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A Within-trial Contrast Effect and its Implications for Several Social Psychological Phenomena

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Contrast refers to a comparison between two conditions of reward such that the relation between them is magnified (relative to an appropriate control condition). It is an effect that is opposite in direction from generalization (which is a form of averaging). Three kinds of contrast have received substantial empirical attention: Incentive contrast in which a sudden change in reward (either an increase or a decrease) results in an overreaction to the change, relative to a control condition; anticipatory contrast in which an anticipated improvement in reward results in less consumption of an initial reward; and differential or behavioral contrast in which a change in reward associated with one stimulus results in a change in behavior associated with a second stimulus in the opposite direction. Here I discuss a fourth kind of contrast that I call within-trial contrast. In this form of contrast a discriminative stimulus is preferred when it follows a less appetitive event (effort, delay, or the absence of reward). A model of this kind of contrast is proposed that is based on a presumed change in the hedonic state of the organism between the end of the less appetitive event and the reward (or stimulus signaling the reward). It is distinguished from an account based on the relative reduction in delay to reinforcement. Finally, I suggest that a general form of this within-trial contrast may help to explain various complex human social phenomena including cognitive dissonance, justification of effort, the effect of extrinsic rewards on behavior that is maintained by intrinsic rewards, and learned industriousness.

The idea of contrast, as it has been applied to behavior, was borrowed from visual perception. When, for example, a white shape on a black background is projected on the retina, the edges of the shape are made subjectively more distinct by the process of lateral inhibition. That is, each sensory neuron in the retina is not only activated by light but at the same time the effect of that activation is to tend to inhibit the effect of the activation of neighboring neurons. Specifically, when a sensory neuron on the light side of an edge of the shape is activated it will tend to reduce below baseline the effect of the activation of those neurons on the dark side of the edge (making the dark edge appear even darker than the surrounding dark areas). A corresponding but opposite effect occurs on the dark side of the edge because the relative absence of activation of those neurons on the dark side of the edge of the shape results in little inhibition of the effect of activation on the adjacent neurons on the light side. Thus, the light side of the edge appears even brighter than the central area of the shape. Such contrast effects amplify the effect of the change in light that appears at the edges of objects, allowing for better edge detection.

What all contrast effects have in common is the presence, at other times, of a second condition that is different from the target condition. Often, the effect of the second condition is to exaggerate the difference between the conditions. In his 1996 book, Charles Flaherty said:

Contrast undoubtedly exerts an influence in a variety of animal and human behaviors – sharpening the borders between reward alternatives, promoting dissatisfaction (or excessive satisfaction), redirecting behaviors, and biasing judgments in a nonrational fashion. However, we are far from understanding exactly the degree to which contrast effects are important in the behavior of lower animals and humans, and exactly how and why they occur. (p. 176)

Although there have been numerous attempts to account for contrast effects, Mackintosh (1974) concluded that no single principle will suffice.

An understanding of contrast is made even more difficult by the fact that under many conditions effects opposite in direction to contrast can be demonstrated. In fact, one could argue that it is at least as reasonable to predict that when a change in conditions occurs, the initial reaction to that change would be an under-reaction or averaging of the conditions before and after the change—a kind of behavioral inertia or behavioral momentum (Nevin, 1992). One of the most widely accepted traditional theories of behavior (Hull, 1943; Spence, 1937) had as one of its primary tenets, the generalization of effects between training in the presence of reward and testing in its absence, such that the degree of behavioral momentum depended on the similarity of the test conditions to the training conditions. The fact that contrast is not ubiquitous suggests that the term contrast is little more than a label that helps us to classify the phenomenon. It should not provide one with a false sense of understanding.

In this article, I will first describe the various kinds of contrast that have been traditionally studied in animals; in particular, incentive contrast, anticipatory contrast, and differential or behavioral contrast. Then, I will examine research on a form of contrast I call *within-trial contrast*, in which events prior to a stimulus affect an animal's relative preference for that stimulus. Finally, I will explore the applicability of these within-trial contrast effects to theories of human social behavior, including cognitive dissonance, justification of effort, the effect of extrinsic rewards on behavior that is maintained by intrinsic rewards, and learned industriousness.

Various Forms of Contrast

Incentive Contrast

In incentive contrast, the magnitude of reward that has been experienced for many trials suddenly changes; 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, a reward for which they would normally work) 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 incentive contrast). Conversely, rats trained to run for a small amount of food and shifted to a large amount of food were found to run faster than rats trained to run for the larger amount of food from the start (positive incentive contrast). By its nature, incentive contrast must be as-

sessed following the shift in reward magnitude rather than in anticipation of the change because, generally, only a single shift is experienced.

Several accounts of incentive contrast have been proposed. For example, Capaldi (1972) proposed that downward shifts in reward magnitude could be attributed to a *generalization decrement*. According to this theory, any change in context should lead to a performance decrement and the magnitude of reward can be thought of as a change in context. The appeal of this theory is its simplicity; however, the supporting evidence has not been strong. According to the generalization decrement account, contrast depends on the novelty of the shift in reward magnitude but incentive contrast effects have been found even with repeated shifts between large and small rewards (Maxwell et al. 1976; Shanab, Domino, & Ralph, 1978).

Furthermore, the generalization decrement account of negative incentive contrast fails to account for positive incentive contrast. Instead, it predicts an effect in the opposite direction. That is, when animals are shifted from a low magnitude of reward to a high magnitude of reward, the generalization decrement account predicts slower rather than faster running, than by animals that ran to the higher magnitude of rewards from the start. Although positive incentive contrast has not been as easy to obtain as negative incentive contrast (due perhaps to ceiling effects), there is sufficient evidence for its existence (Crespi, 1942, 1944; Zeaman, 1949) to question any theory that consistently predicts a decrement in running speed with any change in the magnitude of reward.

Amsel's (1958) *frustration theory* has also been applied to incentive contrast effects (see also Gray, 1987). According to frustration theory, the experience of withdrawal of reward (or, in the case of contrast, a reduction of reward) causes frustration which competes with the acquired running response. Although frustration theory does not address itself to findings of positive incentive contrast, one can posit, as Crespi (1942) did, an opposite kind of emotional response, 'elation' to account for faster running when the reward shifts from a lower magnitude to a higher magnitude.

Anticipatory Contrast

In a second form of contrast, anticipatory contrast, there are repeated experiences with the incentive shift, and the dependent 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 a nonconsummatory behavior like 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 with no change in concentration (Flaherty, 1982). The fact that the measure of contrast involves differential rates of the consumption of a reward makes this form of contrast different from the others.

The most obvious account of negative anticipatory contrast is that the initial saccharin solution was *devalued* by its association with the following preferred strong sucrose solution (Flaherty & Checke, 1982). However, research that has attempted to test this theory has not provided support. For example, in a within-subject design, when the saccharin solution that was followed by the sucrose solu-

tion was associated with one contextual cue (S1) and the saccharin solution that was followed by a similar saccharin solution was associated with a different contextual cue (S2), when negative anticipatory contrast was found there was no evidence of a preference for the context associated with S2 (Flaherty et al. 1995).

An alternative theory, proposed by Flaherty (1996) to account for negative anticipatory contrast, is *response competition*. According to this account, when the sucrose solution appears at a location that is different from the saccharin solution, animals anticipate the appearance of the sucrose solution and leave the saccharin solution early. However, research has shown that when the two solutions were presented at the same location, a significant negative anticipatory contrast effect was still found (Flaherty, Grigson, Coppotelli, & Mitchell, 1996).

A third theory, proposed by Flaherty (1996), is that anticipation of the sucrose solution *inhibits* drinking of the saccharin solution in preparation for additional drinking of the sucrose solution. This theory is supported by the negative correlation between the amount of suppression of saccharin drinking and the amount of facilitation of sucrose drinking (Flaherty, Turovsky, & Krauss, 1994).

Differential or Behavioral Contrast

A third form of contrast involves the presence 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 magnitudes of reward that were signaled by the brightness of the alley 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, for example, 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 presented randomly. 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 & Boakes, 1971; Reynolds, 1961). 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 vice versa. Are the pigeons reacting to the current schedule (1) in the context of the poorer preceding schedule or (2) in the anticipation that the next schedule may be poorer?

