JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1998, **69,** 199–221 NUMBER 2 (MARCH)

HABITUATION TO THE REINFORCER MAY CONTRIBUTE TO MULTIPLE-SCHEDULE BEHAVIORAL CONTRAST

FRANCES K. MCSWEENEY AND JEFFREY N. WEATHERLY

WASHINGTON STATE UNIVERSITY AND
MCNEESE STATE UNIVERSITY

Habituation to the reinforcer may contribute to multiple-schedule behavioral contrast. According to this argument, reducing reinforcers in one component of a multiple schedule reduces habituation to the reinforcer. Reducing habituation enhances the value, or effectiveness, of the remaining reinforcers, producing positive contrast. Enriching the reinforcers in one component increases habituation to that reinforcer. Increasing habituation decreases the effectiveness of the reinforcer, producing negative contrast. Such an idea is simple and parsimonious. It is not contradicted by any well-established finding in the contrast literature. It makes several tested and untested predictions that are unusual. However, habituation cannot explain all contrast. A complete explanation requires postulating that at least one additional mechanism, controlled by the conditions of reinforcement in the following component, also contributes to contrast.

Key words: behavioral contrast, multiple schedule, within-session changes in responding, habituation, sensitization, following-component effect, local contrast

Multiple-schedule behavioral contrast has been studied frequently, but it is not well understood (Williams, 1997). Contrast is an inverse relation between the rate of responding in one component of a multiple schedule and the conditions of reinforcement in the other component (e.g., McSweeney & Norman, 1979). Positive contrast is an increase in responding during a constant (contrast) component when the conditions of reinforcement in the other (variable) component worsen (e.g., rate of reinforcement decreases). Negative contrast is a decrease in responding during a constant component when the other component improves (e.g., rate of reinforcement increases).[1] Behavioral contrast is central to many theories of operant responding because it illustrates that reinforcers have relative, rather than absolute, effects on behavior (e.g., Herrnstein, 1970; Rachlin, 1973; Williams, 1983). Contrast is also central to many applications of conditioning (e.g., Gross & Drabman, 1981). However, despite its importance, no generally accepted theory of contrast has been offered, and the literature has not been reviewed since Williams (1983).

We review some of the contrast literature and argue that only two assumptions are required to account for most results. First, assume that a decremental effect analogous to habituation accrues to a reinforcer each time it is presented, just as habituation accrues with the repeated presentation of any other evocative stimulus (e.g., Thompson & Spencer, 1966). Second, assume that the ability of a reinforcer to support instrumental responding decreases as the habituation-like effect increases. In that case, reducing the rate of reinforcement in one component of a multiple schedule would reduce the overall amount of habituation to that reinforcer. The remaining reinforcers would be more effective (less habituation) and support a higher rate of responding (positive contrast). Providing more reinforcers in one component would increase habituation to the reinforcer, reducing the effectiveness of the remaining reinforcers.

This material is based on work supported by the National Science Foundation under Grants IBN-9207346 and IBN-9403719. We thank Samantha Swindell for suggesting Figure 1 and Cam L. Melville for his comments on an earlier version of this paper.

Reprints may be obtained from Frances K. McSweeney, Department of Psychology, Washington State University, Pullman, Washington 99164-4820 (E-mail: fkmcs@mail.wsu.edu).

[1] Changes in many aspects of the reinforcer (e.g., its rate of delivery, its type) produce behavioral contrast. Therefore, contrast is attributed to a "worsening" or "improvement" in the conditions of reinforcement in one component of a multiple schedule. The different aspects of the reinforcer that alter behavior are sometimes said to contribute to the value of the reinforcer. That is the sense in which the term *value* is used in this paper. It is a synonym for the effectiveness of the reinforcer in controlling operant behavior.

Those reinforcers would support a lower rate of responding (negative contrast).

To be more specific, contrast is often measured by comparing responding during a baseline multiple schedule that provides the same conditions of reinforcement in both components (e.g., a multiple variable-interval [VI] *x* VI *x* schedule) to responding during a contrast schedule that provides different conditions of reinforcement (e.g., a multiple VI *x* VI *y* schedule; McSweeney & Norman, 1979). Assume that the baseline is a multiple VI 60-s VI 60-s schedule that delivers a maximum of 60 reinforcers per hour on the average. Positive contrast could be produced by changing this baseline to a multiple VI 60-s extinction schedule that delivers approximately 30 reinforcers per hour. If each delivery of the reinforcer produces some habituation to that reinforcer, then less habituation occurs during the contrast sessions than during the baseline sessions. As a result, the reinforcers delivered in the constant VI 60-s component are more effective and support a higher rate of responding during the contrast phase than during the baseline phase (positive contrast). Negative contrast might be produced by changing the baseline to a multiple VI 60-s VI 15-s schedule that delivers a maximum of 150 reinforcers per hour on the average. Because the contrast schedule delivers more reinforcers than the baseline, more habituation occurs. As a result, the reinforcers delivered in the constant VI 60-s component are less effective and support a lower rate of responding during the contrast phase than during the baseline phase (negative contrast).

Changing reinforcement may produce other effects on behavior than changing habituation. For example, rate of responding varies directly with the rate of reinforcement that is contingent on that response (e.g., Catania & Reynolds, 1968). This instrumental effect of reinforcement will be confounded with changes in habituation in the component that is altered to produce contrast (the variable component). For example, if rate of reinforcement increases in the variable component, then responding during that component will be determined jointly by an increase in responding that results from an increase in the rate of contingent reinforcement and by a decrease in responding that results from increased habituation to the reinforcer. Responding during the constant contrast component will provide a relatively pure measure of the change in habituation. The relation between responding and reinforcement will not change in that component because the rate of reinforcement for responding in that component is constant. Habituation to the reinforcer will change because increasing the rate of reinforcement in the variable component will produce more habituation to the reinforcer, regardless of the component in which that reinforcer is delivered.

EVIDENCE FOR HABITUATION TO THE REINFORCER

Habituation to the reinforcer would not provide a plausible account for contrast unless independent evidence revealed a decremental effect on reinforcer effectiveness analogous to habituation. Much evidence supports this idea, and most of it was collected during multiple schedules similar to those used to study contrast. These data will be described only briefly here because they have been reviewed elsewhere (McSweeney, Hinson, & Cannon, 1996; see also Swithers & Hall, 1994).

Rate of responding often increases, decreases, or increases and then decreases within sessions of operant conditioning (e.g., McSweeney, 1992). Such within-session changes in responding are frequently reported. For example, McSweeney and Roll (1993) cited approximately 200 studies, conducted in many different laboratories, that reported those changes.

To date, many potential explanations for within-session changes in responding have been questioned. Questionable explanations include recovery from handling (McSweeney & Johnson, 1994), anticipation of events that follow the session (McSweeney, Weatherly, & Swindell, 1995), changes in a general motivational state such as arousal (e.g., McSweeney, Swindell, & Weatherly, 1996a), changes in interfering adjunctive responses (e.g., McSweeney, Swindell, & Weatherly, 1996a), changes in factors related to the act of responding such as muscular warm-up or fatigue (e.g., Weatherly, McSweeney, & Swindell, 1995), and changes in attention defined in two different ways (e.g., McSweeney, Roll,

& Weatherly, 1994; McSweeney, Weatherly, & Swindell, 1996b). Explanations that attribute within-session changes to strongly linked opponent processes (e.g., Solomon & Corbit, 1974) are also suspect because the early-session increases in responding often occur without the late-session decreases, and vice versa (e.g., McSweeney & Roll, 1993).

In contrast to these questionable explanations, systematic changes in the effectiveness of the reinforcer that could produce the changes in responding have been observed over the course of a session. McSweeney, Weatherly, and Swindell (1996a) examined responding when pigeons pecked keys for a repeatedly presented (mixed grain) reinforcer and for a different, infrequently presented probe (wheat) reinforcer. The rate at which mixed grain was presented varied across conditions. Responding for mixed grain mainly decreased within the session when mixed grain was provided at high rates (e.g., a VI 15-s or VI 30-s schedule). Responding for the infrequently presented wheat was relatively constant across the session. Finding changes in the rate of responding for mixed grain relative to the rate for wheat strongly suggests that the value, or effectiveness, of mixed grain changed within the session (e.g., Baum, 1974; Miller, 1976). The use of relative response rates rules out many alternative explanations for decreases in responding. For example, if subjects became more fatigued as the session progressed, then the rate of pecking should have decreased for both mixed grain and wheat, not just for mixed grain.

The essential feature of our account is that repeated exposure to the reinforcer eventually causes the effectiveness of the reinforcer to decline temporarily. We prefer to characterize this effect as an habituation-like process rather than as a satiation effect for reasons discussed elsewhere (e.g., McSweeney et al., 1996; McSweeney & Roll, in press). A central feature of our argument is that habituation and within-session changes in operant responding have similar empirical characteristics. This suggests that the two phenomena are produced by the same theoretical variables. McSweeney et al. (1996) showed that habituation and within-session changes share at least eight empirical characteristics. In both cases, the peak rate of responding is often reached earlier in the session, and the decline in responding is steeper when stimuli are presented at higher than at lower rates. Both changes in responding spontaneously recover over time. Both changes are altered by experience. In both cases, the form of the changes depends on the exact nature of the stimulus conditions. Both phenomena are produced by retrospective factors that accumulate over time, rather than by anticipation of events to come. Neither change can be attributed to effector fatigue. Both are general phenomena that occur for a wide variety of species performing a wide variety of responses. Finally, the basic form of the changes is similar. The changes are often bitonic, but the increases may occur without the decreases and vice versa.

Since the time of McSweeney et al.'s (1996) review, four more empirical similarities have been shown. These similarities include dishabituation (McSweeney & Roll, in press), stimulus specificity (McSweeney, Swindell, & Weatherly, 1996b; McSweeney, Weatherly, & Swindell, 1996a), faster habituation for less intense than for more intense stimuli (Melville, Rue, Rybiski, & Weatherly, 1997), and slower habituation for more variable stimuli than for less variable stimuli (Melville et al., 1997; see McSweeney & Roll, in press, for details).

To put the strength of finding 12 empirical similarities in perspective, the term *habituation* has been applied to phenomena that share as few as three of the characteristics of habituation (Eisenstein & Peretz, 1973). Gill withdrawal in *Aplysia,* a widely used preparation for the study of habituation, shows six of Thompson and Spencer's (1966) original nine characteristics (Pinsker, Kupfermann, Castellucci, & Kandel, 1970), although it might share more of a revised list.

