$). Following training, when pigeons were given a choice between the S+ (positive stimulus) that previously followed the FR1 and the S+ that previously followed the FR20 ($S^{+}_{\text{Low Effort}}$ vs. $S^{+}_{\text{High Effort}}$), they chose the S+ that followed the greater response requirement in training. Similarly, when a choice was given between the two former S− (negative stimulus; $S^{-}_{\text{Low Effort}}$ vs. $S^{-}_{\text{High Effort}}$), the pigeons chose the S− that followed the greater response requirement in training. It was hypothesized that this effect resulted from the contrast between the greater effort (or perhaps from the additional delay to reinforcement) associated with additional responding to the initial stimulus and the secondary reinforcing effect of presentation of the discriminative stimuli. Thus, Clement et al., proposed that the value of the hues was judged relative to the motivational state in which the animal found itself immediately prior to their presentation (presumably somewhat more aversive in the case of the FR20 schedule). According to Clement et al., because the 20-peak requirement that preceded the $S^{+}_{\text{High Effort}}$ vs. $S^{-}_{\text{High Effort}}$ discrimination was relatively less appetitive (or perhaps more aversive) than the single peak that preceded the $S^{+}_{\text{Low Effort}}$ vs. $S^{-}_{\text{Low Effort}}$ discrimination, the onset of the $S^{+}_{\text{High Effort}}$ vs. $S^{-}_{\text{High Effort}}$ discrimination had greater relative value than the onset of the $S^{+}_{\text{Low Effort}}$ vs. $S^{-}_{\text{Low Effort}}$ discrimination. The preference found for the $S^{-}_{\text{High Effort}}$ over the $S^{-}_{\text{Low Effort}}$ was attributed to the transfer of value from the higher valued $S^{+}$ to the $S^{-}$ with which it was presented in training (see Zentall & Sherburne, 1994; Zentall, Sherburne, Roper, & Kraemer, 1996).

The results of Clement et al. (2000) bear some similarity to earlier work on motivational contrast effects (see Flaherty, 1996, for a review). That is, if one assumes that in each case the value of the $S^{+}$ reflects the value of reinforcement associated with it, then the value of reinforcement was influenced by the animal’s state just prior to presentation of the discriminative stimuli. The purpose of the present experiments was to further characterize this new result. In the first experiment, we asked whether it is necessary for differential effort to precede the discriminative stimuli, or would the anticipation of differential effort be sufficient to produce the contrast effect. Thus, what if, instead of the FR20 that preceded the discriminative stimuli in Clement et al., there was an initial stimulus (e.g., vertical lines) that on some trials was followed by a simple simultaneous discrimination and on other trials was followed by a high FR response requirement? Furthermore, what if, on other trials there was a different initial stimulus (e.g., horizontal lines) that on some trials was followed by a different simple simultaneous discrimination and on other trials was followed by a lower FR response requirement (see Figure 1)? Would a preference be found for the set of discriminative stimuli associated with the same initial stimulus as the high FR response over the set of discriminative stimuli associated with the same initial stimulus as the low FR response? In other words, is it possible to demonstrate this form of contrast when the greater effort response is not presented on the same trial as the discriminative stimuli but perhaps may have been expected—a second-order contrast effect?

In Experiment 2, we investigated the generality of this second-order contrast effect. Contrast effects are typically reported in experiments in which the amount or probability of reinforcement is manipulated rather than the effort to obtain reinforcement. If the present effects produced by manipulation of the FR requirement are attributable to contrast, it should be possible to demonstrate similar effects by replacing the differential FR requirement with
Three horizontally aligned rectangular response keys (3.0 cm wide, 2.5 cm high, and 0.8 cm apart) were located on the response panel. An in-line stimulus projector (Industrial Electronic Engineering, Model 10, Van Nuys, CA) mounted behind each response key could illuminate the center key with white vertical lines (V) on a black background, white horizontal lines (H) on a black background, as well as plain white field (W), and each of the side keys with red (R), green (G), blue (B), and yellow (Y) stimulus fields (Kodak Wratten filters Numbers 26, 60, 38, and 9, respectively). Access to presentations of mixed grain (Purina Pro Grains) was permitted through a horizontally centered 5.2 × 5.8 cm aperture located midway between the bottom edge of the pecking keys and the floor. Reinforcement consisted of raising the illuminated feeder for 1.5 s. A houselight (GE 1820) mounted in the center of the ceiling provided general illumination during the intertrial interval (ITI). Extraneous sound was masked by white noise presented through a speaker mounted behind the response panel and by noise from an exhaust fan mounted on the exterior of the chamber. All contingencies were controlled by a microcomputer and interface located in an adjacent room.

**Procedure**

Each pigeon was assigned to one of four subgroups (n = 2). The four hues (R, G, Y, B) were assigned to the two simultaneous discriminations, S+/Low Effort S−/Low Effort and S+/High Effort S−/High Effort, such that each color served equally often as S+/Low Effort* S−/Low Effort* S+/High Effort* and S−/High Effort*. To reduce the likelihood of stimulus generalization between the stimuli on test trials, all training discriminations were between red and yellow and between blue and green, the stimulus pairs found to be most difficult to discriminate. The rationale for using a simultaneous discrimination (S+/S−) rather than a simpler single-stimulus S+ was that it would reduce the novelty of the choice on test trials (see Clement et al., 2000).

**Training.** The design of Experiment 1 is presented in Figure 1. Each trial began with the onset of either V (signaling the possibility of a low-effort trial) or H (signaling the possibility of a high-effort trial) on the center key to which 10 responses were required. Half of the 48 trials initiated by V resulted in the presentation of the white stimulus on the center key. One response to the white stimulus (FR1) resulted in reinforcement on a random 50% of the trials and a 10-s ITI. For the remaining trials initiated by V, the S+/Low Effort S−/Low Effort simultaneous discrimination was presented. Five responses to the stimulus designated as S+ resulted in reinforcement on a random 50% of the trials and a 10-s ITI. Five responses to the stimulus designated as S−/Low Effort always resulted in the ITI alone. Partial reinforcement was used to avoid ceiling effects on choice trials in test (see Clement, Weaver, Sherburne, & Zentall, 1998).