Williams (1981) attempted to distinguish between these mechanisms by presenting pigeons with triplets of signaled trials in an *ABA* design (with the richer schedule designated as *A*) and comparing their behavior to that of pigeons trained with an *AAA* design. He found very different kinds of contrast in the first and last *A* components of the *ABA* sequence. In the first *A* component, Williams found a generally higher relative level of responding that was maintained over training sessions (see Williams, 1983). In the last *A* component, however, he found a higher

relative level of responding primarily at the start of the component, an effect known as local contrast (Terrace, 1966) and the level of responding was not maintained over training sessions (see 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 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). There is evidence, however, that it is not that the richer schedule appears better, but that the richer schedule will soon get worse. Williams (1992) found a negative correlation between rate of pecking and choice. Consistent with a contrast effect, pigeons peck at a higher rate at stimuli that predict a worsening schedule of reinforcement. However, when given a choice between two similar schedules, one that occurs prior to a worsening schedule of reinforcement and the other that occurs prior to a non-worsening schedule of reinforcement, the pigeons prefer the one that occurs prior to the non-worsening schedule.

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 it reflects 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.

Within-trial Contrast Effect

This line of research began with the question; does effort (in the form of a relatively large response requirement) followed by a stimulus associated with reward, affect the value of that stimulus. More specifically, for example, on some trials a pigeon experiences one stimulus (e.g., a red light) preceded by a small response requirement (1 response) and on other trials it experiences a second stimulus (e.g., a green light) preceded by a large response requirement (20 responses). Both stimuli are followed by rewards of equal magnitude. If the pigeon is now given a choice between the red and green stimuli, will it show a preference?

According to traditional learning theories (e.g., Hull, 1943) the pigeon should not show a preference between the two stimuli because the value of a stimulus should depend on its consequences rather than its antecedents. Alternatively, one could conceive of the high effort trials on which a green light appears as being less valued than the low effort trials on which a red light appears. If this were the case, the red light should be preferred over the green light. A second alternative hypothesis is that presentation of the hue is valued by the pigeon relative to or in contrast to the effort that preceded it. If this were the case, the conditioned reinforcing value of the hue would be judged as having relatively more value when it is preceded by the high effort response; and the green light should be preferred over the red. Finally, it is possible that the differential effort sets the occasion for

the hue that follows it. If this were the case, then hue preference on choice trials should depend on the effort that preceded it. That is, if the choice of hue is preceded by a high-effort response, then the green hue (that followed the high effort response in training) should be preferred, whereas if the choice of hue is preceded by a low-effort response, then the red hue (that followed the low effort response in training) should be preferred.
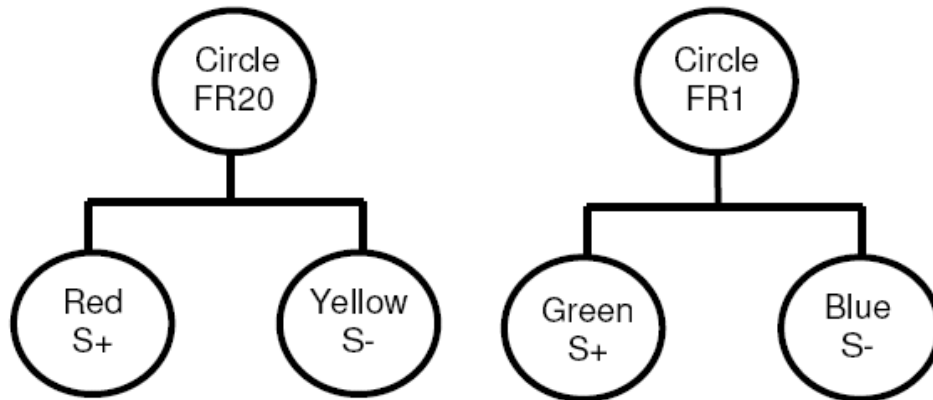

Figure 1. Design of experiment by Clement et al. (2000), in which one pair of discriminative stimuli followed 20 pecks and the other pair of discriminative stimuli followed 1 peck.

To test these hypotheses, during training, each of the two response requirements (high effort, 20 responses, and low effort, 1 response) were followed by a simple simultaneous discrimination (e.g., red positive, yellow negative or green positive, blue negative, respectively) that appeared on the left and right response keys (Clement, Feltus, Kaiser, & Zentall, 2000). The design of this experiment is presented in Figure 1. On test trials involving a choice between the two positive (S+) stimuli, the pigeons preferred the S+ that in training had been preceded by 20 pecks over the S+ that in training had been preceded by only 1 peck (see Figure 2). Interestingly, when the pigeons were given a choice between the two negative (S-) stimuli, they also showed a strong tendency to prefer the S- that in training had been preceded by 20 pecks over the S- that in training had been preceded by only 1 peck. (For an explanation of this S- preference, see Clement, Weaver, Sherburne, & Zentall, 1998.)

To determine whether the differential response requirement experienced during training had an effect when it preceded the choice on test trials, three kinds of S+ and S- test trials were presented: Test trials preceded by only one peck to the circle, test trials preceded by 20 pecks to the circle, and test trials with no circle presented prior to presentation of the discriminative stimuli. Clement et al. (2000) found that the number of pecks that preceded choice of the two S+ or S- stimuli (0, 1, or 20 pecks) on test trials had little effect on stimulus choice (see Figure 2). Thus, the pigeons did not learn to use the response requirement as a conditional cue to anticipate choice of the appropriate stimulus. Instead, it appeared that the hue that had followed the greater effort in training had taken on added value, relative to the hue that had followed less effort, and that the actual effort experienced on test trials had little effect.
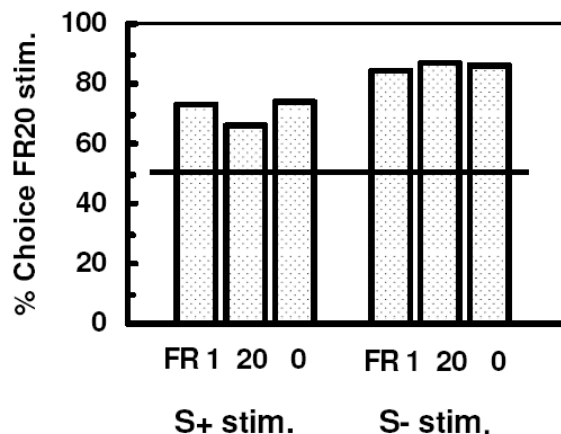
Figure 2. Results obtained by Clement et al. (2000). Pigeons preferred the S+ and the S- that in training followed 20 pecks over the S+ and S- that followed 1 peck.

We also asked if pigeons would show a similar preference for a more direct measure of food preference: the location of food that followed greater effort over a different location of the same food that followed less effort (Friedrich & Zentall, 2004). To answer this question, we conducted an experiment involving two feeders: one that provided food on trials in which 30 pecks were required to the center response key, the other that provided the same food on trials in which a single peck was required to the center response key.

On half of the training trials, one peck was required and the preferred feeder was raised. On the remaining trials, 30 pecks were required and the nonpreferred feed was raised. Over the course of training, we found that there was a significant increase in preference for the originally nonpreferred feeder (associated with the FR30 response). For a control group, each of the two response requirements was followed equally often by each feeder. This group showed no systematic increase in preference for their nonpreferred feeder (see Figure 3). Thus, it appears that the value of the location of food can be enhanced by being preceded by a high-effort response as compared to a low-effort response.

A Model of Within-trial Contrast in Animals

The within-trial contrast effect can be modeled as follows (see Figure 4): First, set the relative hedonic state of the pigeon at the start of each trial to H. Next, assume that keypecking (or the time required to make those pecks) is a relatively aversive event that results in a negative change in hedonic state. Also, assume that obtaining the reinforcer causes a shift to a positive hedonic state (relative to the pigeon's hedonic state at the start of the trial). The final assumption is that the value of the reinforcer depends on the *relative change* in hedonic state (i.e., the change in hedonic state from the end of the response requirement to the appearance of the reinforcer or the appearance of the S+ that signals reinforcement (or in the case of the location-of-food experiment, the location of the raised feeder, see Figure 4). Thus, because the change in hedonic state following a high-effort response is larger than the change in hedonic state following a low-effort response, the relative value of the reinforcer following a high-effort response should be greater than
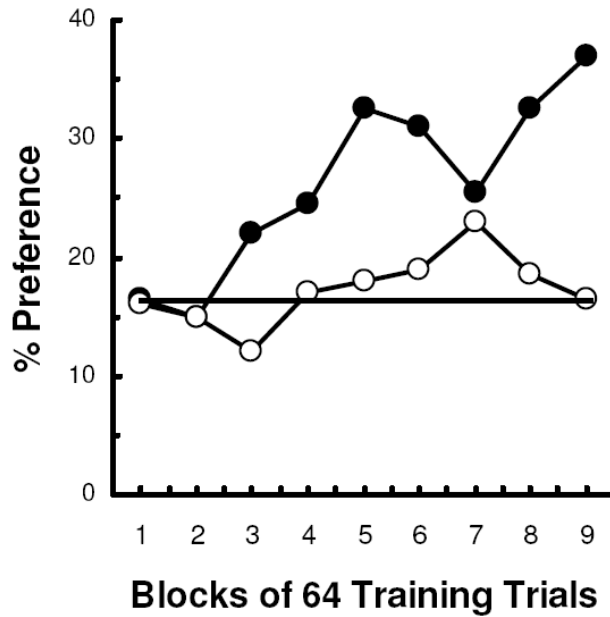
that of the low-effort response.