Our argument is entirely empirical. We avoid espousing a particular theory of habituation. To date, many theories have been proposed (e.g., Sokolov, 1963; Wagner, 1976), but no single one of them has gained universal acceptance (e.g., see Mackintosh, 1987, for criticisms of Wagner's theory).

Our empirical approach makes testing the present theory more difficult. If we had defined habituation in terms of changes in an internal state or a theoretical variable, we could ask whether this state or variable changed appropriately whenever contrast was observed. In the absence of such a test, the presence of habituation is revealed when behavior conforms to a series of characteristics (e.g., Thompson & Spencer, 1966). We show that here. We first show that the fundamental characteristics of contrast are consistent with the idea that habituation to the reinforcer contributes to contrast. Then we argue that the empirical characteristics of habituation allow this theory to make several unusual predictions, some of which have been confirmed and some of which are untested. Finally, we evaluate evidence that seems to contradict the theory. We conclude that habituation to the reinforcer is consistent with most of the characteristics of contrast, but that a second mechanism must also be postulated to account for all results in the literature on multiple-schedule behavioral contrast.

Throughout this paper, we confine our discussion to the contrast that is observed on multiple schedules. Although contrast is also observed during concurrent schedules (e.g., McSweeney, Melville, & Higa, 1988), a discussion of concurrent-schedule contrast would make this paper too long. Several authors have also argued that different factors produce concurrent- and multiple-schedule contrast (e.g., Rachlin, 1973; Zentall, Weaver, & Sherburne, 1996).

HABITUATION TO THE REINFORCER IS CONSISTENT WITH THE FUNDAMENTAL CHARACTERISTICS OF CONTRAST

The present theory is consistent with several generally accepted characteristics of behavioral contrast. Because these characteristics are also consistent with many other theories of contrast, they do not provide strong support for the present theory. However, the theory would be rejected if it was not consistent with these findings.

Changes in Reinforcement Produce Contrast

The present theory attributes contrast to differences in habituation to the reinforcer between the baseline and contrast phases. Consistent with this idea, contrast is produced by changes in reinforcement, not by changes in other factors (e.g., rate of responding; Williams, 1983). Larger changes in the rate of reinforcement between the baseline and contrast phases also produce larger contrast when baseline rate of reinforcement is constant (e.g., McLean, 1995; Reynolds, 1963; for potentially related findings see Bloomfield, 1967; Harper & McLean, 1992, Experiment 1; Nevin, 1974; Nevin, Mandell, & Atak, 1983).

The Choice of Discriminative Stimuli and Instrumental Response Plays Little Role in Contrast

The present theory attributes contrast to differential habituation to the reinforcer. The choice of discriminative stimuli and instrumental response should not alter this habituation. Therefore, these choices should not alter contrast unless procedural problems arise. For example, the observation of contrast requires discrimination between the components of the multiple schedule (e.g., Rachlin, 1973). No contrast will occur if the component stimuli are too similar to support discrimination. Except in these problematic cases, however, the choice of discriminative stimuli and instrumental response should have no influence on contrast.

Consistent with this idea, contrast has been reported for instrumental responses (e.g., treadle pressing) and discriminative stimuli (e.g., diffuse stimuli, stimuli located off the response operandum) that were once thought not to produce contrast (e.g., Williams, 1983; Williams & Heyneman, 1981). Contrast is also observed when qualitatively different responses produce reinforcers in the two components (Beninger & Kendall, 1975, Experiment 4; Howard, 1979; King & McSweeney, 1987; Manabe, 1992, when contrast is defined as we have defined it here; Premack, 1969). For example, Beninger and Kendall reported contrast for key pressing when reinforcers for lever pressing were withdrawn and contrast for lever pressing when reinforcers for key pressing were withdrawn.

Scull and Westbrook (1973) failed to find contrast for lever pressing when reinforcers for key pecking were removed, and vice versa. However, several problems make their results difficult to interpret. For example, baseline response rates were not recovered after the contrast manipulation. Therefore, fluctuations in response rates over time may have interfered with the observation of contrast.

Introducing a Timeout Produces Positive Contrast

Positive contrast occurs when the second component of a multiple schedule is replaced by a timeout or blackout (e.g., Reynolds, 1961; Vieth & Rilling, 1972). No reinforcers are delivered during timeouts. Therefore, no habituation should occur, and the effectiveness of reinforcers may spontaneously recover (e.g., Thompson & Spencer, 1966). Both factors should increase the effectiveness of the reinforcers relative to baseline, yielding positive contrast.

Longer timeouts should allow more spontaneous recovery of reinforcer effectiveness than do shorter timeouts. Therefore, the reinforcers in the constant component should support faster responding when longer timeouts are introduced. This effect was confirmed by Mackintosh, Little, and Lord (1972) and by Taus and Hearst (1970), but not by Williams (1990, Experiment 1). Williams reported that introducing a 15-s timeout between components reduced rather than increased response rate during the components. However, the schedule was not repeated without the timeout after sessions with the timeout were conducted. Therefore, changes in response rates cannot clearly be attributed to the presence of the timeout rather than to the passage of time and its correlated variables.

A VI Schedule May Be Used As a Baseline for Assessing Contrast

As argued above, contrast is often measured by comparing responding during a baseline multiple schedule that provides the same conditions of reinforcement in both components (e.g., a multiple VI *x* VI *x* schedule) with responding during a contrast schedule that provides different conditions (e.g., a multiple VI *x* VI *y* schedule; McSweeney & Norman, 1979). Because a simple VI *x* schedule delivers the same rate of reinforcement as a multiple VI *x* VI *x* schedule, the schedules should produce equal habituation. Unless habituation also occurs to the component stimuli that are present during multiple schedules but not during simple schedules, a simple VI *x* schedule could be used in place of a multiple VI *x* VI *x* schedule as a baseline for measuring contrast. Although it may seem obvious that simple VI *x* and multiple VI *x* VI *x* schedules should work equally well as baselines, some theories of behavioral contrast predict that they should not (e.g., Herrnstein, 1970).

Several results are consistent with this prediction. First, simple VI *x* and multiple VI *x* VI *x* schedules support similar rates of responding (McSweeney, 1980; McSweeney & Dericco, 1976; Spealman & Gollub, 1974). Second, response rate is often higher during the VI *x* component of a multiple VI *x* VI *y* schedule than during a simple VI *x* schedule when the VI *x* component is richer than the VI *y* component (Halliday & Boakes, 1974; Hearst, 1971; Hearst & Gormley, 1976; Mackintosh et al., 1972; McSweeney, 1980; Pear & Wilkie, 1971). That is, positive contrast occurs when contrast is measured using a simple VI *x* schedule baseline. Third, response rate is lower during a VI *x* component than during a simple VI *x* schedule when the VI *x* component is leaner than the VI *y* (Bloomfield, 1967; Freeman, 1971; McSweeney, 1982b). That is, negative contrast occurs using a simple VI *x* schedule as baseline.

Differences in responding between VI *x* components and simple VI *x* schedules also appear under conditions that produce behavioral contrast and not under conditions that do not produce contrast (McSweeney, Dougan, & Farmer, 1986a, 1986b). For example, positive contrast is observed for pigeons pressing treadles when high, but not low, baseline rates of reinforcement are used. Negative treadle-press contrast is observed even when low baseline rates are used. Consistent with the present argument, the rate of treadle pressing during the richer VI *x* component of a multiple schedule is faster than the rate of pressing during a simple VI *x* schedule when the VI *x* component or schedule provides a high, but not a low, rate of reinforcement. The rate of treadle pressing during the leaner VI *x* component of a multiple schedule is slower than the rate of pressing during a simple VI *x* schedule, even when the VI component or schedule provides a low rate of reinforcement (McSweeney et al., 1986a).

Contrast Occurs Regardless of Whether Response-Dependent or Response-Independent Reinforcers Are Altered

Habituation should occur whenever stimuli, such as food and water, are presented, not just when they act as reinforcers. Several findings are consistent with this idea. First, changing a multiple VI *x* VI *x* schedule to a multiple VI *x* variable-time (VT) *x* schedule does not produce contrast (e.g., Marcucella, 1976; Wilkie, 1972). The two schedules deliver equal rates of reinforcement. Therefore, they should produce equal habituation, and no contrast is expected. Second, positive contrast occurs when a multiple VI *x* VT *x* schedule is changed to a multiple VI *x* extinction schedule (Halliday & Boakes, 1974). Removing noncontingent reinforcers should reduce habituation, making the remaining reinforcers more valuable and producing positive contrast. Third, negative contrast occurs when a VI *x* schedule is changed to a multiple VI *x* VT *y* schedule in which the VT *y* component is richer than the VI *x* component (Freeman, 1971). The VT *y* component provides more reinforcers and therefore should produce more habituation than a comparable amount of time in the VI *x* schedule. Greater habituation should reduce the effectiveness of the reinforcers, yielding negative contrast. Finally, negative contrast (a decrease in response rate) occurs in both components of a multiple schedule when response-independent reinforcers are added to a timeout between the components (Harper & McLean, 1992; Nevin, 1974; Nevin et al., 1983). Again, adding response-independent reinforcers should increase habituation and produce negative contrast.

Positive and Negative Contrast Are Produced by Symmetrical Variables

To a large extent, the present theory provides symmetrical explanations for positive and negative contrast (but see the later discussion of producing positive contrast by dishabituation and violations of stimulus specificity). That is, if manipulating an independent variable in one direction (e.g., decreasing rate of reinforcement) decreases habituation and produces positive contrast, then manipulating the variable in the opposite direction (e.g., increasing rate of reinforcement) should increase habituation and produce negative contrast.

A few experiments failed to demonstrate the symmetry of contrast. That is, one type of contrast failed to occur under conditions opposite to those that produced the other type (e.g., Ettinger & McSweeney, 1981; King & McSweeney, 1987; McSweeney, 1978; Schwartz, 1975). However, failures to observe an effect are always difficult to interpret. For example, in the absence of a scale of reinforcer effectiveness, it cannot be argued that the manipulations used to produce positive and negative contrast were equally large. Therefore, failures to observe one type of contrast can always be attributed to the use of a weaker manipulation for that type of contrast than for the other, rather than to fundamental differences in the variables that produce the two types of contrast (McSweeney, 1987; see also Williams, 1992).