Half of the 48 trials initiated by H resulted in presentation of the white stimulus on the center key, but following this stimulus, 30 responses (FR30) were required to the white stimulus to terminate the stimulus, obtain reinforcement (on a random 50% of the trials), and initiate the 10-s ITI. For the remaining trials initiated by H, the S+/High Effort S−/High Effort simultaneous discrimination was presented. Five responses to the stimulus designated as S+/High Effort were reinforced on a random 50% of the trials, and responses to the S−/High Effort were never reinforced. To summarize, presentation of the discriminative stimuli following V represents an upward shift in the expected effort required, whereas presentation of the discriminative stimuli following H represents a downward shift in the expected effort required. The four trial types were presented in random order with the constraint that any trial type could not appear on more than three consecutive trials.

Each session consisted of a total of 96 trials, and sessions were conducted 6 days a week. For all animals, training consisted of the attainment of 90% correct choices on both discriminations in a single training session, followed by 20 additional sessions of overtraining.

**Test.** Each of five test sessions included 24 test trials intermixed among 72 training trials. Half of the test trials involved a choice between...
S\textsuperscript{+} Low Effort and S\textsuperscript{+} High Effort\textsuperscript{1} whereas the remaining test trials involved a choice between S\textsuperscript{−} Low Effort and S\textsuperscript{−} High Effort. On one third of the test trials involving each stimulus pair, V was presented as the initial stimulus, on one third of the test trials H was presented, and on the remaining test trials there was no prior stimulus (NPS). An FR5 was required for all choices on test trials, and all choices were reinforced 50% of the time. All test trials were randomly ordered, and the test stimuli were counterbalanced for position (left and right). In all analyses and in all experiments, the .05 level of statistical significance was adopted.

Results

Training

The pigeons acquired the two simple-simultaneous hue discriminations to the joint criterion in an average of 5.75 sessions. The S\textsuperscript{+} Low Effort, S\textsuperscript{−} Low Effort and S\textsuperscript{+} High Effort, S\textsuperscript{−} High Effort discriminations were acquired to criterion in an average of 4.75 and 4.62 sessions, respectively. When these values were subjected to a t test, they were found to be not significantly different (t < 1). Similarly, mean total errors made during acquisition of the S\textsuperscript{+} Low Effort S\textsuperscript{−} Low Effort discrimination (14.6 errors) and S\textsuperscript{+} High Effort S\textsuperscript{−} High Effort discrimination (17.9 errors) were not significantly different (t < 1). Finally, terminal levels of performance on the two discriminations (mean performance on the last training day for S\textsuperscript{+} Low Effort S\textsuperscript{−} Low Effort 99.0%, and S\textsuperscript{+} High Effort S\textsuperscript{−} High Effort 100%) were not significantly different (t < 1).

Test

When given a choice between the former S+ stimuli (S\textsuperscript{+} Low Effort vs. S\textsuperscript{+} High Effort), pigeons chose the S\textsuperscript{+} High Effort; the S+ that in training was preceded by a stimulus associated with high effort, on 66.5% of the trials. A t test performed on these preference scores indicated that the difference was significantly different from chance, t(7) = 3.74. When given a choice between the former S− stimuli (S\textsuperscript{−} Low Effort vs. S\textsuperscript{−} High Effort), pigeons preferred the S− High Effort; the S− that in training was preceded by a stimulus associated with high effort, on 65.2% of the trials. Again, a t test indicated that the difference was significantly different from chance, t(7) = 2.87. Evaluation of the test trials, according to which initial stimulus preceded presentation of test pair, indicated that the effect of the initial stimulus (the low-effort stimulus, the high-effort stimulus, or no initial stimulus) on the choice of either the S+ or the S− was not significant, F(2, 14) = 1.01 and 3.61, respectively. The test data from Experiment 1 are presented in Figure 2.

Discussion

In training, one initial stimulus was associated on some trials with a high response requirement and on other trials was associated with an S\textsuperscript{+} High Effort S\textsuperscript{−} High Effort discrimination, whereas the other initial stimulus was associated on some trials with a low response requirement and on other trials was associated with an S\textsuperscript{+} Low Effort S\textsuperscript{−} Low Effort discrimination. On test trials, pigeons preferred both the S\textsuperscript{+} High Effort over the S\textsuperscript{−} Low Effort and S\textsuperscript{−} High Effort over the S\textsuperscript{−} Low Effort. These results are inconsistent with a simple account that posits that the low-effort stimulus signals a low-effort (easy) trial and the high-effort stimulus signals a high-effort (hard) trial, because according to this theory stimuli that follow the low-effort stimulus should be preferred over stimuli that follow the high-effort stimulus.

These results are also inconsistent with one of the hypotheses suggested by Clement et al. (2000) that the initial event may be directly associated with the discriminative stimuli such that whichever initial stimulus precedes the choice on test trials will determine the test–stimulus preference (a context effect).

Instead, the present results further support the hypothesis proposed by Clement et al. (2000) that pigeons judge the relative value of discriminative stimuli in contrast to their motivational state immediately preceding the onset of the discriminative stimuli and, in the present case, in contrast to their expectation associated with the same initial stimulus. Most important, these results suggest that the expectation of an event can serve as a basis against which to judge the value of the discriminative stimuli.