Figure 3. Results obtained by Friedrich and Zentall (2004). Graph shows the increase in preference for the originally nonpreferred feeder as a function of being associated with the high effort (30-peck) response (filled circles). The preferred feeder was associated with the low effort (1-peck response). For the control group, both feeders were equally often associated with the high effort response and the low effort response (open circles). The solid line indicates the baseline preference for the originally nonpreferred feeder.
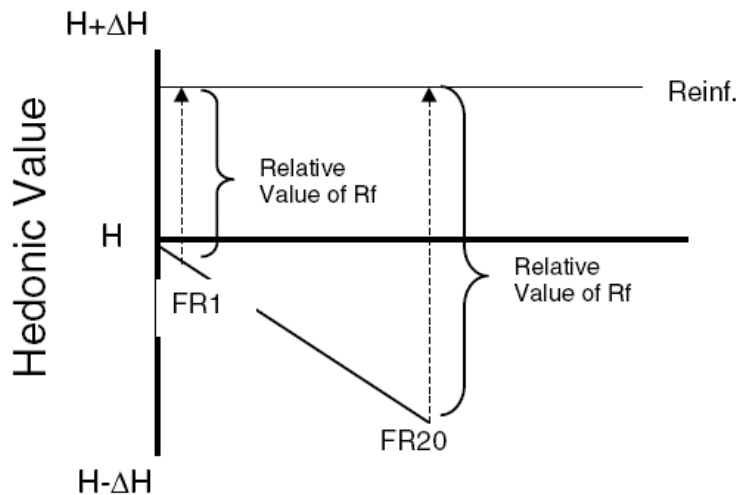

Figure 4. A model based on change in relative hedonic state, proposed to account for within-trial contrast effects. According to the model, trials begin with a relative hedonic state, H; keypecking results in a negative change in hedonic state, H - ΔH_1 for FR1 and H - ΔH_{20} for FR20; obtaining a reinforcer results in a positive change in hedonic state, H + ΔH_{Rf}; the net change in hedonic state depends on the difference between H + ΔH_{Rf} and H - ΔH_1 on an FR1 trial and between H + ΔH_{Rf} and H - ΔH_{20} on an FR20 trial.

Relative Aversiveness of the Prior Event

Delay to Reinforcement as an Aversive Event

If the interpretation of this effect that is presented in Figure 4 is correct, then any prior event that is relatively aversive (compared with the alternative event on other trials) should result in a similar enhanced preference for the stimuli that follow. For example, given that pigeons should prefer a shorter delay to reinforcement over a longer delay to reinforcement, according to this theory, they should also prefer discriminative stimuli that follow a longer delay over those that follow a shorter delay.
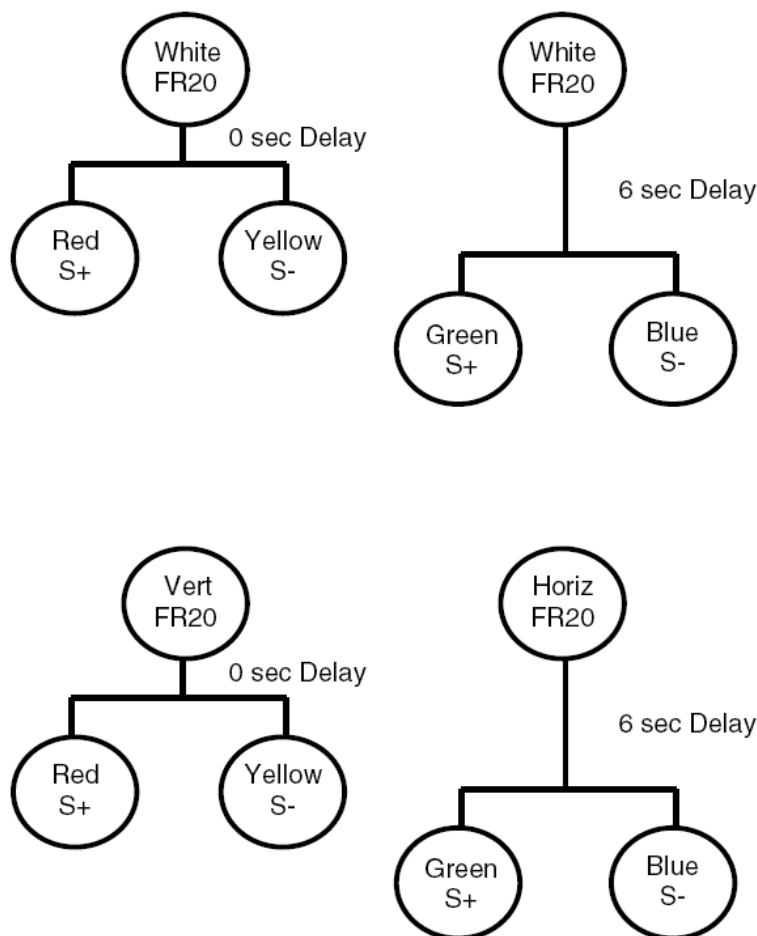

Figure 5. Design of experiments by DiGian et al. (2004), in which one pair of discriminative stimuli followed a delay and the other pair of discriminative stimuli followed the absence of a delay. Top: The delay and absence of a delay were unsignaled. Bottom: The delay and absence of a delay were signaled.

To test this hypothesis, we trained pigeons to peck the center response key (20 times on all trials) to produce a pair of discriminative stimuli (as in Clement et al., 2000). On some trials, pecking the response key was followed immediately by one pair of discriminative stimuli (with no delay), whereas on the remaining trials,

pecking the response key was followed by a different pair of discriminative stimuli, but only after a delay of 6 sec (see top panel of Figure 5). On test trials, the pigeons were given a choice between the S+ stimuli, but unlike in the previous experiments, no preference was found (DiGian, Friedrich, & Zentall, 2004, Unsignaled Delay Condition).

However, there was an important difference between the manipulation of effort used in the first two experiments and the manipulation of delay used by DiGian et al. (2004). In the first two experiments, once the pigeon had made a single peck to the initial stimulus and the discriminative stimuli failed to appear, the pigeon could anticipate that 19 additional pecks would be required. Thus, whatever emotional state (e.g., frustration) might be produced by encountering a high-effort trial would be experienced in the context of having to make additional responses. In the case of the delay manipulation, however, the pigeon could not anticipate whether a delay would occur or not; and at the time the delay occurred, no further responding was required. Thus, with the delay manipulation, the pigeon would not have to experience a comparable degree of presumed frustration in the context of responding. Would the results be different if the pigeons could anticipate the delay at a time that responding was required?

To test this hypothesis, the delay to reinforcement manipulation was repeated, but this time the initial stimulus was predictive of the delay (DiGian et al., 2004, Signaled Delay Condition). Thus, on half of the trials, a vertical line appeared on the response key and pecking resulted in the immediate appearance of one pair of discriminative stimuli (e.g., red and yellow). On the remaining trials, a horizontal line appeared on the response key and pecking resulted in the appearance of the other pair of discriminative stimuli (e.g., green and blue), but only after a 6-sec delay (see bottom panel of Figure 5). For this condition, the pigeons could anticipate whether pecking would result in a delay or not, so they too would be pecking in the context of presumed frustration. When pigeons in this condition were tested, as in the effort manipulation experiments, they showed a significant preference for the S+ that in training had followed the delay. Once again, the experience of an aversive event produced an increase in the value of the positive discriminative stimulus that followed. Furthermore, the results of this experiment demonstrated that it may be necessary for the animals to anticipate the aversive event for contrast to be found.