A better way to assess the symmetry of contrast is to study changes in the sizes of both positive and negative contrast as a function of several independent variables (e.g., McSweeney, 1982a). If symmetrical theories are correct, then manipulating an independent variable should produce similar changes in both types of contrast unless technical problems arise (e.g., ceiling or floor effects). When this has been done, striking symmetries have been observed. For example, the absolute sizes of both positive and negative contrast vary inversely with component duration when pigeons peck keys (McSweeney, 1982a). The absolute sizes of both positive and negative contrast increase and then decrease or remain relatively constant with increases in component duration when pigeons press treadles (McSweeney, Dougan, Higa, & Farmer, 1986) or rats press levers (McSweeney & Melville, 1991). The absolute sizes of both positive and negative contrast also vary directly with baseline rates of reinforcement when pigeons peck keys (McSweeney et al., 1986).

UNUSUAL PREDICTIONS OF THE PRESENT THEORY

The present theory also makes predictions that are unusual and that therefore provide stronger support for the theory than the predictions discussed in the previous section.

Dishabituation May Produce Positive Contrast

Some influential theories of contrast imply that changes in the reinforcer produce contrast (e.g., Williams, 1983). The present theory implies a similar conclusion, but adds that introducing any strong stimulus should also produce positive contrast through dishabituation (the restoration of responding to a habituated stimulus, e.g., Thompson & Spencer, 1966). Consistent with this idea, adding punishers (Brethower & Reynolds, 1962; Terrace, 1968) or signals for the availability of reinforcers (Brownstein & Hughes, 1970; Brownstein & Newsom, 1970; Hughes, 1971; Lander, 1971; Marcucella, 1976; Reynolds & Limpo, 1968; Wilkie, 1973; 1977) to one component of a multiple schedule may produce positive contrast in the constant component.

Some results reported in these studies are particularly difficult to reconcile with traditional theories of contrast (e.g., Herrnstein, 1970). For example, Reynolds and Limpo (1968) reported that signaling reinforcers increased the rate of reinforcement obtained in that component and decreased the rate of reinforcement obtained in the other component. Some influential theories of contrast imply that increases in the rate of reinforcement in the component with signals should decrease response rate in the other component (negative contrast). The decrease in the rate of reinforcement obtained in the other component should further exaggerate this decrease. As a result, those earlier theories imply that response rate should decrease in the component without signals, the opposite of what Reynolds and Limpo observed.

Dishabituation can explain these results as long as it is strong enough to overcome the decrease in reinforcement in the component without signals and any additional habituation produced by an increase in the total reinforcers obtained per session. This is plausible because the decrease in nonsignaled reinforcers was small and was offset by the increase in reinforcement in the component with signals, yielding little change in the total rate of reinforcement obtained over the session.

A few studies failed to find contrast when punishers (Rachlin, 1966) or signals (Griffin & Stewart, 1977; Gutman & Fenner, 1982; Williams, 1980) were added, contradicting the predictions of dishabituation. The explanation for these failures is not known. One possibility is that the punishers and signals were too weak to produce dishabituation. Rachlin used a shock intensity that was weak enough to allow recovery of the suppression of responding in the component to which punishers were added. Manipulation of a line on the response key served as the signal for reinforcement in all of the signaled reinforcement studies that failed to report contrast, with the exception of 4 subjects in Experiment 2 of Gutman and Fenner. The studies that produced contrast used more substantial signals (e.g., illuminating the houselight, Wilkie, 1973, 1977; illuminating the response key that was dark at other times, Brownstein & Hughes, 1970; Hughes, 1971).

It might be objected that habituation should occur to dishabituators when they are repeatedly presented (e.g., Thompson & Spencer, 1966). Therefore, contrast cannot be attributed to dishabituation without explaining why the added punishers or signals did not lose their effectiveness with repeated presentation. Although contrast did become somewhat smaller over successive sessions in some studies (e.g., Brownstein & Newsom, 1970), as would be expected if subjects habituated to the dishabituating signals, changes in the size of contrast with experience were not always observed.

Several factors may have reduced habituation to the dishabituators. First, habituation occurs at different rates for different stimuli (e.g., Hinde, 1970). Habituation is not always found for strong stimuli, such as some of the shocks used as punishers (e.g., Groves & Thompson, 1970). Second, the use of a multiple schedule ensured that the presentation of punishers or signals was interrupted periodically when the unpunished or no-signals component was presented. This would allow some spontaneous recovery of the effectiveness of the punishers and signals, reducing habituation to them. Third, specific procedural details used in some studies probably reduced habituation. For example, Terrace (1968) changed the intensity of the shock from session to session. This should reduce habituation, because habituation is relatively specific to the stimulus that is delivered.

Some plausible alternative explanations for the effects of signals and punishers should also be considered before dishabituation is accepted. Adding punishers is sometimes assumed to be functionally equivalent to the removal of food (de Villiers, 1980; Williams, 1983). Adding signals for reinforcement may convert the time when the signal is not present to a signal for the absence of reinforcement (an S−). By these arguments, adding punishers and signals produce positive contrast because removing positive reinforcers and introducing an S− both produce positive contrast.

The idea that punishers are functionally equivalent to the removal of food remains a viable alternative to dishabituation as an explanation for the effect of introducing punishers. But several data question the idea that adding signals for reinforcement produces contrast by creating an S−. Hughes (1971) conducted a baseline multiple VI *x* VI *x* schedule. Then he added signals for reinforcement to one component. Finally, he added extra stimuli that did not signal the availability of reinforcement to the component with signals. Hughes reported that adding signals for reinforcement produced positive contrast in the constant component. Adding extra, nonpredictive, stimuli further increased this response rate. That is, adding extra stimuli produced positive contrast, even when those stimuli did not signal reinforcement and therefore did not create a timeout from reinforcement during the rest of the component. Hughes' results are consistent with dishabituation because the additional stimuli should function as dishabituators regardless of whether or not they signal reinforcement.

Brownstein and Newsom (1970) reported that adding a signal to one component of a multiple fixed-interval (FI) FI schedule produced large positive contrast in the other component. An S− might be thought to be already present during FI schedules, because the time that immediately follows the reinforcer cannot contain another reinforcer. Adding another stimulus to signal the availability of reinforcement should not create a new S− or substantially alter the existing one. Nevertheless, the addition of the signal produced substantial positive contrast. Brownstein and Newsom's results are consistent with dishabituation, because signals should act as dishabituators regardless of whether they are added to FI or VI schedules.

Lander (1971) conducted a baseline multiple VI 1-min VI 1-min schedule in which one component was signaled by a red light on the response key and the other was signaled by adding three vertical lines to the red key. In a second signaled reinforcement condition, the second-component stimulus changed from three vertical lines on red to three vertical lines on black when reinforcers were available. Then Lander measured the generalization gradient for line orientation. He found an excitatory gradient, with a peak rate of responding at the actually presented vertical line orientation. If the changes in key color from red to black created an S−, then the generalization gradient for line orientation should have been inhibitory, not excitatory (e.g., Hearst, Besley, & Farthing, 1970). This study could be criticized, however. Line orientation may have become excitatory because the lines were present just before food was delivered as well as during the early part of the interval. The experiment should be repeated using a stimulus as S− that does not appear at other times.

The idea that punishers and signals for reinforcement produce contrast through dishabituation requires further study. Several arguments can be made in its favor. Dishabituation is parsimonious because it accounts for the effect of two manipulations, adding signals and punishers, with a single mechanism. It does so without requiring special assumptions, such as that the addition of punishment is functionally equivalent to the removal of reinforcement. This assumption may eventually prove to be correct, but it is not required by the present theory. Dishabituation is also more consistent with some reported results than are alternative explanations for the effects of signals and punishers. Nevertheless, additional predictions of dishabituation should be tested in future studies. For example, the mere presentation of a strong stimulus should produce dishabituation. Therefore, adding aversive stimuli and signals should produce positive contrast when those stimuli are delivered independently of, not just contingent on, responding and when they are presented randomly as well as when they signal the availability of reinforcement.

Violating Stimulus Specificity Produces Positive Contrast

Many authors argue that a decrease in responsiveness to a repeatedly presented stimulus should not be called *habituation* until sensory adaptation and effector fatigue are ruled out as explanations for that decrease (e.g., Thorpe, 1966). Adaptation and fatigue are often ruled out by changing the nature of the presented stimulus (e.g., from a loud to a softer tone). Adaptation and fatigue should not be eliminated by slight changes in the stimulus. Therefore, the decrease in responsiveness is habituation if responding recovers when the new stimulus is presented. Recently, *stimulus specificity* has been elevated to a fundamental property of habituated behavior (e.g., Swithers & Hall, 1994). It has been argued that habituation is relatively specific to the stimulus that is presented and that therefore changing the presented stimulus should restore habituated responding.

If habituation contributes to contrast, then changes in the reinforcer might disrupt habituation and produce positive contrast, even if those changes do not obviously alter the value or effectiveness of the reinforcer. For example, the timing of a stimulus may be part of the complex to which subjects habituate (e.g., Broster & Rankin, 1994; Davis, 1970). If so, then changing the timing of reinforcers without changing their overall rate of delivery might produce positive contrast. Consistent with this idea, positive contrast occurs when subjects move from a multiple VI *x* VI *x* schedule to a multiple VI *x* FI *x* schedule (Wilkie, 1977; Experiment 1; see also Wilkie, 1977, Experiment 3).

The present theory is only partially consistent with results reported by Williams (1976). He studied pigeons responding on a multiple VI 90-s VI 90-s schedule with alternating 90-s components. Then he changed one component so that the reinforcer was available after a fixed period of 5, 45, or 80 s in different conditions. Positive contrast was observed during the constant VI 90-s component when the reinforcer in the second component was available after 45 or 80 s but not after 5 s. If the timing of the reinforcer is part of the stimulus to which subjects habituate, then contrast should have been observed for each of these delays. However, several factors make Williams' results difficult to interpret. For example, baseline response rates increased across the experiment, making it difficult to separate positive contrast from a general increase in response rate.

Again, alternative explanations for the effect of introducing an FI schedule must be considered. One possibility is that reinforcers are less effective when they are presented on an FI *x* schedule than when they are presented on a VI *x* schedule. If changes in reinforcer value produce contrast, then substituting a less valuable FI schedule for a more valuable VI schedule should produce positive contrast. Consistent with this argument, subjects usually prefer variable to fixed schedules that provide the same rates of reinforcement (e.g., Field, Tonneau, Ahearn, & Hineline, 1996).