Experiment 2

Experiment 2 was designed to further determine whether contrast between expectation and outcome was responsible for the preferences found on test trials in Experiment 1. If such second-order contrast was responsible for choice, then it should be possible to produce a similar contrast effect by manipulating the probability of reinforcement rather than the amount of effort. Traditionally, contrast is produced by creating a discrepancy between expected and obtained rewards (see, e.g., Crespi, 1942). Thus, the question is, can pigeons use the expectation of reinforcement associated with an initial stimulus as a baseline against which to contrast the subsequent probability of reinforcement associated with the S+ in a simultaneous discrimination? In other words, if an initial stimulus associated with an overall low probability of reinforcement is followed by a simultaneous discrimination associated with a higher probability of reinforcement, would the presumed

\[ \text{Figure 2. Preference for the } S^{+} \text{ High Effort and } S^{-} \text{ High Effort stimuli, which followed the horizontal lines in training. On other trials in training, } \]

\[ \text{the horizontal lines were followed by a high-effort response (30 pecks were required). Test trials were preceded by vertical } \]

\[ \text{lines (low), horizontal lines (high), or no prior stimulus (nps). Error bars represent one standard error of the mean. Stim = } \]

\[ \text{stimulus; Train = training; } S^{+} = \text{ positive stimulus; } S^{-} = \text{ negative stimulus.} \]
resulting positive contrast produce a preference for those stimuli over stimuli with a similar history of reinforcement but that followed an initial stimulus associated with an overall higher probability of reinforcement, presumably resulting in negative contrast?

The design of Experiment 2 is illustrated in Figure 3. In Experiment 2, the probability of reinforcement associated with the initial event (relative to the S+) from the simple simultaneous discriminations that followed was manipulated by presenting trials on which the initial stimulus was always followed directly by food or by the absence of food. Thus, if half of the trials following a particular initial stimulus were always followed by food and the remaining trials were followed by a simple simultaneous discrimination for which responses to the S+ were associated with food at a lower probability, then presentation of the discriminative stimuli would represent a downward shift in the overall expected probability of reinforcement. Similarly, if half of the trials following a particular initial stimulus were never followed by food and the remaining trials were followed by a simple simultaneous discrimination for which responses to the S+ were associated with food at a higher probability, then presentation of the discriminative stimuli would represent an upward shift in the overall expected probability of reinforcement. If this analysis is correct, pigeons should prefer the discriminative stimulus associated with the upward shift in the probability of reinforcement over those associated with the downward shift in the probability of reinforcement, and they should do so in spite of the fact that the actual probability of reinforcement associated with the discriminative stimuli would be the same.

Method

Subjects

Subjects were 8 experimentally naive White Carneaux pigeons (Columba livia) otherwise similar to those used in Experiment 1. The subjects were maintained and housed as were those in Experiment 1.

Apparatus

The apparatus used in Experiment 2 was the same as that used in Experiment 1.

Vertical Lines

(HR10)

100% Food

S+HP S+HP

No Food

S+LP S+LP

50% Food

Horizontal Lines

(HR10)

50% Food

100% Food

Figure 3. Design of Experiment 2: Expectancy of reinforcement. S+ = positive stimulus; S− = negative stimulus; HP = stimuli that followed vertical-line initial stimuli, which on other trials were followed by a high probability of reinforcement (100%); LP = stimuli that followed horizontal-line initial stimuli, which on other trials were followed by a low probability of reinforcement (0%); FR = fixed ratio; FR10 = 10 pecks were required; FR5 = 5 pecks were required.

Procedure

As in Experiment 1, each pigeon was assigned to one of four groups. The four hues (R, G, Y, B) were assigned to the two simultaneous discriminations S+Low Prob S−Low Prob and S+High Prob S−High Prob as they were in Experiment 1.

Training. Each trial began with the onset of either V or H on the center key to which 10 responses were required. Half of the trials initiated by V resulted in the presentation of food (no white key and 100% reinforcement) and a 10-s ITI. For the remaining trials initiated by V, the S+High Prob S−High Prob simultaneous discrimination followed the FR10 response. Five responses to the stimulus designated as S+High Prob resulted in reinforcement on a random 50% of the trials and a 10-s ITI. Responses to the stimulus designated as S−High Prob resulted in a 10-s ITI (0% reinforcement). Thus, once the simultaneous discrimination was acquired, the overall probability of reinforcement associated with V should have been about 75%, and on trials when it was followed by the discriminative stimuli, the probability of reinforcement should have decreased to 50% when presented.

The remaining trials were initiated by H. Half of those trials resulted in 0% reinforcement (again there was no white key) and the ITI. For the remaining trials initiated by H, the S+Low Prob S−Low Prob simultaneous discrimination followed the FR10 response. Five responses to the stimulus designated as S+Low Prob were reinforced on a random 50% of the trials, and responses to the S−Low Prob were never reinforced. Thus, the overall probability of reinforcement associated with H should have been about 25%, and on trials when it was followed by the discriminative stimuli it should have increased to 50% when presented. To summarize, presentation of the discriminative stimuli following V represented a downward shift in the expected probability of reinforcement, whereas presentation of the discriminative stimuli following H represented an upward shift in the expected probability of reinforcement.

Each session consisted of a total of 96 trials, and sessions were conducted 6 days a week. For all animals, training consisted of the attainment of 90% correct choices on both discriminations in a single training session, followed by 20 additional sessions of overtraining.

Test. The test procedure was the same as that used in Experiment 1. Half of the test trials involved a choice between S+Low Prob and S+High Prob, whereas the remaining test trials involved a choice between S−Low Prob and S−High Prob. On one third of the test trials involving each stimulus pair V was presented as the initial stimulus, on one third of the test trials H was presented, and the remaining test trials there was no prior stimulus (nps). All choices on test trials were reinforced 50% of the time. All test trials were randomly ordered and the test stimuli counterbalanced for position (left and right).