Absence of Reinforcement as an Aversive Event

A related form of relatively aversive event is the absence of reinforcement in the context of reinforcement on other trials (Amsel, 1958). If the model is correct, reinforcement versus its absence prior to the appearance of the discriminative stimuli should result in a preference for discriminative stimuli that follow the absence of reinforcement? To test this hypothesis, pigeons were once again trained to peck a response key to produce a pair of discriminative stimuli. On some trials, pecking the response key was followed immediately by 2-s access to food from the feeder and then immediately by the presentation of one pair of discriminative stimuli, whereas on the remaining trials, pecking the response key was followed by the absence of food (for 2 s) and then by the presentation of a different pair of discriminative stimuli (see top panel of Figure 6). On test trials, the pigeons were

given a choice between the S+ stimuli, but again, as in the delay manipulation, they showed no preference (Friedrich, Clement, & Zentall, 2005).

However, when the initial stimulus was predictive of the reinforcement condition that followed (see bottom panel of Figure 6) pigeons did show a significant preference for the S+ that in training had followed the absence of reinforcement. Thus, once again, the experience of a relatively aversive event produced an increase in the value of the positive discriminative stimulus that followed; but only when the relatively aversive event could be anticipated.
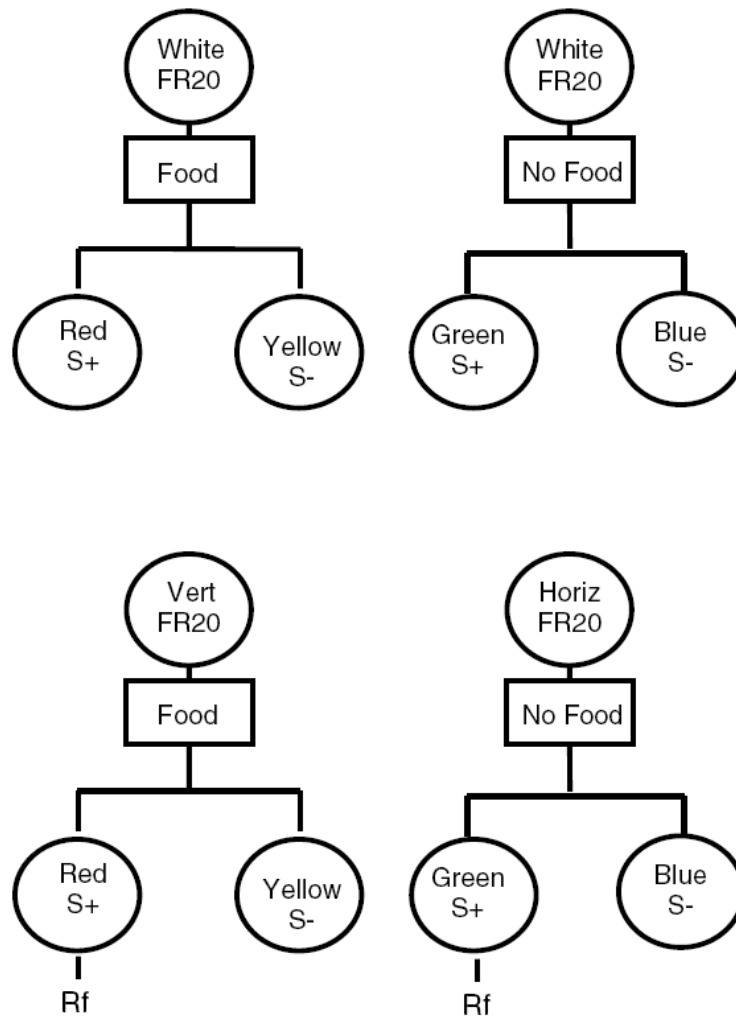

Figure 6. Design of experiments by Friedrich and Zentall (2004), in which one pair of discriminative stimuli followed reinforcement and the other pair of discriminative stimuli followed the absence of reinforcement. Top: The reinforcement and absence of reinforcement were unsignaled. Bottom: The reinforcement and absence of reinforcement were signaled.

Anticipation of Effort as the Aversive Event

Can anticipated effort, that does not actually occur, serve as the aversive event that increases the value of stimuli signaling reinforcement that follows? This question addresses the issue of whether the contrast between the initial aversive

event and the conditioned reinforcer depends on actually experiencing the relatively aversive event just prior to presentation of the discriminative stimuli.

One account of the added value that accrues to stimuli that follow greater effort is that during training, the greater effort expended produces a heightened state of arousal, and in that heightened state of arousal, the pigeons learn more about the discriminative stimuli that follow than about the discriminative stimuli that follow the lower state of arousal produced by lesser effort. If a heightened state of arousal leads to better learning about the discriminative stimuli that followed the more aversive event, one might expect faster or better learning of that discrimination; however, examination of the acquisition functions for the two simultaneous discriminations offers no support for this hypothesis. Over the various experiments that we have conducted, there has been no tendency for the simultaneous discrimination that followed greater effort, longer delays, or the absence of reinforcement, to have been acquired faster or to a higher level than the discrimination that followed less effort, shorter delays, or reinforcement. On the other hand, those discriminations were acquired very rapidly and we might have missed a small difference in the rate of discrimination acquisition sufficient to produce a preference for the S+ stimulus that followed the more aversive event.

Thus, the purpose of the next experiment was to ask if we could obtain a preference for the discriminative stimuli that followed a signal that more effort might be required, but actually was not required on that trial. More specifically, at the start of half of the training trials, pigeons were presented with a vertical line on the center response key that signaled that a small effort later might be required. On half of the vertical-line trials, pecking the vertical line replaced it with a white key and a single peck to the white key resulted in reinforcement. On the remaining vertical-line trials, pecking the vertical line replaced it with a simultaneous discrimination $S+_{FR1}S-_{FR1}$ on the left and right response keys and choice of the $S+_{FR1}$ was reinforced. A schematic presentation of the design of this experiment appears in Figure 7.

Figure 7. Design of experiment by Clement and Zentall (2002, Experiment 1), in which they studied the effect of the anticipation of effort (rather than actual effort) on the preference for the discriminative stimuli that followed.

On the remaining training trials, the pigeons were presented with a horizontal line on the center response key that signaled that a greater effort might later be required. On half of the horizontal-line trials, pecking the horizontal line replaced it with a white key and 30 pecks to the white key resulted in reinforcement. On the remaining horizontal-line trials, pecking the horizontal line replaced it with

a different simultaneous discrimination S+$_{FR30}$S-$_{FR30}$ on the left and right response keys and choice of the S+$_{FR30}$ was reinforced. On test trials, when the pigeons were given a choice between S+$_{FR1}$ and S+$_{FR30}$, once again, they showed a significant preference for S+$_{FR30}$. Thus, the expectation of differential effort, rather than actual differential effort, appears to be sufficient to produce a differential preference for the stimuli that follow.

In this experiment, it is important to note that the events that occurred in training on trials involving the two pairs of discriminative stimuli were essentially the same. It was only on the other half of the trials, those trials in which the discriminative stimuli did not appear, that differential responding was required. These results extend the findings of the earlier research to include anticipated effort and rule out differential effort-producing arousal as the basis for within-trial contrast.

Anticipation of the Absence of Reinforcement as the Aversive Event

If anticipated effort can function as a relative conditioned aversive event, can the anticipated absence of reinforcement serve the same function? Using a design similar to that used to examine differential anticipated effort, we evaluated the effect of differential anticipated reinforcement (Clement & Zentall, 2002, Experiment 2). A schematic presentation of the design of this experiment appears in Figure 8. On test trials, consistent with the results of the earlier research, when the pigeons were given a choice between S+$_{Rf}$ and S+$_{NRf}$, they showed a significant preference for S+$_{NRf}$. Thus, the anticipation of an aversive, absence-of-food event appears to produce a preference for the S+ that follows it; an effect that is similar to the anticipation of a high effort response.
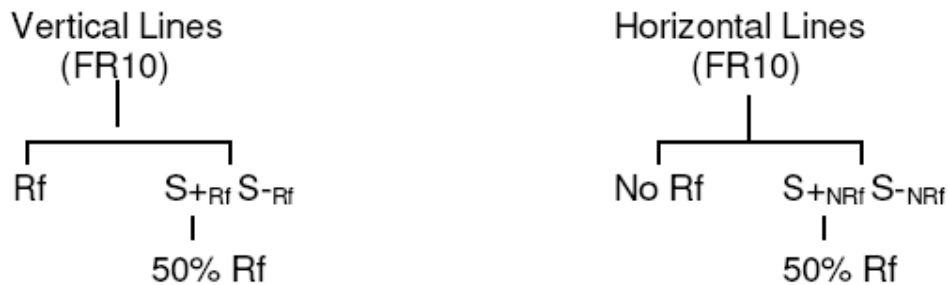