Rather than providing a competing explanation for the effect of introducing FI schedules, the present theory may help to explain why VI *x* schedules are preferred to FI *x* schedules. If habituation is faster and more pronounced when stimuli are presented at fixed rather than variable intervals (Broster & Rankin, 1994; Davis, 1970), then the same reinforcers should be less valuable (more habituation) when presented on an FI schedule than on a VI schedule. If this is true, then the present theory may also have implications for understanding the preference for variability that is observed in many literatures.

Introducing an FI schedule might also produce contrast because it introduces an S−, not because it violates stimulus specificity. As argued above, the time that immediately follows the reinforcer on an FI schedule cannot contain another reinforcer, and is therefore an S−. Introducing an S− is known to produce positive contrast.

The previously cited experiment by Brownstein and Newsom (1970) challenges this explanation. Brownstein and Newsom found that adding explicit external signals for reinforcement to one component of a multiple FI FI schedule produces positive contrast. If an S− is present during an FI schedule, then the contrast created by this S− should also be present during multiple FI FI schedules. Adding an additional signal for nonreinforcement should not substantially alter this S−, and therefore should not create contrast.

The present theory should be tested further under conditions that cannot be explained by the creation of an S−. For example, many relatively neutral stimuli accompany the delivery of reinforcers (e.g., the sound and illumination of the food hopper). Experiments could determine which of these stimuli are part of the reinforcer complex to which habituation occurs by changing one of them late in an experimental session. If response rate increased after the stimulus change, then it would be assumed that habituation had occurred to that aspect of the stimulus. If so, then introducing the same stimulus change in one component of a multiple VI *x* VI *x* schedule should violate stimulus specificity and produce positive contrast in the other component, regardless of whether it created an S− or not.

Contrast May Be Accompanied by Changes in Reinforcer Value

The present theory attributes contrast to differences in reinforcer effectiveness between the baseline and contrast phases. This change in effectiveness should be measurable. Consistent with this idea, Bloomfield (1969) used a choice test to measure preference for components associated with multiple VI VI or multiple VI extinction schedules. The difference in preference for the VI component between the baseline and contrast schedules (i.e., the change in reinforcer effectiveness) was highly correlated (0.96) with the difference in the absolute response rates during the VI schedule in the baseline and contrast schedules (i.e., the size of contrast; see *Following-Component Contrast* below for a discussion of some failures to find appropriate changes in reinforcer effectiveness).

Contrast Is Not Transient but It Changes over Time

Most theories of contrast apply to steady-state behavior (e.g., Herrnstein, 1970). Therefore, they predict that contrast will be found even after repeated exposure to the situation, but they are silent about how contrast changes with experience. The present theory also predicts that contrast will occur after many sessions as habituation continues to develop within sessions and spontaneous recovery continues to occur between sessions. However, the present theory implies that contrast will change with experience as long-term habituation develops and supplements short-term habituation (e.g., Wagner, 1976). Short-term habituation is present early in training and is usually attributed to unlearned factors. Long-term habituation develops with experience and is often attributed to learning (e.g., Wagner, 1976). Consistent with the present theory, contrast is observed even after subjects have responded on a schedule for many sessions (e.g., Hearst, 1971; Selekman, 1973), but its size may decrease over sessions (Bloomfield, 1966; Pear & Wilkie, 1971; Sadowsky, 1973; Selekman, 1973; Terrace, 1966).

The present theory can explain the decrease in the size of contrast with experience in several ways, only one of which will be described here. As discussed above, habituation is relatively specific to the characteristics of the presented stimulus (e.g., Swithers & Hall, 1994). When some aspect of reinforcement is changed at the beginning of the contrast phase, the stimulus change alone may restore responding until habituation develops again to the new conditions of reinforcement. When rate of reinforcement is reduced to produce positive contrast, the increase in response rate due to the stimulus change will add to the increase in responding that occurs because fewer reinforcers produce less habituation. Therefore, positive contrast should be largest at the beginning of the contrast phase and should decrease as habituation develops to the new conditions of reinforcement.

This particular explanation predicts that the absolute size of negative contrast should increase with experience. When rate of reinforcement first increases to produce negative contrast, the increase in response rate due to the stimulus change should partially offset the decrease in responding from greater habituation, thus reducing the size of negative contrast. The size of negative contrast should increase as habituation develops to the new conditions of reinforcement. To the best of our knowledge, this prediction has not been tested.

Local Contrast

The present theory attributes behavioral contrast to differences in habituation between the baseline and contrast phases. A different type of contrast, local contrast, may be partially explained by dynamic changes in habituation within sessions. Rate of responding often (e.g., Bernheim & Williams, 1967; Freeman, 1971; Malone, 1976; Nevin & Shettleworth, 1966) but not always (e.g., Buck, Rothstein, & Williams, 1975; Freeman, 1971; White, 1995) increases sharply with the transition from the leaner to the richer component and then decreases with time in the richer component (positive local contrast). Response rate also decreases sharply with the transition from the richer to the leaner component and then increases with time in the leaner component (negative local contrast).[2]

With a few exceptions (e.g., Rachlin, 1973), most theories of behavioral contrast offer no explanation for local contrast. The present theory does. Response rates should be higher at the beginning of the richer component because that component follows a time during which fewer reinforcers are delivered. Therefore, the effectiveness of the habituated reinforcer should spontaneously recover to some extent. Response rates should be lower at the beginning of the leaner component because this component follows a time of denser reinforcer presentation that produces greater than average habituation.[3]

Some characteristics of local contrast are consistent with the present theory. For example, local contrast is more evident in longer components than in shorter components (e.g., Hinson & Staddon, 1981; White, Pipe, McLean & Redman, 1985). Longer components provide more time for either the spontaneous recovery of reinforcer effectiveness or further habituation to the reinforcer. Other findings on local contrast are less consistent with the present theory. These findings will be discussed below in *Following-Component Contrast*.

Component Duration

The size of contrast changes with changes in component duration, although there is some question about whether absolute or relative component duration is the critical variable (Aronson, Balsam, & Gibbon, 1993). When pigeons peck keys and the components are of equal duration, contrast is usually larger for shorter components than for longer components (e.g., McLean, 1995; McSweeney, 1982a; McSweeney & Melville, 1988; Spealman, 1976; Williams, 1979; 1980). When pigeons press treadles (McSweeney et al.,

---

[2] The term *local contrast* also refers to the aftereffects of stimulus presentation (e.g., Hinson & Malone, 1980). That is, responding may be faster when a component follows a leaner component than when it follows itself (positive local contrast). Responding may be slower when a component follows a richer component than when it follows itself (negative local contrast). This type of local contrast is also consistent with the present theory. Reinforcers should be more valuable and support more responding after a leaner component because the leaner component produces less than average habituation. Reinforcers should be less valuable and support less responding after a richer component because richer components produce greater than average habituation.

The sensitivity parameter of the generalized matching law (e.g., Baum, 1974) is often largest immediately after a component transition (e.g., White, Pipe, & McLean, 1984). This finding will not be discussed because changes in the sensitivity parameter can be produced by changes in responding during either or both components. Therefore, these changes are not related in a simple way to local contrast as we have defined it.

[3] The changes in response rates that constitute local contrast appear to occur as soon as the component changes, not after the delivery of the first reinforcer. One potential explanation for this finding is that habituation to the reinforcer, as other aspects of reinforcement, may come under stimulus control. That is, it is often assumed that response rate changes abruptly at the transitions between the components of a multiple schedule because the stimulus that signals each component comes to control a rate of responding that is appropriate for the conditions of reinforcement that are presented in that component. It seems reasonable to assume that the amount of habituation that has occurred to the reinforcer up to that point in the session is one of the conditions of reinforcement that could be signaled by the component stimulus.

However, an alternative should be considered before this is accepted. The changes in response rates that represent local contrast are averages. Response rates are often averaged across several components and sessions if results are presented for individual subjects. Rates are often averaged across components, sessions, and subjects if results are presented for the mean of all subjects. Averaging can convert abrupt transitions in responding to smooth functions. Therefore, it is possible that the changes in response rates that represent local contrast actually occur only after the delivery of a reinforcer, not when the component changes.

Two procedural details strengthen the plausibility of this argument. First, the frequent use of VI schedules ensures that reinforcers are delivered at different times during different components. Therefore, averaging across abrupt transitions in response rates that occurred at these different times would result in a smooth change in response rate. Second, in many cases, reinforcers that are not delivered during one component of a multiple schedule are not canceled but are held over for delivery during the next appearance of that schedule. Such a procedure increases the probability that a reinforcer will be delivered quickly after a component transition, making it difficult to tell whether the delivery of a reinforcer or the component transition controlled the change in response rate.

The possibility that response rates change only after the delivery of a reinforcer, not with the change in component stimulus, deserves investigation. Although some data bear on this issue (e.g., Bernheim & Williams, 1967, presented some cumulative records), the data are few and hard to interpret.

1986) or rats press levers (McSweeney & Melville, 1991) and the components are of equal duration, contrast is also larger or similar in size for components of intermediate duration (e.g., 1 min) than for long (e.g., 16 min) components, but induction (the opposite of contrast) may be found when components are very short (e.g., 5 s).

The effect of component duration might be produced by the same factors that produce local contrast. According to this argument, short components sample only the time immediately after a component transition when response rate is highest (positive local contrast) or lowest (negative local contrast). Longer components sample more of the time during which subjects respond at intermediate rates.

In support of this idea, Williams (1983) argued that varying component duration has two different effects. First, contrast is larger for longer durations than for shorter durations of the component that is varied to produce contrast (e.g., the extinction component; de Rose, 1986; Ettinger & Staddon, 1982; Hinson & Staddon, 1981; Williams, 1989; Wilton & Clements, 1971; see also Aronson et al., 1993). According to the present theory, longer extinction components should allow longer time for reinforcer effectiveness to recover, yielding larger differences in the effectiveness of the reinforcers in the baseline and contrast phases and therefore more contrast. Second, contrast is smaller the longer the duration of the component in which contrast is measured (Ettinger & Staddon, 1982; Hinson, Malone, McNally, & Rowe, 1978; Williams, 1989; see also Aronson et al., 1993). Shorter components should sample only the time at the beginning of the component when response rate is highest (positive local contrast) or lowest (negative local contrast). Longer components should predominantly sample times of intermediate response rates.