Results

Training

The pigeons acquired the two simple-simultaneous hue discriminations to a joint criterion in an average of 5.12 sessions. The S+Low Prob S−Low Prob and S+High Prob S−High Prob discriminations were acquired to criterion in an average of 4.25 and 3.87 sessions, respectively. When these values were subjected to a t test, they were found to be not significantly different (t < 1). Similarly, mean total errors made during acquisition of the S+Low Prob S−Low Prob discrimination (22.5 errors) and the S+High Prob S−High Prob discrimination (20.4 errors) were not significantly different (t < 1). Finally, terminal levels of performance on the two discriminations (mean performance on the last training day for S+Low Prob S−Low Prob 100%, and S+High Prob S−High Prob 100%) were exactly the same.
Test

When given a choice between the former S+ stimuli (S+\text{Low Prob} vs. S+\text{High Prob}), pigeons chose S+\text{Low Prob}, the S+ that in training was preceded by a stimulus associated with a lower probability of reinforcement, on 66.9% of the trials. A t test performed on these preference scores indicated that the difference was significantly different from chance, \( t(7) = 3.04 \). When given a choice between the former S− stimuli (S−\text{Low Prob} vs. S−\text{High Prob}), pigeons preferred S−\text{Low Prob}, the S− that in training was preceded by a stimulus associated with a lower probability of reinforcement, on 72.1% of the trials. Again, a t test indicated that the difference was significantly different from chance, \( t(7) = 3.29 \).

Evaluation of the test trials, according to which initiating event preceded presentation of test pair, indicated that the initiating event (V, H, or no initial stimulus) had little effect on choice for either the S+ or the S−. Error bars represent one standard error of the mean. Stim = stimulus; Train = training; S+ = positive stimulus; S− = negative stimulus.

Discussion

When the probability of reinforcement associated with the discriminative stimuli represents a shift in reinforcement probability from that associated with the initial stimulus to the value associated with the discriminative stimuli themselves, it appears that the relative value of the discriminative stimuli depends on the change in probability of reinforcement from what was expected in the presence of the initial stimulus. This preference was found in spite of the fact that the actual probability of reinforcement associated with those discriminative stimuli was the same.

The results of Experiment 2 suggest that contrast between the expectancy of reinforcement and actual reinforcement can account for the stimulus preference on test trials. Furthermore, these results suggest that this second-order contrast effect is a general phenomenon that likely occurs whenever discriminative stimuli are associated with an outcome that is better or worse than the alternative outcome that might occur on other trials signaled by the same initial stimulus.

Experiment 3

Although it appears that the stimulus preferences found in Experiment 2 were produced both by positive contrast on low-probability-of-reinforcement trials and by negative contrast on high-probability-of-reinforcement trials, in fact, either type of contrast alone could have produced the preferences found. The purpose of Experiment 3 was to assess the relative contributions of positive and negative contrast in this design.

In Experiment 3, the positive group experienced conditions that should result in positive contrast but no negative contrast, whereas the negative group experienced conditions that should result in negative contrast but no positive contrast (see Figure 3). For the positive group, the procedure was similar to that used in Experiment 2 except the probability of reinforcement for correct responses to either S+ stimulus in the simultaneous discrimination was increased to 100%. Thus, the initial low-probability-of-reinforcement stimulus was associated with reinforcement on 50% of the trials, and the initial high-probability-of-reinforcement stimulus was associated with reinforcement on 100% of the trials. Because of this modification, presentation of the discriminative stimuli on low-probability-of-reinforcement trials should result in an upward shift in the expected probability of reinforcement from 50% to 100% (positive contrast), whereas presentation of the other discriminative stimuli on high-probability-of-reinforcement trials should result in no change in the expected probability of reinforcement (100% in the presence of the initial stimulus and 100% in the presence of the discriminative stimuli).

For the negative group, the probability of reinforcement associated with low-probability-of-reinforcement trials did not change when the discriminative stimuli appeared. On half of the trials involving the low-probability-of-reinforcement stimulus, food followed the initial stimulus 50% of the time, and on the remaining trials involving the low-probability-of-reinforcement stimulus, responses to the S+ were reinforced 50% of the time. Thus, the low-probability-of-reinforcement stimulus was associated with reinforcement on about 50% of the trials. On half of the trials involving the high-probability-of-reinforcement stimulus, food followed the initial stimulus with a probability of 100%, whereas on the remaining trials involving the high-probability-of-reinforcement stimulus, responses to the S+ were reinforced on 50% of the trials. Thus, the overall high-probability-of-reinforcement stimulus was associated with reinforcement on about 75% of the trials. Again both S+ stimuli were associated with reinforcement 50% of the time, however, presentation of the discriminative stimuli on trials associated with an initial stimulus with a high probability of reinforcement should result in a downward shift in the expected probability of reinforcement from about 75% to 50% (i.e., negative contrast), whereas presentation of the discriminative stimuli on trials associated with an initial stimulus with a low probability of reinforcement should result in no shift in the expected probability of reinforcement (50% in the presence of the initial stimulus and about 50% in the presence of the discrimin-
innate stimuli). The complete design of Experiment 3 appears in Figure 5.

**Method**

**Subjects**

Subjects were 16 experimentally naive White Carneaux pigeons (*Columba livia*) similar to those used in Experiment 2. The subjects were maintained and housed as were those in Experiments 1 and 2.

**Apparatus**

The apparatus used in Experiment 3 was the same as that used in Experiments 1 and 2.

**Procedure**

Each pigeon was assigned to one of four subgroups as in the previous experiments. Again, the four hues (R, G, Y, B) were assigned to the two simultaneous discriminations $S^+_{\text{Low Prob}}$, $S^-_{\text{Low Prob}}$ and $S^+_{\text{High Prob}}$, $S^-_{\text{High Prob}}$ as they were in Experiment 2. V served as the low-probability-of-reinforcement stimulus, and H served as the high-probability-of-reinforcement stimulus.