Figure 8. Design of experiment by Clement and Zentall (2002, Experiment 2), in which they studied the effect of the anticipation of reinforcement (rather than actual reinforcement) on the preference for the discriminative stimuli that followed.
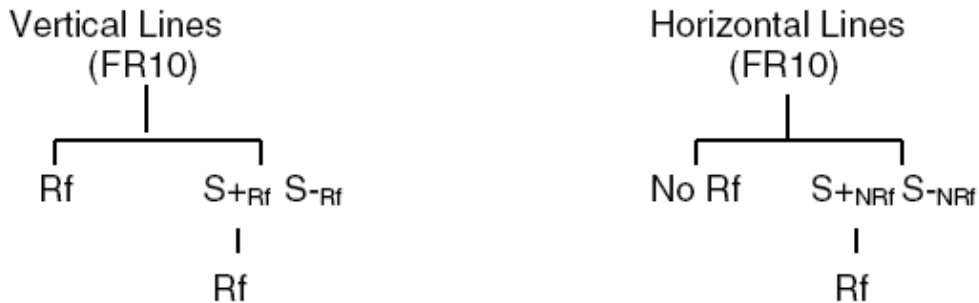
In a follow-up experiment (Clement & Zentall, 2002, Experiment 3), we examined whether preference for the discriminative stimuli associated with the anticipation of the absence of food was produced by positive contrast between the certain absence of food and a 50% chance of food (on discriminative stimulus trials) or negative contrast between the certain anticipation of food and a 50% chance of food (on the other set of discriminative stimulus trials). To accomplish this, on vertical-line trials, for Group Positive, the conditions of reinforcement were essentially nondifferential (i.e., reinforcement always followed vertical-line trials whether the discriminative stimuli were presented or not). On half of the vertical-line trials, reinforcement was presented immediately for responding to the vertical

line. On the remaining vertical-line trials, reinforcement was presented for responding to the S+ in the simultaneous discrimination. Thus, there should have been little contrast established between these two kinds of trial. A schematic presentation of the design of this experiment appears in the left top panel of Figure 9.

On horizontal-line trials, however, on half of the trials, no reinforcement always followed responses to the horizontal line. On the remaining horizontal-line trials, reinforcement was presented for responding to the S+ in the other simultaneous discrimination. Thus, for this group, on horizontal-line trials, there was the opportunity for positive contrast to develop on discriminative stimulus trials (i.e., the pigeons should expect that reinforcement might not occur on those trials and they may experience positive contrast when it does occur; see right top panel of Figure 9).

For Group Negative, on all horizontal-line trials, the conditions of reinforcement were essentially nondifferential (i.e., the probability of reinforcement on horizontal-line trials was always 50%, whether the trials involved discriminative stimuli or not). Thus, on half of the horizontal-line trials, reinforcement was provided immediately with a probability of .50 for responding to the horizontal line. On the remaining horizontal-line trials, reinforcement was presented for choices of the S+, but only on half of the trials. Thus, there should have been little contrast established between these two kinds of horizontal line trials (see the right bottom panel of Figure 9).

Group Positive

Vertical Lines (FR10)

Rf   S+$_{Rf}$ S-$_{Rf}$
|
Rf

Horizontal Lines (FR10)

No Rf   S+$_{NRf}$ S-$_{NRf}$
|
Rf

Group Negative

Vertical Lines (FR10)

Rf   S+$_{Rf}$ S-$_{Rf}$
|
50% Rf

Horizontal Lines (FR10)

50% Rf   S+$_{NRf}$ S-$_{NRf}$
|
50% Rf

Figure 9. Design of experiment by Clement and Zentall (2002, Experiment 3), in which they studied the effect of the anticipation of reinforcement (rather than actual reinforcement) on the preference for the discriminative stimuli that followed to distinguish between positive contrast and negative contrast.

On vertical-line trials, however, on half of the trials, reinforcement was presented immediately (with a probability of 1.00) for responding to the vertical line. On the remaining vertical-line trials, reinforcement was provided for choice of the S+ with a probability of .50. Thus, for this group, on vertical-line trials, there was the opportunity for negative contrast to develop on discriminative stimulus trials (i.e., the pigeons should expect that reinforcement is quite likely and they may experience negative contrast when it does not occur; see left bottom panel of Figure 9).

On test trials, when pigeons in Group Positive were given a choice between the S+ stimuli, they showed a significant preference for the positive discriminative stimulus that in training was preceded by a horizontal line (the initial stimulus that on other trials was followed by the absence of reinforcement). Thus, Group Positive showed evidence of positive contrast.

When pigeons in Group Negative were given a choice between the S+ stimuli, they also showed a significant preference for the positive discriminative stimulus that in training was preceded by a horizontal line (the initial stimulus that on other trials was followed by a lower probability of reinforcement than on comparable trials involving the vertical line). Thus, Group Negative showed evidence of negative contrast. In this case, the contrast should be described as a reduced preference for the positive discriminative stimulus preceded by the vertical line, which on other trials was associated with a higher probability of reinforcement (1.00). Thus, in this experiment, evidence was found for both positive contrast and negative contrast.

Delay Reduction Account

(After Fantino & Abarca, 1985)

Absolute delay reduction
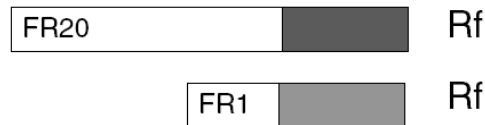
Relative delay reduction

Figure 10. Comparison of the absolute and relative reduction in delay to reinforcement signaled by the positive discriminative stimuli following the Fixed Ratio 20 (dark gray) and the Fixed Ratio 1 (light gray). The two positive discriminative stimuli signal the same absolute reduction in the delay to reinforcement (they appear at the same time relative to reinforcement) but if one considers the proportion of the trial occupied by the positive discriminative stimulus, the relative reduction in delay to reinforcement signaled by the positive stimulus that follows the Fixed Ratio 20 is greater (closer to reinforcement)than the relative reduction in delay to reinforcement signaled by the positive stimulus that follows the Fixed Ratio 1.

Contrast or Relative Delay Reduction?

To this point, we have described the stimulus (and location) preference in terms of a contrast effect. However, it is also possible to interpret this effect in terms of the *delay reduction hypothesis* (Fantino & Abarca, 1985). According to the delay reduction hypothesis, a stimulus which predicts reinforcement sooner in its presence than in its absence will become a conditioned reinforcer. In the present experiments, the relation between the discriminative stimuli and the reinforcers should be the same (see Figure 10, top). Thus, one could argue that the S+ stimuli do not differentially reduce the delay to reinforcement. But, the delay reduction hypothesis can also be applied in a relative sense. That is, one can consider the predictive value of the discriminative stimuli relative to the total duration of the trial. If one considers delay reduction in terms of its duration relative to the duration of the whole trial, then the delay reduction hypothesis may be relevant to the present designs (see Figure 10, bottom). For example, in the case of the differential effort manipulation (Clement et al., 2000), because it takes longer to produce 20 responses than to produce 1 response, 20-response trials would be longer than 1-response trials; and the appearance of the discriminative stimuli would occur relatively later in a 20-response trial than in a 1-response trial. The later in a trial that the discriminative stimuli appear, the closer their onset would be to reinforcement, relative to the start of the trial and thus, the greater relative reduction in delay that their appearance would represent.

Using the same logic, a trial with a delay is longer than a trial without a delay (DiGian et al., 2004). Thus, stimuli that appear after a delay should appear relatively later in the trial than stimuli that appear without a delay. The delay reduction hypothesis can also account for the effects of reinforcement versus the absence of reinforcement. In this case, the duration of trials with and without reinforcement is the same prior to the appearance of the discriminative stimuli. However, the delay reduction hypothesis considers the critical time to be the interval between reinforcements. Thus, on trials in which the discriminative stimuli are preceded by reinforcement, the time between reinforcements is short, so the discriminative stimuli should be associated with little reduction in delay to reinforcement. On trials in which the discriminative stimuli are preceded by the absence of reinforcement, however, the time between reinforcements is long (it is the time between reinforcement on the preceding trial and reinforcement on the current trial), so the discriminative stimuli on the current trial should be associated with a relatively large reduction in delay to reinforcement.