Habituation does not easily explain why induction, the opposite of contrast, is observed for short components (i.e., 5 s) when pigeons press treadles or rats press levers. However, this may be an experimental artifact. The experiments that examined key-peck contrast usually presented both components on a single operandum. The experiments that examined treadle- and lever-press contrast presented the components on different operanda. Two operanda were used because contrast may be difficult to produce for treadle and lever pressing, and the use of two operanda usually facilitates contrast. As a result, however, subjects may have had difficulty changing components quickly for treadle and lever pressing but not for key pecking. This difficulty may have physically interfered with the observation of contrast when components were as short as 5 s. Although McSweeney and Melville (1988, Experiment 3) found large key-peck contrast for short components even when they used a two-key procedure, the size of contrast has not been examined as a function of component duration when the components are presented on a single lever or on a single treadle.

Contrast Is Observed Across Qualitatively Different Reinforcers

Contrast occurs when qualitatively different reinforcers appear in the components of the multiple schedule. Changing the rate at which one type of reinforcer is delivered produces contrast for a different reinforcer (Beninger, 1972; Beninger & Kendall, 1975; McSweeney et al., 1988; Premack, 1969). For example, Beninger and Kendall reported that the rate of lever pressing for pellets increased when milk was withdrawn, and lever pressing for milk increased when pellets were withdrawn. Changing the nature but not the rate of a different reinforcer also produces contrast (Ettinger & McSweeney, 1981; Ettinger, McSweeney, & Norman, 1981; Higa & McSweeney, 1987). For example, Ettinger et al. observed contrast when a schedule that provided a moderately preferred grain in both components was changed to a schedule that provided a moderately preferred grain in one component and a highly preferred (negative contrast) or a less preferred (positive contrast) grain in the other component.

Contrast across different reinforcers is sometimes asymmetrical. For example, Ettinger and McSweeney (1981) and Higa and McSweeney (1987) both found contrast for water when the other component changed to food, but they did not find contrast for food when the other component changed to water (see also Beninger & Kendall, 1975; McSweeney et al., 1988). However, failures to find contrast are difficult to interpret. For example, larger changes in reinforcer effectiveness might be required to produce contrast for food than for water. The failure to find contrast could then be attributed to the use of an ineffective procedure rather than to fundamental differences in contrast for qualitatively different reinforcers.

Contrast across qualitatively different reinforcers is often explained by assuming that different reinforcers occupy points along a common scale of reinforcer value (e.g., Miller, 1976). If a common scale is assumed, and if changes in reinforcer value produce contrast, then contrast should be produced by changing the nature of the reinforcer in the variable component to one that is of higher or lower value than the one presented in the constant component. Contrast should also be produced by removing qualitatively different reinforcers.

The present theory offers a different explanation for contrast across different reinforcers. Habituation may generalize from one stimulus to other similar stimuli (e.g., Thompson & Spencer, 1966). Therefore, changing the rate of delivery or the nature of one reinforcer (e.g., milk) may alter the amount of habituation to a second similar reinforcer (pellets) that is held constant. Altering habituation should produce contrast.

Eventually, the present theory may also have to assume a common scale of reinforcer value to explain all contrast across qualitatively different reinforcers. Although this remains to be established, it is not obvious that enough generalization would occur between stimuli as different as food and water to produce contrast. However, before a common scale of value is assumed, some predictions of the present theory can be pitted against predictions of a common scale.

An experiment might empirically establish that two qualitatively different reinforcers are equally valuable by showing that subjects respond at equal rates during the components of a concurrent schedule that provides one reinforcer in one component and the other in the other component. Then a multiple-schedule baseline could be established that provided one of those reinforcers in both components. A contrast manipulation could be performed in which the reinforcer in one component was changed to the other equally valuable reinforcer. Then baseline should be recovered. Postulating a common scale of reinforcer value predicts that no contrast should occur when an equally valuable but different reinforcer is substituted for the reinforcers in one component of a multiple schedule. The present theory predicts that positive contrast should occur. Because of a generalization decrement, the qualitatively different reinforcers in the changed component should produce less habituation to the first-component reinforcers than actual presentation of those first-component reinforcers (baseline). Reduced habituation should produce positive contrast.

Successive Independence

Most theories of contrast imply that interactions occur over a temporal distance. That is, they attribute contrast to changes in the conditions of reinforcement in the variable component even though the variable component is not present at the time that contrast is measured in the constant component. McLean and White questioned this idea when they showed that the distribution of responding in one component of a multiple concurrent schedule is independent of the distribution of reinforcers in the other component (successive independence; e.g., McLean, 1988; McLean & White, 1983; see also Charman & Davison, 1983).

The designs of these experiments are complex. Nevertheless, the present theory, unlike many theories of contrast, is consistent with McLean and White's (1983) conclusion. We attribute contrast to a change in the effectiveness of the reinforcers that are presented during the constant component. Changes in the reinforcers that are delivered in the variable component produce this change in the effectiveness of constant-component reinforcers. Nevertheless, the altered effectiveness of the constant-component reinforcers, not the conditions of reinforcement in the other component, is directly responsible for contrast.

FINDINGS THAT ARE NOT PREDICTED BY THE PRESENT THEORY

Three sets of findings are not obviously predicted by the present theory. We find that two of these sets do not provide strong evidence against the theory because the data are difficult to interpret. However, stronger evidence shows that habituation to the reinforcer is an incomplete explanation for multiple-schedule behavioral contrast.

Contrast May Be Larger in the Presence of a Competing Response

Hinson and Staddon (1978) reported that positive contrast was larger when a running wheel was present in both components of a multiple schedule than when the wheel was absent. There is no obvious reason why the presence of a wheel should alter habituation to the reinforcer, and therefore it should not alter contrast produced by this habituation (see also McSweeney, Swindell, & Weatherly, 1996a). Hinson and Staddon's results are difficult to interpret, however. First, Williams (1983) concluded that discrimination was better when the running wheel was present than when it was not. Therefore, differences in discrimination, rather than the presence of the wheel, might have produced the differences in contrast. Second, the direction of causality is unclear. The reallocation of wheel running may have resulted from rather than have caused contrast (McLean, 1992). Finally, although changes in response competition may change the size of contrast, changes in competition are not necessary to produce contrast. Contrast occurs even when the amount of competition does not appear to change (Dougan, McSweeney, & Farmer, 1985; Dougan, McSweeney, & Farmer-Dougan, 1986; see also Williams & Wixted, 1994).

Reallocation of Extraneous Reinforcers

McLean and colleagues (e.g., McLean, 1992, 1995; McLean & White, 1983) distinguished between reinforcers that are programmed by the experimenter and those that the subject obtains independent of the schedule arranged by the experimenter (extraneous reinforcers). They argued that the reallocation of extraneous reinforcers produces contrast. According to this theory, positive contrast occurs when a reduction in the programmed reinforcers in one component leads to the reallocation of extraneous reinforcers from the constant contrast component to the reduced reinforcement component. In accordance with the matching law (e.g., Herrnstein, 1970), the reduction in extraneous reinforcers in the constant contrast component increases responding for the programmed reinforcers, producing positive contrast. Likewise, an improvement in reinforcement in one component reallocates extraneous reinforcers away from that component to the constant contrast component. The increase in extraneous reinforcers in the constant component reduces behavior for the programmed reinforcers, producing negative contrast. McLean reported the predicted reallocation of extraneous reinforcers when a multiple schedule was provided on one operandum and extraneous reinforcers were available on a second operandum (e.g., McLean, 1992, 1995).

The present theory does not predict the reallocation of extraneous reinforcers. McLean's results, however, are open to various interpretations. Although McLean (1995) has questioned their conclusions, Williams and Wixted (1994) argued that contrast is too large to be produced solely by reinforcer reallocation. Williams and Wixted also demonstrated a direct effect of manipulating rate of reinforcement in McLean's data. More important, McLean's results are correlational. That is, the size of contrast was correlated with the reallocation of extraneous reinforcers. Although McLean argued that contrast did not produce the reallocation of reinforcers, he did not rule out that both contrast and reallocation could be produced by more fundamental variables.

Following-Component Contrast

Habituation may contribute to behavioral contrast, but it cannot provide a complete explanation for all contrast. Contrast occurs during procedures that should not produce differential habituation. For example, Williams (1991) presented a VI 2-min schedule during Stimulus A and Stimulus C. Stimulus A preceded Stimulus B, which signaled a VI 30-s schedule. Stimulus C preceded Stimulus D, which signaled extinction. The A-B and C-D pairs of stimuli were presented randomly throughout the session. Subjects responded faster during Stimulus C than during Stimulus A (contrast), even though differential habituation should not have occurred in the presence of the two stimuli. Because the stimulus pairs were presented randomly, the habituation to the reinforcer that occurred up to the time of presentation of a pair of stimuli did not differ for Stimulus A and Stimulus C. Habituation should not be altered by the conditions of reinforcement in the following component because habituation is controlled by events in the past, not by events in the future. Therefore, no differential habituation should occur, and the present theory predicts no contrast.

However, just as habituation provides an inadequate account for all contrast, changes in the following conditions of reinforcement also fail to explain all contrast. They do not account for all of the contrast reported in some studies (e.g., Farley, 1980; Williams, 1989, 1992; Williams & Wixted, 1986), and a habituation-like effect supplements the effect of following reinforcers in some studies. For example, Williams (1990, Experiment 1) found no evidence of following-component contrast. That is, responding during a VI 1-min component was slower, not faster, when that component was followed by extinction than when it was followed by a VT 30-s schedule. But Williams' results were consistent with habituation to the reinforcer when responding was compared across phases of the experiment. As predicted by the present theory, response rates were higher when a VI 1-min component was always followed by extinction (less habituation) than when it was sometimes followed by extinction and sometimes by a VT 30-s schedule (more habituation).[4]

The distinction between contrast that is produced by habituation and contrast that is produced by the following conditions of reinforcement can help to explain some conflicting results in the contrast literature. As argued earlier, Bloomfield (1969; see *Contrast May Be Accompanied by Changes in Reinforcer Value* above) reported that changes in reinforcer value were highly correlated with the size of contrast under conditions that produced differential habituation. Postulating a second mechanism that produces contrast helps to explain why other studies failed to find appropriate changes in reinforcer value when contrast was observed (Williams, 1991, 1992; see also Farley, 1980). For example, in the experiment by Williams (1991) described earlier, subjects responded faster during Stimulus C than during Stimulus A (contrast), but Stimulus A was preferred to Stimulus C during probe preference trials, not vice versa. As just argued, however, differential habituation to the reinforcer could not occur in this experiment. Instead, the reported contrast must have been produced by differences in the conditions of reinforcement in the following component. Therefore, the data are consistent with the idea that contrast produced by differential habituation is accompanied by appropriate changes in reinforcer value. Contrast produced by manipulating the following reinforcers might be accompanied by no change, or by the opposite change, in reinforcer value.