**Training: Positive group.** The procedure for the positive group was similar to that used in Experiment 2 with the exception that responses to the stimuli designated as $S^+_{\text{Low Prob}}$ and $S^+_{\text{High Prob}}$ were reinforced 100% of the time. Thus, the overall probability of reinforcement associated with V, the initial stimulus associated with a high probability of reinforcement, was 100%, whereas the overall probability of reinforcement associated with H, the initial stimulus associated with a low probability of reinforcement, was 50%. Therefore, presentation of the discriminative stimuli following V represented no shift in the probability of reinforcement (from 100% to 100%), whereas presentation of the discriminative stimuli following H represented an upward shift in the probability of reinforcement from 50% to 100%.

**Training: Negative group.** The procedure was similar to that used for Experiment 2 with the exception that responses to the stimuli designated as $S^+_{\text{Low Prob}}$ and $S^+_{\text{High Prob}}$ were reinforced 100% of the time. Thus, the overall probability of reinforcement associated with V, the initial stimulus associated with a high probability of reinforcement, was 100%, whereas the overall probability of reinforcement associated with H, the initial stimulus associated with a low probability of reinforcement, was 50%. Therefore, presentation of the discriminative stimuli following V represented no shift in the probability of reinforcement (from 100% to 100%), whereas presentation of the discriminative stimuli following H represented an upward shift in the probability of reinforcement from 50% to 100%.

Training: Negative group. The procedure was similar to that used for Experiment 2 with the exception that responses to the stimuli designated as $S^+_{\text{Low Prob}}$ and $S^+_{\text{High Prob}}$ were reinforced 100% of the time. Thus, the overall probability of reinforcement associated with V, the initial stimulus associated with a high probability of reinforcement, was 100%, whereas the overall probability of reinforcement associated with H, the initial stimulus associated with a low probability of reinforcement, was 50%. Therefore, presentation of the discriminative stimuli following V represented no shift in the probability of reinforcement (from 100% to 100%), whereas presentation of the discriminative stimuli following H represented an upward shift in the probability of reinforcement from 50% to 100%.

**Results and Discussion**

**Training**

**Positive group.** The pigeons in the positive group acquired the two simple-simultaneous hue discriminations to criterion in an average of 5.38 sessions. The $S^+_{\text{Low Prob}}$, $S^-_{\text{Low Prob}}$, and $S^+_{\text{High Prob}}$, $S^-_{\text{High Prob}}$ discriminations were acquired to criterion in an average of 5.38 and 5.25 sessions, respectively. When these values were subjected to a $t$ test, they were found to be not significantly different ($t < 1$). Similarly, mean total errors made during acquisition of the $S^+_{\text{Low Prob}}$, $S^-_{\text{Low Prob}}$ discrimination (17.9 errors) and $S^+_{\text{High Prob}}$, $S^-_{\text{High Prob}}$ discrimination (14.6 errors) were not significantly different ($t < 1$). Finally, terminal levels of performance on the two discriminations (mean performance on the last training day for $S^+_{\text{Low Prob}}$, $S^-_{\text{Low Prob}}$, 97.9%, and $S^+_{\text{High Prob}}$, $S^-_{\text{High Prob}}$, 99.5%) were not significantly different ($t < 1$).

**Negative group.** The pigeons in the negative group acquired the two simple-simultaneous hue discriminations in an average of 6.67 sessions. Sessions to criterion for the $S^+_{\text{Low Prob}}$, $S^-_{\text{Low Prob}}$, and $S^+_{\text{High Prob}}$, $S^-_{\text{High Prob}}$ discriminations were acquired to criterion in an average of 6.63 and 6.12 sessions, respectively. When these values were subjected to a $t$ test, they were found to be not significantly different ($t < 1$). Similarly, mean total errors made during acquisition of the $S^+_{\text{Low Prob}}$, $S^-_{\text{Low Prob}}$ discrimination (26.1 errors) and $S^+_{\text{High Prob}}$, $S^-_{\text{High Prob}}$ discrimination (24.2 errors) were not significantly different ($t < 1$). Finally,

![Figure 5](image-url)  

*Figure 5.* Design of Experiment 3: Expectancy of reinforcement. $S^+$ = positive stimulus; $S^-$ = negative stimulus; HP = stimuli that followed vertical-line initial stimuli, which on other trials were followed by a high probability of reinforcement (100%); LP = stimuli that followed horizontal-line initial stimuli, which on other trials were followed by a low probability of reinforcement (0% for the positive group, 50% for the negative group); FR = fixed ratio; FR10 = 10 pecks were required; FR5 = 5 pecks were required.
terminal levels of performance on the two discriminations (mean performance on the last training day for \( S^+_{\text{Low Prob}} \), \( S^-_{\text{Low Prob}} \), 98.4%, and \( S^+_{\text{High Prob}} \), \( S^-_{\text{High Prob}} \), 99.0%) were not significantly different (\( t < 1 \)).

**Test**

**S+ preference.** When given a choice between the former \( S^+ \) stimuli (\( S^+_{\text{Low Prob}} \) vs. \( S^+_{\text{High Prob}} \)), pigeons in the positive group chose \( S^+_{\text{Low Prob}} \) on 60.1% of the trials, and pigeons in the negative group chose the \( S^+_{\text{Low Prob}} \) on 58.2% of the trials. In each case, the pigeons preferred the \( S^+ \) that in training was preceded by a stimulus associated with a lower probability of reinforcement (see the two sets of bars labeled “S+” in Figure 6). A \( t \) test performed on the pooled \( S^+ \) data from the positive group indicated that this preference was significantly different from chance, \( t(7) = 2.61 \). To test for the effects of the initial stimulus on test trials, a one-way repeated measures analysis of variance (ANOVA) was performed on the \( S^+ \) preference scores for the positive group with initial stimulus (\( V, H \), or \( nps \)) as the independent variable. The analysis indicated the effect of initial stimulus was not significant (\( F < 1 \)).