The relative delay reduction hypothesis has a more difficult time accounting for the effects of differential anticipated effort that does not actually occur (Clement & Zentall, 2002, Experiment 1) because discriminative stimulus trials were not differentiated by number of responses, delay, or reinforcement. Thus, all trials with discriminative stimuli should have been of comparable duration. The same is true for the effects of differential anticipated reinforcement (Clement & Zentall, 2002, Experiments 2 and 3) because that manipulation occurred on trials separate from the trials with the discriminative stimuli.

Further problems for the delay reduction hypothesis come from the different results found with signaled versus unsignaled delay (DiGian et al., 2004) and signaled versus unsignaled absence of food (Friedrich et al., 2005). According to

the delay reduction hypothesis, it should not matter whether or not the delay or the absence of food is signaled, comparable preferences should have been found. However, preferences for stimuli that followed a delay and the absence of food were found only when those events were signaled. Thus, taken as a whole, the contrast account appears to offer a more parsimonious account of the data.

Still, it should be possible to distinguish between the delay reduction and contrast accounts with the use of a design similar to that used in the first experiment. But instead of requiring that the pigeons peck many times on half of the trials and a few times on the remaining trials, one could use two schedules that accomplish the same result while holding the duration of the event constant. This objective could be accomplished by using a fixed interval schedule (FI, the first response after a fixed duration would present one pair of discriminative stimuli) on half of the trials and a differential reinforcement of other behavior schedule (DRO, the absence of key pecking for the same fixed duration would present the other pair of discriminative stimuli) on the remaining trials. According to the contrast account, the pigeons should prefer the discriminative stimuli that follow whichever of the two schedules is least preferred (the schedule preference would have to be assessed independently). According to the delay reduction hypothesis, if trial duration is held constant and the two pairs of discriminative stimuli occupy the same relative proportion of the two kinds of trial, the pigeons should not differentially prefer either pair of discriminative stimuli.

Another approach to testing the delay reduction account would be to use the delay to reinforcement procedure used by DiGian et al. (2004), but to manipulate where in the trial the delay occurs. For example, all trials would begin with the onset of a ready signal. On some trials, pecks to the ready signal would turn on the initial stimulus and pecks to the initial stimulus would initiate the delay followed by presentation of the discriminative stimuli. On the remaining trials, pecks to the ready signal would initiate the delay followed by the initial stimulus and pecks to the initial stimulus would be followed by presentation of the discriminative stimuli. Thus, the same delay would occur on all trials, however, on some trials the delay would occur after the initial stimulus whereas on other trials it would occur before the initial stimulus. According to the delay reduction hypothesis, as trial duration is held constant, there should be no difference in the relative delay reduction signaled by the discriminative stimuli. If, however, it is the aversiveness of the delay immediately prior to the onset of the discriminative stimuli that is responsible for the differential preference found in earlier research, the pigeons should prefer the S+ that immediately follows the delay, over the S+ that immediately follows the initial stimulus.

What Kind of Contrast is Within-trial Contrast?

The within-trial contrast effects reported in the present research appear to be somewhat different from the forms of contrast previously described in the introduction. In the case of incentive contrast, there is a sudden unanticipated change in the magnitude of reinforcement that occurs between phases of an experiment rather than within trials. In the case of within-trial contrast, the trial events are predictable very early in the trial.

Anticipatory contrast involves the reduction in consummatory behavior

that comes in anticipation of an improvement in reward. It would appear to be more similar to within-trial contrast because the transition is experienced many times over. In fact, this kind of contrast depends on the animal's ability to predict the improvement in reinforcing conditions that will come. However, the measure of anticipatory contrast occurs at a time in the trial prior to the experimental manipulation, whereas the measure of within-trial contrast occurs at a time in the trial following the experimental manipulation. Furthermore, in the case of anticipatory contrast, the measure of contrast involves differential rates of consumption of a reward rather than preference (in the case of within-trial contrast) or running speed (in the case of incentive contrast).

Differential or behavior contrast is similar to within-trial contrast because it involves the random alternation of two signaled outcomes. In the case of behavioral contrast, it is more difficult to specify the source of the contrast because anticipatory and consequent effects are often confounded, however, as already noted, when those effects have been isolated it appears that the anticipatory effects are greater and are more long lasting (Williams, 1981). Furthermore, the measure of positive behavioral contrast, increased responding to the positive stimulus in anticipation of the presentation of the negative stimulus, does not show up in preference tests, suggesting that the positive stimulus is serving as a signal for an upcoming worsening schedule of reinforcement (Williams, 1992).

Within-trial contrast of the kind described here would appear to be most similar to local contrast effects found with behavioral contrast procedures. Local contrast occurs at the start of a trial with a positive stimulus immediately following a trial with a negative stimulus (or a negative stimulus immediately following a trial with a positive stimulus) and those transitions are at least somewhat predictable. However, the fact that local contrast effects are rather transient and the measure of positive local contrast is an increase in response rate, whereas the measure of within-trial contrast involves a preference test, suggests that the underlying mechanisms responsible for these two effects may be different.

Relation Between Contrast and Various Human
Social Psychological Phenomena

Cognitive Dissonance

Cognitive dissonance is defined by the conflict that arises when one's behavior (e.g., one smokes) is discrepant from one's beliefs (e.g., that smoking is bad for one's health). According to cognitive dissonance theory, when such a conflict arises, one should be motivated to resolve the discrepancy (Festinger, 1957). One possibility is to change one's behavior and stop smoking. However, because it is often difficult to change one's behavior, one is more likely to alter one's beliefs. In this case, one might justify the smoking behavior by noting its positive effects (it reduces tension, it helps control one's weight, it provides pleasure) or downplaying its negative effects (smoking is not any more dangerous to one's health than the danger of having an automobile accident).

Several hypotheses have been proposed to account for dissonance phenomena, the best known of which is Festinger's (1957) dissonance reduction. Alternatively, Bem (1967) has proposed that it is not the psychological discomfort

that comes from dissonance that results in a change in belief but an inference about one's beliefs that arises from one's behavior. Thus, if one is smoking, one might reason that it can't be too bad for one's health.

A third account of dissonance phenomena was suggested by Tedeschi, Schlenker, and Bonoma (1971). They suggested that attitudes appear to change when behavior is inconsistent with beliefs because people want others to have a good impression of them (impression management theory). In experiments, participants only appear to change their attitudes to avoid being viewed unfavorably by the experimenter. That is, it is important to appear to be consistent.

Alternatively, it may be that a contrast-like process is involved. Several research paradigms have been used in the study of cognitive dissonance and although the results of these experiments all can be interpreted as a form of contrast, some are more directly amenable to a contrast analysis than others.

Induced-compliance Paradigm. In Festinger's classic experiment (Festinger & Carlsmith, 1959), after completing a tedious task, participants were paid either $1 or $20 to misinform another participant about how interesting the task was. When participants were then asked to evaluate their interest in the task, those who were paid only $1 rated the task more interesting than those who were paid $20. Festinger explained these results as follows: Participants who were paid $20 could justify their willingness to misinform by noting the value of the payment. Thus, there should be no conflict (although one might question their ethics). However, those who were paid only $1 could not justify their willingness to misinform; for them, the only way to explain their behavior was to alter their previous belief that it was not an interesting task and now claim that the task was in fact interesting.
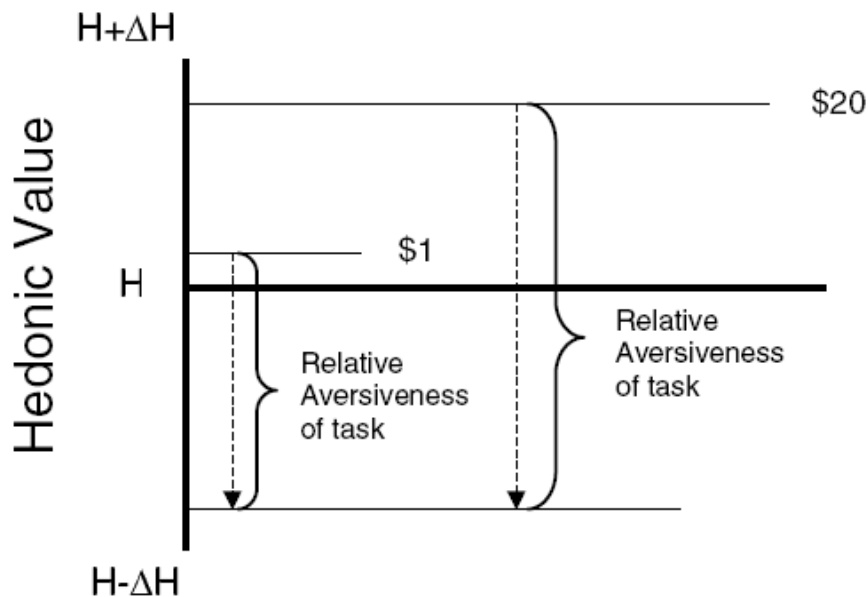

Figure 11. The model based on change in relative hedonic state as applied to the results of Festinger and Carlsmith (1959). The reduction in value from $20 to the aversiveness of the tedious task was greater than the reduction in value from $1 to the aversiveness of the same tedious task.