Postulating two different types of behavioral contrast might also explain why two different patterns of local contrast are sometimes found. As argued above (see *Local Contrast*), habituation to the reinforcer is consistent with finding that rate of responding often decreases during the richer component and increases during the leaner component of a multiple schedule. Habituation to the reinforcer is not easily compatible with the opposite pattern of results that has also been reported (e.g., Buck et al., 1975).

The factors that produce different patterns of local contrast have not been identified. Therefore, there are many possible explanations for these patterns. One potential explanation is that the first pattern of local contrast occurs when contrast is produced by differential habituation. The second pattern occurs when contrast is produced by the following conditions of reinforcement. Such an idea is highly speculative, but the present theory makes it testable. As will be argued below, the present theory specifies procedures that may be used to provide independent measures of the contrast produced by each of these mechanisms.

UNTESTED PREDICTIONS

Several untested implications of the present theory have been mentioned in preceding sections. We will close by describing only three (of many) additional predictions. To the best of our knowledge, the first two predictions are unique to the present theory.

---

[4] By identifying two mechanisms that contribute to contrast, we do not wish to argue that only two mechanisms contribute. The situation may be more complex. For example, a Pavlovian variable similar to that identified by the additive theories (e.g., Rachlin, 1973) may contribute when the operant response interacts with the Pavlovian response supported by the discriminative stimulus and reinforcer. However, consideration of other contributing variables is beyond the scope of this paper.

Experiments should employ appropriate procedures to test these predictions. Parameters should be selected to produce differential habituation during the baseline and contrast phases (e.g., intermediate to high rates of reinforcement, intermediate to long sessions). A procedure that produces only habituation contrast should also be used. For example, many studies compare responding during baseline sessions to responding during other contrast sessions (e.g., across-sessions procedures; Reynolds, 1961). If the components of the multiple schedule alternate, as they do in most but not all (e.g., McLean & Morritt, 1994) studies, this procedure may produce both types of contrast. Contrast produced by differential habituation will be present because different rates of reinforcement are presented during baseline and contrast sessions. Contrast produced by differences in the following conditions of reinforcement will be present because the components alternate. Therefore, the changed component follows the unchanged one.

The appropriate method for testing the present theory is an across-sessions procedure with random presentation of the components. Random presentation makes the next component unpredictable and eliminates contrast produced by following reinforcers. The procedure used by Williams (1991) provides a relatively pure measure of contrast produced by the following reinforcers. The baseline and contrast conditions are presented within a single session (a within-session procedure). The baseline and contrast conditions are presented randomly so that no more habituation accumulates to the reinforcers up to the time that either one is presented. Finally, a three-component (or more) multiple schedule is used so that conditions of reinforcement can be manipulated in the component that follows the contrast component without altering conditions in the component that precedes it. The following predictions should be tested using this random-component across-sessions procedure.

Contrast Should Be Insensitive to Deprivation for the Reinforcer

Changes in deprivation do not alter habituation to food when rats are at least 18 days old (Swithers-Mulvey, Miller, & Hall, 1991). If this finding turns out to hold generally, and if contrast is produced by habituation, then manipulating deprivation for the reinforcer should have little effect on the size of contrast, at least when adult rats respond for food.

Induction May Occur at the Beginning of the Session and in Short Sessions

So far, we have related contrast to the decrease in response rate that may occur during sessions of operant conditioning (habituation to the reinforcer). We have ignored the increase in responding that sometimes occurs early in the session (e.g., McSweeney, 1992). McSweeney et al. (1996) interpreted this increase as an instance of *sensitization,* defined as an increase in responsiveness to a stimulus with its repeated presentation (e.g., Groves & Thompson, 1970). Sensitization is often observed during the first few presentations of a stimulus (Groves & Thompson, 1970).

The observation of sensitization allows the present theory to make a unique prediction. If sensitization occurs early in a session, then induction (the opposite of contrast) might be observed early in the session as well as in short sessions. Short sessions should sample only the time of early-session responding when induction is observed.

Figure 1 illustrates this prediction. It presents hypothetical changes in the effectiveness (value) of a reinforcer over the course of a 60-min session. Because a relatively low rate of reinforcement is delivered during the contrast schedule in the positive contrast graph, the effectiveness of the reinforcer changes little across the session (e.g., McSweeney, 1992). That is, little sensitization or habituation occurs. An intermediate rate of reinforcement is delivered during the baseline schedule in both graphs. Therefore responding increases somewhat early in the session (sensitization) and then decreases (habituation). A high rate of reinforcement is delivered by the contrast schedule in the negative contrast graph. The peak rate of responding is reached earlier and the within-session changes in responding are larger when reinforcers are delivered at higher rates (e.g., McSweeney, 1992).

Assuming that rate of responding changes with changes in reinforcer effectiveness, Fig-

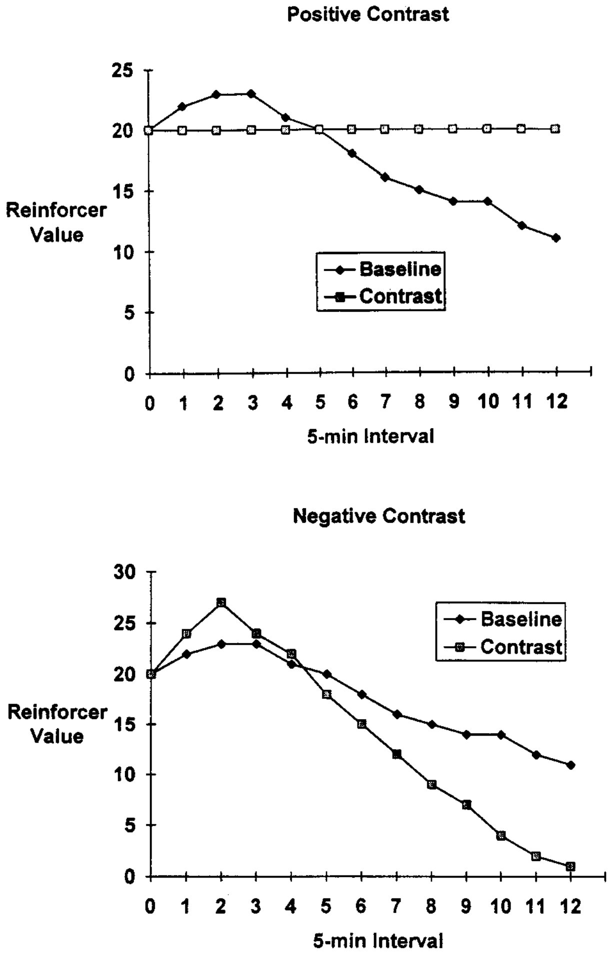

Fig. 1. Hypothetical changes in the value of a reinforcer delivered over the course of a 60-min session. Results are presented for responding during baseline (diamonds) and contrast (squares) schedules for both positive (top graph) and negative (bottom graph) contrast. In both graphs, the value of the reinforcer is arbitrarily assumed to be 20 units before any reinforcers are delivered (time 0).

ure 1 shows that induction occurs early in the session. That is, early in the session, responding should be faster during baseline than during the contrast condition in the positive contrast condition, and responding should be faster during the contrast condition than during the baseline condition in the negative contrast condition.

Contrast Should be Larger Later in the Session and in Longer Sessions

Figure 1 shows that both positive (contrast responding faster than baseline) and negative (baseline responding faster than contrast) contrast are observed later in the session. It also shows that the size of contrast increases as the session progresses. Because longer sessions sample the time of larger contrast for a longer period than do shorter sessions, contrast should also be larger in longer than in shorter sessions. By longer and shorter sessions, we mean sessions that fall within the range commonly found in the literature (i.e., 20 to 80 min). The predictions of the present theory become more complicated for longer sessions. For example, in some cases, habituation might become complete in both the baseline and contrast phases, negating the present prediction. In extremely long sessions (e.g., 24 hr), subjects might also show repeated habituation and spontaneous recovery to the reinforcer, yielding cycles of operant responding and pausing.

CONCLUSIONS

The present paper has examined the massive and often contradictory literature on multiple-schedule behavioral contrast. The review is not complete. We have not discussed the effect of varying reinforcer size, baseline rate of reinforcement, or the length of a time-out that separates the components during both the baseline and contrast sessions. The data on these topics appear to be too conflicting to support strong conclusions. However, we did review much of the literature.

We have argued that habituation to the reinforcer contributes to contrast. Positive contrast (an increase in responding) is observed when reducing the reinforcers in one component results in less overall habituation to the reinforcer. As a result, reinforcers delivered during the constant component are more valuable and support a higher rate of responding (positive contrast). Negative contrast (a decrease in responding) is observed when improving the reinforcers in one component results in more habituation. This makes the reinforcers delivered during the constant component less effective, and they support a lower rate of responding (negative contrast).

Two objections may be raised to this theory. First, it is incomplete because it cannot account for all observations of contrast. However, there is broad agreement that contrast is multiply determined (e.g., de Rose, 1986; Dougan, Farmer-Dougan, & McSweeney, 1989; Dougan et al., 1985, 1986; Hassin-Herman, Hemmes, & Brown, 1992; Williams, 1983), a view that is supported by explicit evidence. As we have argued, some evidence shows that contrast occurs in the absence of differential habituation when the conditions of reinforcement in the following component are changed. Other evidence indicates that contrast produced by differences in the following reinforcers must be supplemented by an additional process (or processes) to account for all contrast (see also Williams, 1997). A habituation-like effect is one possible candidate.