A similar \( t \) test performed on the pooled \( S^+ \) data from the negative group indicated that preference for the \( S^+_{\text{Low Prob}} \) was not significantly different from chance (\( t < 1 \)). Although this preference was not statistically significant, the difference between the significant \( S^+ \) preference for the positive group (60.1%) and the nonsignificant \( S^+ \) preference for the negative group (58.1%) was sufficiently small that it would be inappropriate to conclude anything about the difference between them. To test for the effects of the initial stimulus on test trials, a one-way repeated measures ANOVA was performed on the \( S^+ \) preference scores for the negative group. The analysis indicated that the effect of initial stimulus again was not significant (\( F < 1 \)).

**S- preference.** When given a choice between the former \( S^- \) stimuli (\( S^-_{\text{Low Prob}} \) vs. \( S^-_{\text{High Prob}} \)), pigeons in the positive group chose \( S^-_{\text{Low Prob}} \) on 68.7% of the trials, and pigeons in Group Negative chose the \( S^-_{\text{Low Prob}} \) on 47.8% of the trials (see the two sets of bars labeled “S-” in Figure 6). A \( t \) test performed on the pooled \( S^- \) data from the positive group indicated that this preference was significantly different from chance, \( t(7) = 2.78 \). A one-way repeated measures ANOVA performed on the \( S^+ \) preference scores with initial stimulus (\( V, H \), or \( nps \)) as the independent variable indicated that this effect was not significant (\( F < 1 \)).

A \( t \) test performed on the pooled \( S^- \) data from the negative group indicated that this preference was not significantly different from chance (\( t < 1 \)). Again, a one-way repeated measures ANOVA performed on the \( S^- \) preference scores with initial stimulus (\( V, H \), or \( nps \)) as the independent variable indicated that this effect was not significant (\( F < 1 \)).

Thus, in Experiment 3, on tests involving a choice between the two \( S^+ \) stimuli, significant effects of positive contrast but not negative contrast were found. However, given the similarity of the two effects (60.1% and 58.2%), we believe that it would be unwise to conclude that negative contrast was not present. Furthermore, as can be seen in Figure 5, because of constraints on the relative probability of reinforcement, the shift in reinforcement probability for the positive group on horizontal-line trials was 50%, whereas the shift in reinforcement probability for the negative group on vertical line trials was only 25%. Thus, the nature of the experi-

![Figure 6](image-url)  
**Figure 6.** Preference for the \( S^+_{\text{Low Prob}} \) and \( S^-_{\text{Low Prob}} \) stimuli that followed the horizontal lines in training. On other trials in training, the horizontal lines were followed by a low probability (Low Prob) of reinforcement. For the positive group (left), the only source of contrast should be positive contrast between the two trial types that followed the vertical lines. For the negative group (right), the only source of contrast should be negative contrast between the two trial types that followed the horizontal lines. Test trials were preceded by horizontal lines (low), vertical lines (high), or no prior stimulus (\( nps \)). Error bars represent one standard error of the mean. \( S^+ \) = positive stimulus; \( S^- \) = negative stimulus; \( \text{Stim} \) = stimulus; \( \text{Train} \) = training.
mental manipulation for the negative group may have ensured that a relatively small contrast effect would be found.

Not surprisingly, the positive and negative contrast effects (60.1% and 58.2%, respectively) were not quite as large as was the contrast effect found in Experiment 2 (68.1%), in which all pigeons experienced both a positive and a negative contrast manipulation. In fact, between experiments, there is some suggestion that the positive and negative contrast effects found in Experiment 3 may be additive. Specifically, the sum of the differences between the positive and negative contrast preferences and chance (10.1% + 8.2% = 18.3%) were comparable to the combined contrast effect found in Experiment 2 (18.1%).

On tests involving a choice between the two $S^-$ stimuli, the effects were not as consistent. Although there appeared to be a positive contrast effect involving the $S^-$ stimuli (68.7% for the positive group), a similar negative contrast effect was not found (48.3% for the negative group). Why there was no evidence of a preference between the two $S^-$ stimuli for the negative group is not clear. It is possible that for the negative group the differential value of the two $S^+$ stimuli did not result in sufficient differential transfer to the two $S^-$ stimuli.

General Discussion

The results of the present experiments support and extend findings reported by Clement et al. (2000) in which stimuli (both $S^+$ stimuli and $S^-$ stimuli) that followed greater effort were preferred over those that followed less effort. Clement et al. hypothesized that it was the contrast experienced by the pigeon between its motivational state just prior to the onset of the discriminative stimuli and its state after the discriminative stimuli were presented. In Experiment 1, we found similar effects on preference when we manipulated expected effort rather than actual effort. This result is consistent with a contrast effect because a decrease in effort from what was expected should result in positive contrast, whereas an increase in effort from what was expected should result in negative contrast. In Experiment 2, we found that similar effects could be obtained using differential probability of reinforcement rather than differential effort, such that an improvement in the probability of reinforcement from what was expected should result in positive contrast, whereas a worsening in the probability of reinforcement from what was expected should result in negative contrast. The similarity of the effects found in Experiments 1 and 2 suggests the generality of conditions under which this effect can be found. In Experiment 3, we found that positive contrast and perhaps also negative contrast contributed to the effects found in Experiment 2.

It could be argued that the contrast effect reported in our earlier research (Clement et al., 2000) might have resulted from the relative delay to reinforcement that accompanied the higher ratio response (Fantino & Abarca, 1985), because it took the pigeons longer to complete the FR20 than the FR1. According to the delay reduction hypothesis, presentation of a stimulus associated with a longer delay to reinforcement associated with the discriminative stimuli, the delay reduction hypothesis can account for these data if one considers the entire trial as the unit of analysis and the relative delay reduction signaled by the discriminative stimulus as its value. Assume that it took the pigeons an average of about 1 s to complete the FR1 and about 10 s to complete the FR20. Furthermore, when the discriminative stimuli were presented, the stimulus chosen remained on for 6 s following the first response, and if the $S^+$ had been selected, reinforcement followed immediately. Thus, in the case of an FR20 trial, the discriminative stimulus signaled approximately the last 38% of the trial, whereas in the case of an FR1 trial, the discriminative stimulus signaled approximately the last 86% of the trial. This means that in the case of an FR20 trial, the discriminative stimuli provide a better relative signal of impending reinforcement than the discriminative stimuli on an FR1 trial.