The complexity of the Festinger and Carlsmith (1959) experiment, its important language component, and the fact that it used a between-subjects design makes it difficult to translate this task into one that could be used with animals, however, a model similar to the one presented in Figure 4 can be applied to the design of the Festinger and Carlsmith experiment. In this case, it can be assumed that following performance of the tedious task, all subjects start in a relatively negative hedonic state. Providing them with a monetary reward should have improved that state differentially for the two amounts of reward (see Figure 11) but when asked to evaluate their interest in the task (i.e., looking back at their prior negative hedonic state), the subjects who were given the large ($20) reward should have seen a larger discrepancy between their current and past state and thus, they should have rated the task as less interesting – just as they did.

Free-choice Paradigm. When humans make choices between alternatives of relatively equal value, dissonance is often created by the lost opportunity represented by the alternative not chosen. For example, students may have difficulty choosing to attend one college over another. After finally making their choice, they may shift from comparing the positive and negative attributes of the two, to focusing on the positive attributes of the chosen college and the negative attributes of the unchosen one. This form of cognitive dissonance is seen in the greater relative value attributed to a chosen alternative after a choice than the same alternative before the choice (Shultz & Lepper, 1996).

In this case, having to make a difficult decision is aversive and the added value attributed to the alternative chosen may come from the contrast between the relatively aversive prechoice state and the relatively more favorable postchoice state. The positive change in state experienced (no longer having the decision to make) is then attributed to the chosen alternative.

Justification of Effort. When added value is given to rewards that are difficult or embarrassing to obtain it has been explained in terms of cognitive dissonance. For example, Aronson and Mills (1959) had participants read aloud as an initiation test before being allowed to listen to a group discussion. Participants who had to read aloud embarrassing, sexually explicit material (severe test) judged the later group discussion as more interesting than those who read material that was not sexually explicit (mild test). Aronson and Mills argued that to justify their behavior (reading embarrassing material aloud) participants experiencing the sever test had to increase the value of listening to the group discussion that followed.

Interpretation of the results of this experiment on justification of effort is made difficult because of the complexity of the social context. For example, how might past experiences with initiations affect one's judgment of group value? High initiation groups may actually have more value (at least socially) than low initiation groups.

More important, the design of the justification of effort experiment is actually quite similar to the design of the within-trial contrast experiment. What is manipulated in the justification of effort experiment is the aversiveness of the prior initiation event and the dependent measure is the effect that the initiation has on the value of the group discussion. In the within-trial contrast experiment, it is the relative aversiveness of the initial event that is manipulated and the dependent

measure is the relative value of the discriminative stimuli that follow.

Festinger, himself, believed that his theory also applied to the behavior of nonhuman animals (Lawrence & Festinger, 1962); but, the examples he provided were only remotely related to the cognitive dissonance research that had been conducted with humans and the results that were obtained were easily accounted for with simpler behavioral mechanisms (e.g., the partial reinforcement extinction effect, which was attributed by others to a generalization decrement, Capaldi, 1967, or an acquired response in the presence of frustration, Amsel, 1958). Thus, it may be that cognitive dissonance does not require a cognitive social account. Instead, it may be a form of contrast in which the relative improvement in conditions is judged relative to the aversiveness of the events that precede them (as in the justification of effort and induced compliance paradigms) or comparison of choice alternatives is judged relative to ones perspective prior to and following the choice (as in the free-choice paradigm).

Intrinsic versus Extrinsic Reinforcement

Contrast effects of the kind reported here may also be responsible for the well-known capacity of extrinsic reinforcement to reduce intrinsic motivation (Deci, 1975; but see also Eisenberger & Cameron, 1996). If rewards are given for activities that may be intrinsically rewarding (e.g., puzzle solving), then providing extrinsic rewards for such an activity may lead to a subsequent reduction in that behavior when extrinsic rewards are no longer provided. This effect has been interpreted as a shift in self-determination or locus of control (Deci & Ryan, 1985; Lepper, 1981). But, such effects can also be viewed as examples of contrast. In this case, it is the contrast between extrinsic reinforcement and its sudden removal that may be responsible for the decline in performance (Flora, 1990). Compare this result with Tinklepaugh's (1928) finding mentioned earlier that monkeys that are switched from rewards of fruit (preferred) to lettuce (less preferred) often refuse to eat the lettuce.

Such contrast effects are likely to be quite different from those responsible for the results of the within-trial contrast experiments, however, because the removal of extrinsic reinforcement results in a change in actual reward value, relative to the reward value that is expected (i.e., the shift from a combination of both extrinsic and intrinsic reward to intrinsic reward alone). Thus, the effect of extrinsic reinforcement on intrinsic motivation is probably more similar to incentive contrast due to reward shifts of the kind reported by Crespi (1942, i.e., rats run slower after they have been shifted from a large to a small magnitude of reward than rats that have always experienced the small magnitude of reward).

Learned Industriousness

Finally, contrast effects may also be involved in a somewhat different phenomenon that Eisenberger (1992) has called learned industriousness. If one is rewarded for exerting a large amount of effort in performing a task, it may increase one's general readiness to expend effort on other goal-directed tasks. Eisenberger has attributed this effect to the conditioned reward value of effort, a reasonable explanation for the phenomenon; but, contrast may also be involved.

The contrast explanation is as follows: If the original task is difficult and the second task is also difficult, there should be little contrast between the two tasks. However, if the original task is easy and the second task is difficult, there should be negative contrast between the originally easy task and the second, harder task. The negative contrast would be expected to result in a decrease in persistence.

Alternatively, if the original task is easy and the second task is also easy, there should be little contrast between the two tasks. However, if the original task is difficult, and the second task is easy, there should be positive contrast between the originally difficult task and the later easy task. The positive contrast also would be expected to result in an increase in persistence. Thus, in either case, a contrast interpretation of the learned industriousness effect suggests that pretraining on a difficult task should result in better transfer than pretraining on an easy task.

Conclusions About the Generality of Contrast

From the previous discussion, it should be clear that within-trial contrast effects of the kind reported here in pigeons (as well as the other forms of contrast: incentive contrast, anticipatory contrast, and behavioral contrast) may contribute to a number of experimental findings that have been reported with humans, but that traditionally have been explained using more complex cognitive and social accounts. Further examination of these phenomena from the perspective of simpler contrast effects may lead to more parsimonious explanations of what have previously been interpreted to be uniquely human phenomena.

Of course, even if contrast is involved in these more complex phenomena, it does not rule out the additional involvement of more cognitive factors, of the type originally proposed. It would be informative, however, to determine the extent to which contrast effects contribute to these phenomena.

Finally, our description of the various complex social phenomena as possible examples of contrast may give the mistaken impression that such effects are simple and are well understood. As prevalent as contrast effects appear to be, the mechanisms that account for them remain quite speculative. Consider the prevalence of the opposite effect, generalization, in which experience in one context (or with one stimulus value) spreads to other contexts (or stimulus values) in direct proportion to their similarity (Hull, 1943). According to a generalization account, generalization between values of reinforcement should tend to make the values more similar to each other, rather than more different. An important goal of future research should be to identify the conditions that produce contrast and differentiate them from those than produce generalization.

Whatever mechanisms are found to distinguish contrast from generalization effects, contrast effects imply a form of relational learning that cannot easily be accounted for by means of traditional behavioral theories. That is, the large body of research on contrast suggests that the value of a reinforcer depends not only on its absolute value as compared with the value of other available reinforcers, but its value also depends on the relative state of the organism immediately preceding that reinforcer. This is not a radical idea. For example, food is certainly more valued, as indicated by the vigor of an instrumental response, if it is preceded by greater rather than lesser hunger (Clark, 1958). What is perhaps surprising, however, is the implication from our research that if two equally preferred foods A

and B are then consistently experienced in different ways - food A is always presented at a time of greater hunger and food B is always presented at a time of lesser hunger, then given a choice between the two different kinds of food, A should be preferred over B, regardless of the level of hunger of the animal at the time of that choice. This prediction has yet to be tested.