Second, the present theory may seem overly inclusive because it has mechanisms that both decrease (habituation) and increase (sensitization, dishabituation, violations of stimulus specificity, spontaneous recovery) response rate. Such a two-factor theory would necessarily be consistent with a large number of data. However, findings in the literature on habituation constrain the conditions under which response rates may increase. Increases may occur when only a few stimuli have been presented (sensitization); they may occur after the presentation of a strong, different, or extra stimulus (dishabituation), after a change in the nature of the stimulus (violations of stimulus specificity), or when the stimulus has not been presented for a time (spontaneous recovery). These constraints limit the use of response-increasing mechanisms as explanations for failures of the theory. As we have argued, the contrast literature also provides independent evidence for increases in response rates produced by spontaneous recovery, dishabituation, and violation of stimulus specificity.

Several arguments may be made in favor of the present theory. Habituation to the reinforcer is parsimonious because it accounts for contrast with only two simple assumptions. First, it assumes that habituation may occur with the repeated presentation of the reinforcer, as it does with the presentation of other stimuli. Second, it assumes that the effectiveness of a reinforcer decreases as habituation to it develops. These assumptions do not postulate any process beyond those that are compelled by other data. As we argued earlier, within-session decreases in operant responding suggest that habituation occurs to reinforcers (McSweeney et al., 1996). If habituation does not contribute to contrast, then we would have to explain why it does not when other evidence indicates that habituation is often present during the multiple schedules used to study contrast.

Habituation sometimes provides a more parsimonious explanation for reported results than do alternative theories of contrast. For example, habituation can explain why adding punishers produces contrast without postulating that reinforcers and punishers occupy opposite ends of a single continuum. Although this assumption may eventually prove to be correct, the present theory does not rely on its confirmation.

In spite of its simplicity, the present theory makes many predictions, several of which differ from those of other theories. The theory gains its empirical richness by implying that the extensive empirical findings on habituation should also be confirmed in the literature on behavioral contrast. The present review supported this idea by showing that many of the empirical characteristics of contrast are consistent with the idea that habituation contributes to contrast. Some of these characteristics only weakly support the present theory because they are also consistent with other theories of contrast. Such characteristics include the findings that changes in reinforcement produce contrast; larger changes in reinforcement produce larger contrast; the choices of instrumental response and discriminative stimuli have little effect on contrast; introducing a timeout produces contrast; contrast is observed when simple VI schedules serve as baselines; contrast occurs regardless of whether response-dependent or response-independent reinforcers are altered; and positive and negative contrast are symmetrical.

Other characteristics of contrast provide stronger support for the present theory because earlier theories of contrast (e.g., Herrnstein, 1970) either fail to predict them or predict them only with special assumptions. These predictions are that positive contrast is produced by the addition of punishers or signals for reinforcement; positive contrast is produced by changing the timing of delivery of reinforcers; contrast may be accompanied by changes in reinforcer value; contrast is not transient but does change over time; local contrast occurs; the size of contrast varies with component duration; contrast is produced by changes in qualitatively different reinforcers; and contrast is produced by a factor that is present when it is measured.

The present theory makes several unusual predictions that have yet to be tested, including predictions that changing deprivation for the reinforcer should not change the size of contrast (assuming that deprivation turns out generally to not affect habituation); induction may occur at the beginning of the session and in very short sessions; and contrast should be larger later in the session and in longer sessions of conventional length.

A few findings in the contrast literature are less consistent with the present theory. Two of these findings, that contrast may be larger in the presence of a competing response and that contrast may be accompanied by the reallocation of extraneous reinforcers, are difficult to interpret. However, more serious problems come from finding that contrast can occur under conditions that do not produce differential habituation. This implies that habituation to the reinforcer cannot account for all behavioral contrast.

Finally, the present paper has implications for within-session changes in responding. Although within-session changes have been reported in hundreds of past studies from many different laboratories (McSweeney & Roll, 1993), the changes have been treated as problems to control by procedures such as giving warm-up trials (e.g., Hodos & Bonbright, 1972) or time to adapt to the apparatus (e.g., Papini & Overmier, 1985) rather than as phenomena to study. We have argued that within-session changes deserve study in their own right. The present paper provides further justification for studying these changes. It shows that within-session changes may have theoretical implications for other behavioral phenomena (see also McSweeney, Swindell, & Weatherly, 1996b). In particular, studying within-session changes in responding may contribute to an explanation for multiple-schedule behavioral contrast.

REFERENCES

Aronson, L., Balsam, P. D., & Gibbon, J. (1993). Temporal comparator rules and responding in multiple schedules. *Animal Learning & Behavior, 21,* 293–302.

Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior, 22,* 231–242.

Beninger, R. J. (1972). Positive behavioral contrast with qualitatively different reinforcing stimuli. *Psychonomic Science, 29,* 307–308.

Beninger, R. J., & Kendall, S. B. (1975). Behavioral contrast in rats with different reinforcers and different response topographies. *Journal of the Experimental Analysis of Behavior, 24,* 267–280.

Bernheim, J. W., & Williams, D. R. (1967). Time-dependent contrast effects in a multiple schedule of food reinforcement. *Journal of the Experimental Analysis of Behavior, 10,* 243–249.

Bloomfield, T. M. (1966). Two types of behavioral contrast in discrimination learning. *Journal of the Experimental Analysis of Behavior, 9,* 155–161.

Bloomfield, T. M. (1967). Behavioral contrast and relative reinforcement frequency in two multiple schedules. *Journal of the Experimental Analysis of Behavior, 10,* 151–158.

Bloomfield, T. M. (1969). Behavioural contrast and the peak shift. In R. M. Gilbert & N. S. Sutherland (Eds.), *Animal discrimination learning* (pp. 215–241). New York: Academic Press.

Brethower, D. M., & Reynolds, G. S. (1962). A facilitative effect of punishment on unpunished behavior. *Journal of the Experimental Analysis of Behavior, 5,* 191–199.

Broster, B. S., & Rankin, C. H. (1994). Effects of changing interstimulus interval during habituation in *Caenorhabditis elegans. Behavioral Neuroscience, 108,* 1019–1029.

Brownstein, A. J., & Hughes, R. G. (1970). The role of response suppression in behavioral contrast: Signaled reinforcement. *Psychonomic Science, 18,* 50–52.

Brownstein, A. J., & Newsom, C. (1970). Behavioral contrast in multiple schedules with equal reinforcement rates. *Psychonomic Science, 18,* 25–26.

Buck, S. L., Rothstein, B., & Williams, B. A. (1975). A reexamination of local contrast in multiple schedules. *Journal of the Experimental Analysis of Behavior, 24,* 291–301.

Catania, A. C., & Reynolds, G. S. (1968). A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior, 11,* 327–383.

Charman, L., & Davison, M. (1983). On the effects of food deprivation and component reinforcer rates on multiple-schedule performance. *Journal of the Experimental Analysis of Behavior, 40,* 239–251.

Davis, M. (1970). Effects of interstimulus interval length and variability on startle-response habituation in the rat. *Journal of Comparative and Physiological Psychology, 72,* 177–192.

de Rose, J. C. C. (1986). Behavioral contrast in fixed-interval components: Effects of extinction-component duration. *Journal of the Experimental Analysis of Behavior, 45,* 175–188.

de Villiers, P. A. (1980). Toward a quantitative theory of punishment. *Journal of the Experimental Analysis of Behavior, 33,* 15–25.

Dougan, J. D., Farmer-Dougan, V. A., & McSweeney, F. K. (1989). Behavioral contrast in pigeons and rats: A comparative analysis. *Animal Learning & Behavior, 17,* 247–255.

Dougan, J. D., McSweeney, F. K., & Farmer, V. A. (1985). Some parameters of behavioral contrast and allocation of interim behavior in rats. *Journal of the Experimental Analysis of Behavior, 44,* 325–335.

Dougan, J. D., McSweeney, F. K., & Farmer-Dougan, V. A. (1986). Behavioral contrast in competitive and noncompetitive environments. *Journal of the Experimental Analysis of Behavior, 46,* 185–197.

Eisenstein, E. M., & Peretz, B. (1973). Comparative aspects of habituation in invertebrates. In H. V. S. Peeke & M. J. Herz (Eds.), *Habituation. Vol. 2. Physiological substrates* (pp. 1–31). New York: Academic Press.

Ettinger, R. H., & McSweeney, F. K. (1981). Behavioral contrast and responding during multiple food-food, food-water, and water-water schedules. *Animal Learning & Behavior, 9,* 216–222.

Ettinger, R. H., McSweeney, F. K., & Norman, W. D. (1981). Contrast and undermatching as a function of reinforcer duration and quality during multiple schedules. *Journal of the Experimental Analysis of Behavior, 35,* 271–282.

Ettinger, R. H., & Staddon, J. E. R. (1982). Behavioral competition, component duration and multiple-schedule contrast. *Behaviour Analysis Letters, 2,* 31–38.

Farley, J. (1980). Automaintenance, contrast, and contingencies: Effects of local vs. overall and prior vs. impending reinforcement context. *Learning and Motivation, 11,* 19–48.

Field, D. P., Tonneau, F., Ahearn, W., & Hineline, P. N. (1996). Preference between variable-ratio and fixed-ratio schedules: Local and extended relations. *Journal of the Experimental Analysis of Behavior, 66,* 283–295.

Freeman, B. J. (1971). The role of response-independent reinforcement in producing behavioral contrast effects in the rat. *Learning and Motivation, 2,* 138–147.

Griffin, P., & Stewart, D. J. (1977). Line-orientation generalization following signalled-reinforcer training. *Journal of the Experimental Analysis of Behavior, 27,* 151–160.

Gross, A. M., & Drabman, R. S. (1981). Behavioral contrast and behavior therapy. *Behavior Therapy, 12,* 231–246.

Groves, P. M., & Thompson, R. F. (1970). Habituation: A dual-process theory. *Psychological Review, 77,* 419–450.

Gutman, A., & Fenner, D. (1982). Signaled reinforcement, extinction, behavioral contrast, and autopecking. *The Psychological Record, 32,* 215–224.

Halliday, M. S., & Boakes, R. A. (1974). Behavioral contrast without response-rate reduction. *Journal of the Experimental Analysis of Behavior, 22,* 453–462.

Harper, D. N., & McLean, A. P. (1992). Resistance to change and the law of effect. *Journal of the Experimental Analysis of Behavior, 57,* 317–337.

Hassin-Herman, A. D., Hemmes, N. S., & Brown, B. L. (1992). Behavioral contrast: Pavlovian effects and anticipatory contrast. *Journal of the Experimental Analysis of Behavior, 57,* 159–175.