In the present experiments, delay reduction could play a role as well. In Experiment 1, the onset of the discriminative stimuli following the vertical lines would represent an increase in the delay to reinforcement (from the time to make one peck, had discriminative stimuli not appeared, to the time to make five pecks, given that they had appeared), whereas the onset of the discriminative stimuli following the horizontal lines would represent a decrease in the delay to reinforcement (from the time to make five responses on reinforced discriminative stimulus trials). However, the difference in delay to reinforcement signaled by the discriminative stimuli was responsible for the stimulus preferences found in Experiments 1 and 2, the magnitude of the preference found in Experiment 2 should have been greater than that found in Experiment 1. This should be true because of the difference between the two experiments in differential delay to reinforcement on nondiscriminative-stimulus trials. In Experiment 1, the difference between the outcomes on nondiscriminative-stimulus trials on vertical- versus horizontal-line trials was the FR1 versus the FR30 response requirement. In Experiment 2, however, the difference between the outcomes on nondiscriminative-stimulus trials on vertical- versus horizontal-line trials was reinforcement on the present trial versus having to wait at least until the next trial (even longer if reinforcement did not occur on the next trial). Thus, if differential delay of reinforcement was responsible for the preferences found in Experiments 1 and 2, the magnitude of the preferences found should have been greater in Experiment 2. Instead, the magnitude of the effect was virtually the same (66.5% in Experiment 1, 66.9% in Experiment 2). Of course the comparison of effects between experiments provides only suggestive evidence against delay reduction and does not rule out the role of differential delay to reinforcement in the present contrast effects.

The contrast effects found in the present research appear to be somewhat different from the various forms of contrast that have been reported in the literature (see Flaherty, 1996). Flaherty (1996) distinguishes among three kinds of contrast. One is incentive contrast, in which the magnitude of reward that has been experi-
enced for many trials suddenly changes, and the change in behavior that follows is compared with the behavior of a comparison group that has experienced the final magnitude of reinforcement from the start. Early examples of incentive contrast were reported by Tinklepaugh (1928), who found that if monkeys were trained for a number of trials with a preferred reward (e.g., fruit), when they then encountered a less preferred reward (e.g., lettuce, that they would normally readily work for), they often would refuse to eat it. Incentive contrast was more systematically studied by Crespi (1942; see also Mellgren, 1972). Rats trained to run for a large amount of food and shifted to a small amount of food typically run slower than rats trained to run for the smaller amount of food from the start (negative contrast). Conversely, rats trained to run for a small amount of food and shifted to a large amount of food may run faster than rats trained to run for the larger amount of food from the start (positive contrast). By its nature, incentive contrast must be assessed following the shift in reward magnitude rather than anticipation of the change because, generally, only a single shift is experienced.

Incentive contrast would seem to be an adaptive mechanism by which animals can increase their sensitivity to changes in reinforcement density. Just as animals use lateral inhibition in vision to help them discriminate spatial changes in light intensity resulting in enhanced detection of edges (or to provide better ground detection), so too may incentive contrast help the animal detect changes in reinforcement magnitude important to its survival. Thus, incentive contrast may be a perceptually mediated detection process.

In a second form of contrast, anticipatory contrast, there are repeated (typically one a day) experiences with the shift, and the measure of contrast involves behavior that occurs prior to the anticipated change in reward value. Furthermore, the behavior assessed is typically consummatory behavior rather than running speed. For example, rats often drink less of a weak saccharin solution if they have learned that it will be followed by a strong sucrose solution, relative to a control group for which saccharin is followed by saccharin (Flaherty, 1982). This form of contrast differs from others in the sense that the measure of contrast involves differential rates of the consumption of a reward rather than differential rates of approach to reward, as is the case with incentive contrast.

A third form of contrast involves the random alternation of two signaled outcomes. When used in a discrete-trials procedure with rats, the procedure has been referred to as simultaneous incentive contrast. Bower (1961), for example, reported that rats trained to run to both large and small signaled magnitudes of reward ran slower to the small magnitude of reward than rats that ran only to the small magnitude of reward.

The more-often studied, free-operant analog of this task is called behavioral contrast. To observe behavioral contrast, pigeons are trained on an operant task involving a multiple schedule of reinforcement. In a multiple schedule, two (or more) schedules, each signaled by a distinctive stimulus, are randomly alternated. Positive behavioral contrast can be demonstrated by training pigeons initially with equal probability of reinforcement schedules (e.g., two variable-interval 60-s schedules) and then reducing the probability of reinforcement in one schedule (e.g., from variable-interval 60-s to extinction) and noting an increase in the response rate in the other, unaltered schedule (Halliday & Boukes, 1971; Reynolds, 1963). Similar results can be demonstrated in a between-groups design (Mackintosh, Little, & Lord, 1972) in which pigeons are trained on the multiple variable-interval 60-s and extinction schedules from the start and their rate of pecking during the variable-interval 60-s schedule is compared with other pigeons that have been trained on two variable-interval 60-s schedules.

It is difficult to classify behavioral contrast according to whether it involves a response to entering the richer schedule (as with incentive contrast) or the anticipation of entering the poorer schedule (as with anticipatory contrast) because during each session there are multiple transitions from the richer to the poorer schedule and from the poorer to the richer schedule. Thus, when one observes an increase in responding in the richer schedule resulting from the presence of the poorer schedule at other times, it is not clear whether the pigeons are reacting to the fact that the preceding schedule was poorer than the present schedule or are anticipating that the next schedule will be poorer than the present schedule.