References

Amsel, A. (1958). The role of frustrative nonreward in noncontinuous reward situations. *Psychological Bulletin, 55*, 102-119.

Aronson, E., & Mills, J. (1959). The effect of severity of initiation on liking for a group. *Journal of Abnormal and Social Psychology, 59*, 177-181.

Bem, D. J. (1967). Self-perception: An alternative interpretation of cognitive dissonance phenomena. *Psychological Review, 74*, 183-200.

Bower, G. H. (1961). A contrast effect in differential conditioning. *Journal of Experimental Psychology, 62*, 196-199.

Capaldi, E. J. (1967). A sequential hypothesis of instrumental learning, In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 1, pp. 67-156). New York: Academic Press.

Capaldi, E. J. (1972). Successive negative contrast effect: Intertrial interval, type of shift, and four sources of generalization decrement. *Journal of Experimental Psychology, 96*, 433-438.

Clark, F. C. (1958). The effect of deprivation and frequency of reinforcement on variable-interval responding. *Journal of the Experimental Analysis of Behavior, 1*, 221-227.

Cleary, T. L. (1992). The relationship of local to overall behavioral contrast. *Bulletin of the Psychonomic Society, 30*, 58-60.

Clement, T. S., Feltus, J., Kaiser, D. H., & Zentall, T. R. (2000). "Work ethic" in pigeons: Reward value is directly related to the effort or time required to obtain the reward *Psychonomic Bulletin and Review, 7*, 100-106.

Clement, T. S., Weaver, J. E., Sherburne, L. M., & Zentall, T. R. (1998). Effect of the S- on the S+ in a simultaneous discrimination: Negative value transfer or contrast. *Quarterly Journal of Experimental Psychology, 51B*, 363-378.

Clement, T. S., & Zentall, T. R. (2002). Second-order contrast based on the expectation of effort and reinforcement. *Journal of Experiment Psychology: Animal Behavior Processes, 28*, 64-74.

Crespi, L. P. (1942). Quantitative variation in incentive and performance in the white rat. *American Journal of Psychology, 40*, 467-517.

Crespi, L. P. (1944). Amount of reinforcement and level of performance. *Psychological Review, 51*, 341-357.

Deci, E. (1975). *Intrinsic motivation*. New York: Plenum.

Deci, E., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.

DiGian, K. A., Friedrich, A. M., & Zentall, T. R. (2004). Reinforcers that follow a delay have added value for pigeons. *Psychonomic Bulletin and Review, 11*, 889-895.

Eisenberger, R. (1992). Learned industriousness. *Psychological Review, 99*, 248-267.

Eisenberger, R., & Cameron, J. (1996). Detrimental effects of reward. *American Psychologist, 51*, 1153-1166.

Fantino, E., & Abarca, N. (1985). Choice, optimal foraging, and the delay-reduction hypothesis. *Behavioral and Brain Sciences, 8*, 315-330.

Festinger, L. (1957). *A theory of cognitive dissonance*. Evanston, IL: Row, Peterson.

Festinger, L., & Carlsmith, J. M. (1959). Cognitive consequences of forced compliance. *Journal of Abnormal and Social Psychology. 58*, 203-210.

Flaherty, C. F. (1982). Incentive contrast. A review of behavioral changes following shifts in reward. *Animal Learning and Behavior, 10*, 409-440.

Flaherty, C. F. (1996). *Incentive relativity*. New York: Cambridge University Press.

Flaherty, C. F., & Checke, S. (1982). Anticipation of incentive gain. *Animal Learning and Behavior, 10*, 177-182.

Flaherty, C. F., Coppotelli, C., Grigson, P. S., Mitchell, C., & Flaherty, J. E. (1995). Investigation of the devaluation interpretation of anticipatory negative contrast. *Journal of Experiment Psychology: Animal Behavior Processes, 21*, 229-247.

Flaherty, C. F., Grigson, P. S., Coppotelli, C., & Mitchell, C. (1996). Anticipatory contrast as a function of access time and spatial location of saccharin and sucrose solutions. *Animal Learning and Behavior,* **24**, 68-81.

Flaherty, C. F., Turovsky, J., & Krauss, K. L. (1994). Relative hedonic value modulates anticipatory contrast. *Physiology and Behavior,* **55**, 1047-1054.

Flora, S. R. (1990). Undermining intrinsic interest from the standpoint of a behaviorist. *Psychological Record,* **40**, 323-346.

Friedrich, A. M., & Zentall, T. R. (2004). Pigeons shift their preference toward locations of food that take more effort to obtain. *Behavioural Processes*, **67**, 405-415.

Friedrich, A. M., Clement, T. S., & Zentall, T. R. (2005). Reinforcers that follow the absence of reinforcement have added value for pigeons. *Learning and Behavior*, **33**, 337-342.

Gray, J. A. (1987). *The psychology of fear and stress.* Cambridge, UK: Cambridge University Press.

Halliday, M. S., & Boakes, R. A. (1971). Behavioural contrast and response-independent reinforcement. *Journal of the Experimental Analysis of Behavior,* **16**, 429-434.

Hull, C. L. (1943). *Principles of behavior.* New York: Appleton-Century-Crofts.

Keller, K. (1974). The role of elicited responding in behavioral contrast. *Journal of the Experimental Analysis of Behavior,* **21**, 249-257.

Lawrence, D. H., & Festinger, L. (1962). *Deterrents and reinforcement: The psychology of insufficient reward.* Stanford, CA: Stanford University Press.

Lepper, M. R. (1981). Intrinsic and extrinsic motivation in children: Detrimental effects of superfluous social controls. In W. A. Collins (Ed.), *Aspects of the development of competence: The Minnesota Symposium on Child Psychology* (Vol. 14, pp. 155-214). Hillsdale, NJ: Erlbaum.

Mackintosh, N. J. (1974) *The psychology of animal learning.* London, UK: Academic Press.

Mackintosh, N. J., Little, L., & Lord, J. (1972). Some determinants of behavioral contrast in pigeons and rats. *Learning and Motivation,* **3**, 148-161.

Maxwell, F. R., Calef, R. S., Murry, D. W., Shepard, J. C., & Norville, R. A. (1976). Positive and negative successive contrast effects following multiple shifts in reward magnitude under high drive and immediate reinforcement. *Animal Learning and Behavior,* **4**, 480-484.

Mellgren, R. L. (1972). Positive and negative contrast effects using delayed reinforcement. *Learning and Motivation,* **3**, 185-193.

Nevin, J. A. (1992). An integrative model for the study of behavioral momentum. *Journal of the Experimental Analysis of Behavior*, **57**, 301-316.

Reynolds, R. S. (1961). Behavioral contrast. *Journal of the Experimental Analysis of Behavior,* **4**, 57-71.

Shanab, M. E., Domino, J., & Ralph, L. (1978). Effects of repeated shifts in magnitude of food reward upon the barpress rate in the rat. *Bulletin of the Psychonomic Society,* **12**, 29-31.

Shultz, T. R., & Lepper, M. R. (1996). Cognitive dissonance reduction as constraint satisfaction. *Psychological Review,* **103**, 219-240.

Spence, K. W. (1937). The differential response of animals to stimuli differing within a single dimension. *Psychological Review,* **44**, 430-444.

Tedeschi, J. T., Schlenker, B. R., & Bonoma, T. V. (1971). Cognitive dissonance: Private ratiocination or public spectacle? *American Psychologist,* **26**, 685-695.

Terrace, H. S. (1966). Stimulus control. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application.* New York: Appleton-Century-Crofts.

Tinklepaugh, O. L. (1928). An experiment study of representative factors in monkeys. *Journal of Comparative Psychology,* **8**, 197-236.

Williams, B. A. (1981). The following schedule of reinforcement as a fundamental determinant of steady state contrast in multiple schedules. *Journal of the Experimental Analysis of Behavior,* **35**, 293-310.

Williams, B. A. (1983). Another look at contrast in multiple schedules. *Journal of the Experimental Analysis of Behavior,* **39**, 345-384.

Williams, B. A. (1992). Inverse relations between preference and contrast. *Journal of the Experimental Analysis of Behavior,* **58**, 303-312.

Williams, B. A., & Wixted, J. T. (1986). An equation for behavioral contrast. *Journal of the Experimental Analysis of Behavior,* **45**, 47-62.

Zeaman, D. (1949). Response latency as a function of the amount of reinforcement. *Journal of Experimental Psychology,* **39**, 466-483.