Williams (1981) attempted to distinguish between these two mechanisms by presenting pigeons with triplets of trials in an ABA design (with the richer schedule designated as A) and comparing their behavior with that of pigeons trained with an AAA design. Williams found very different kinds of contrast in the two A components. In the first A component, Williams found a generally higher level of responding that was maintained over training sessions (see also Williams, 1983). In the second A component, however, he found a higher level of responding primarily at the start of the component, an effect known as local contrast, and the level of responding was not maintained over training sessions (see also, Cleary, 1992). Thus, there is evidence that behavioral contrast may be attributable primarily to the higher rate of responding by pigeons in anticipation of the poorer schedule rather than in response to the appearance of the richer schedule (Williams, 1981; see also Williams & Wixted, 1986).

It is generally accepted that the higher rate of responding to the stimulus associated with the richer schedule of reinforcement occurs because, in the context of the poorer schedule, that stimulus is a better relative predictor of reinforcement (Keller, 1974). Or in more cognitive terms, the richer schedule seems even better in the context of a poorer schedule. There is evidence, however, that it is not that the richer schedule appears better but that the richer schedule will soon get worse. In support of this distinction, although pigeons peck at a higher rate at stimuli that anticipate a worsening in the probability of reinforcement, when given a choice, pigeons prefer stimuli that they respond to less but that anticipate no worsening in the probability of reinforcement (Williams, 1992). Thus, under these conditions, response rate has been found to be negatively correlated with choice. The implication of this finding is that the increased responding associated with the richer schedule does not reflect its greater value to the pigeon but rather its function as a signal that conditions will soon get worse because the opportunity to obtain reinforcement will soon diminish. This analysis suggests that the mechanism responsible for anticipatory contrast (Flaherty, 1982) and, in the case of behavioral contrast, responding in anticipation of a worsening schedule (Williams, 1981) is likely to be a compensatory or learned response. In this sense, these two forms of contrast are probably quite different from the perceptual-like detection process involved in incentive contrast.
What all contrast effects have in common is the presence, at other times, of a second condition that is either better or worse than the target condition. The effect of the second condition often is to exaggerate the difference between the two conditions. Although there have been attempts to account for these various contrast effects, Mackintosh (1974) concluded that no single principle will suffice (see also Flaherty, 1996). Thus, even before the contrast effect reported here and by Clement et al. (2000) was added to the list, contrast effects resisted a comprehensive explanation.

Procedurally, the contrast effect reported by Clement et al. (2000) appears to be most similar to that involved in anticipatory contrast (Flaherty, 1982) because in each case there is a series of paired events, the second of which is better than the first. High effort is followed by discriminative stimuli in the case of the Clement et al. procedure, and a low concentration of saccharin is followed by a higher concentration of sucrose in the case of anticipatory contrast. However, the effect reported by Clement et al. is seen in the second event (i.e., preference for one S+ over the other) rather than the first (i.e., differential consumption of the saccharin solution).

Alternatively, although successive incentive contrast and the contrast effect reported by Clement et al. (2000) both involve a change in behavior during the second component of the task, the mechanisms responsible for these effects must be quite different. In the case of the Clement et al. (2000) procedure, the pigeons experienced the two-event sequences many hundreds of times prior to test and thus they could certainly learn to anticipate the appearance of the discriminative stimuli and the reinforcers that followed, whereas in the case of successive incentive contrast, the second component of the task could not be anticipated.

The temporal relations involved in the within-trial contrast effect reported by Clement et al. (2000) would seem more closely related to those that have been referred to as local contrast (Terrace, 1966). As already noted, local contrast refers to the temporary change in response rate that occurs following a stimulus change that signals a change in schedule. But local contrast effects tend to occur early in training and they generally disappear with extended training. Furthermore, if local contrast was responsible for the contrast effect reported by Clement et al., they should have found a higher response rate to the positive stimulus that followed the higher effort response than to the positive stimulus that followed the lower effort response. But differences in response rate were not found; only differences in choice.

The choice response measure used by Clement et al. (2000) is also different from the rate measures used in other contrast research (running speed, rate of liquid consumed, and response rate). Although it is often assumed that response rate and choice measures are positively correlated, as already noted, Williams (1992) found that they actually may be negatively correlated. Thus, it would appear that the contrast effect found in the present research may be different from the three classes of contrast previously reported. What characterizes this contrast effect is that it involves extensive experience with an ambiguous outcome, such that different expectancies are established. But unlike other contrast effects based on differential expectancies, these differences in expectancy are associated with two similar outcomes, and those differential expectancies create a preference for the relatively more favorable outcome associated with one initial stimulus over the relatively less favorable outcome associated with the other initial stimulus. And most important, the present research indicates that this preference occurs in the absence of any difference between the two trial types in either the initial event (FR10) or the following event (FR5, simultaneous discrimination). Thus, it can be considered a second-order contrast effect. The first-order effect involves the anticipatory effect that a consequent event (e.g., high effort) has on a preceding initial stimulus (V or H). This anticipatory effect is evidenced by the effect that the initial stimulus has on different consequent events (i.e., on the discriminative stimuli that follow the initial stimulus).

The results of the present experiments not only extend the range of contrast effects and have theoretical implications for the theoretical bases of these effects but they also have implications for analogous effects found in humans (Clement et al., 2000) that have often been interpreted in terms of more complex social psychological constructs such as cognitive dissonance (Festinger, 1957), overjustification of effort (Aronson & Mills, 1959), and work ethic (Greenberg, 1977).

References
Terrace, H. S. (1966). Behavioral contrast and the peak shift: Effects of


Received December 12, 2000
Revision received August 16, 2001
Accepted August 16, 2001