Hearst, E. (1971). Contrast and stimulus generalization following prolonged discrimination training. *Journal of the Experimental Analysis of Behavior, 15,* 355–363.

Hearst, E., Besley, S., & Farthing, G. W. (1970). Inhibition and the stimulus control of operant behavior. *Journal of the Experimental Analysis of Behavior, 14,* 373–409.

Hearst, E., & Gormley, D. (1976). Some tests of the additivity (autoshaping) theory of behavioral contrast. *Animal Learning & Behavior, 4,* 145–150.

Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior, 13,* 243–266.

Higa, J. J., & McSweeney, F. K. (1987). Behavioral contrast in rats when qualitatively different reinforcers are used. *Behavioural Processes, 15,* 131–142.

Hinde, R. A. (1970). Behavioral habituation. In G. Horn & R. A. Hinde (Eds.), *Short-term changes in neural activity and behavior* (pp. 3–40). Cambridge, England: Cambridge University Press.

Hinson, J. M., & Malone, J. C., Jr. (1980). Local contrast and maintained generalization. *Journal of the Experimental Analysis of Behavior, 34,* 263–272.

Hinson, J. M., Malone, J. C., Jr., McNally, K. A., & Rowe, D. W. (1978). Effects of component length and of the transitions among components in multiple schedules. *Journal of the Experimental Analysis of Behavior, 29,* 3–16.

Hinson, J. M., & Staddon, J. E. R. (1978). Behavioral competition: A mechanism for schedule interactions. *Science, 202,* 432–434.

Hinson, J. M., & Staddon, J. E. R. (1981). Some temporal properties of local contrast. *Behaviour Analysis Letters, 1,* 275–281.

Hodos, W., & Bonbright, J. C., Jr. (1972). The detection of visual intensity differences by pigeons. *Journal of the Experimental Analysis of Behavior, 18,* 471–479.

Howard, R. W. (1979). Behavioral contrast in a multiple schedule with topographically different responses in the components. *Journal of General Psychology, 101,* 265–270.

Hughes, R. G. (1971). Probability of signaled reinforcement in multiple variable-interval schedules. *Psychonomic Science, 22,* 57–59.

King, G. R., & McSweeney, F. K. (1987). Contrast during multiple schedules with different component response requirements. *Animal Learning & Behavior, 15,* 97–104.

Lander, D. G. (1971). Stimulus control following response reduction with signaled reinforcement. *Psychonomic Science, 23,* 365–367.

Mackintosh, N. J. (1987). Neurobiology, psychology and habituation. *Behaviour Research and Therapy, 25,* 81–97.

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

Malone, J. C., Jr. (1976). Local contrast and Pavlovian induction. *Journal of the Experimental Analysis of Behavior, 26,* 425–440.

Manabe, K. (1992). Real-time detection of orientation during negative behavioral contrast with key pecking and a turning response. *Journal of the Experimental Analysis of Behavior, 57,* 209–218.

Marcucella, H. (1976). Signalled reinforcement and multiple schedules. *Journal of the Experimental Analysis of Behavior, 26,* 199–206.

McLean, A. P. (1988). Successive independence of multiple-schedule component performances. *Journal of the Experimental Analysis of Behavior, 49,* 117–141.

McLean, A. P. (1992). Contrast and reallocation of extraneous reinforcers between multiple-schedule components. *Journal of the Experimental Analysis of Behavior, 58,* 497–511.

McLean, A. P. (1995). Contrast and reallocation of extraneous reinforcers as a function of component duration and baseline rate of reinforcement. *Journal of the Experimental Analysis of Behavior, 63,* 203–224.

McLean, A. P., & Morritt, C. F. (1994). Contrast and undermatching with regular or irregular alternation of components. *Journal of the Experimental Analysis of Behavior, 61,* 407–416.

McLean, A. P., & White, K. G. (1983). Temporal constraint on choice: Sensitivity and bias in multiple schedules. *Journal of the Experimental Analysis of Behavior, 39,* 405–426.

McSweeney, F. K. (1978). Negative behavioral contrast on multiple treadle-press schedules. *Journal of the Experimental Analysis of Behavior, 29,* 463–473.

McSweeney, F. K. (1980). Differences between rates of responding emitted during simple and multiple schedules. *Animal Learning & Behavior, 8,* 392–400.

McSweeney, F. K. (1982a). Positive and negative contrast as a function of component duration for key pecking and treadle pressing. *Journal of the Experimental Analysis of Behavior, 37,* 281–293.

McSweeney, F. K. (1982b). Responding during simple schedules and during less favorable components of multiple schedules. *Behaviour Analysis Letters, 2,* 345–351.

McSweeney, F. K. (1987). Suppression by reinforcement: A model for multiple-schedule behavioral contrast. *Behavioural Processes, 15,* 191–209.

McSweeney, F. K. (1992). Rate of reinforcement and session duration as determinants of within-session patterns of responding. *Animal Learning & Behavior, 20,* 160–169.

McSweeney, F. K., & Dericco, D. A. (1976). Rates of responding in the pigeon generated by simple and complex schedules which provide the same rates of reinforcement. *Animal Learning & Behavior, 4,* 379–385.

McSweeney, F. K., Dougan, J. D., & Farmer, V. A. (1986a). Simple and multiple schedule responding and behavioral contrast when pigeons press treadles. *Behavioural Processes, 12,* 273–285.

McSweeney, F. K., Dougan, J. D., & Farmer, V. A. (1986b). Simple schedule and signal-key multiple schedule responding and behavioral contrast. *Bulletin of the Psychonomic Society, 24,* 89–90.

McSweeney, F. K., Dougan, J. D., Higa, J., & Farmer, V. A. (1986). Behavioral contrast as a function of component duration and baseline rate of reinforcement. *Animal Learning & Behavior, 14,* 173–183.

McSweeney, F. K., Hinson, J. M., & Cannon, C. B. (1996). Sensitization-habituation may occur during operant conditioning. *Psychological Bulletin, 120,* 256–271.

McSweeney, F. K., & Johnson, K. S. (1994). The effect of time between sessions on within-session patterns of responding. *Behavioural Processes, 31,* 207–218.

McSweeney, F. K., & Melville, C. L. (1988). Positive contrast as a function of component duration using a within-session procedure. *Behavioural Processes, 16,* 21–41.

McSweeney, F. K., & Melville, C. L. (1991). Behavioral contrast as a function of component duration for leverpressing using a within-session procedure. *Animal Learning & Behavior, 19,* 71–80.

McSweeney, F. K., Melville, C. L., & Higa, J. (1988). Positive behavioral contrast across food and alcohol reinforcers. *Journal of the Experimental Analysis of Behavior, 50,* 469–481.

McSweeney, F. K., & Norman, W. D. (1979). Defining behavioral contrast for multiple schedules. *Journal of the Experimental Analysis of Behavior, 32,* 457–461.

McSweeney, F. K., & Roll, J. M. (1993). Responding changes systematically within sessions during conditioning procedures. *Journal of the Experimental Analysis of Behavior, 60,* 621–640.

McSweeney, F. K., & Roll, J. M. (in press). Do animals satiate or habituate to repeatedly-presented reinforcers? *Psychonomic Bulletin & Review.*

McSweeney, F. K., Roll, J. M., & Weatherly, J. N. (1994). Within-session changes in responding during several simple schedules. *Journal of the Experimental Analysis of Behavior, 62,* 109–132.

McSweeney, F. K., Swindell, S., & Weatherly, J. N. (1996a). Within-session changes in adjunctive and instrumental responding. *Learning and Motivation, 27,* 408–427.

McSweeney, F. K., Swindell, S., & Weatherly, J. N. (1996b). Within-session changes in responding during concurrent schedules with different reinforcers in the components. *Journal of the Experimental Analysis of Behavior, 66,* 369–390.

McSweeney, F. K., Weatherly, J. N., & Swindell, S. (1995). Prospective factors contribute little to within-session changes in responding. *Psychonomic Bulletin & Review, 2,* 234–238.

McSweeney, F. K., Weatherly, J. N., & Swindell, S. (1996a). Reinforcer value may change within experimental sessions. *Psychonomic Bulletin & Review, 3,* 372–375.

McSweeney, F. K., Weatherly, J. N., & Swindell, S. (1996b). Within-session changes in responding during delayed matching-to-sample and discrimination procedures. *Animal Learning & Behavior, 24,* 290–299.

Melville, C. L., Rue, H. C., Rybiski, L. R., & Weatherly, J. N. (1997). Altering reinforcer variety or intensity changes the within-session decrease in responding. *Learning and Motivation, 28,* 609–621.

Miller, H. L., Jr. (1976). Matching-based hedonic scaling in the pigeon. *Journal of the Experimental Analysis of Behavior, 26,* 335–347.

Nevin, J. A. (1974). Response strength in multiple schedules. *Journal of the Experimental Analysis of Behavior, 21,* 389–408.

Nevin, J. A., Mandell, C., & Atak, J. R. (1983). The analysis of behavioral momentum. *Journal of the Experimental Analysis of Behavior, 39,* 49–59.

Nevin, J. A., & Shettleworth, S. J. (1966). An analysis of contrast effects in multiple schedules. *Journal of the Experimental Analysis of Behavior, 9,* 305–315.

Papini, M. R., & Overmier, J. B. (1985). Partial reinforcement and autoshaping of the pigeon's key-peck behavior. *Learning and Motivation, 16,* 109–123.

Pear, J. J., & Wilkie, D. M. (1971). Contrast and induction in rats on multiple schedules. *Journal of the Experimental Analysis of Behavior, 15,* 289–296.

Pinsker, H., Kupfermann, I., Castellucci, V., & Kandel, E. (1970). Habituation and dishabituation of the gill-withdrawal reflex in *Aplysia. Science, 167,* 1740–1742.

Premack, D. (1969). On some boundary conditions of contrast. In J. Tapp. (Ed.), *Reinforcement and behavior* (pp. 120–144). New York: Academic Press.

Rachlin, H. (1966). Recovery of responses during mild punishment. *Journal of the Experimental Analysis of Behavior, 9,* 251–263.

Rachlin, H. (1973). Contrast and matching. *Psychological Review, 80,* 217–234.

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

Reynolds, G. S. (1963). Some limitations on behavioral contrast and induction during successive discrimination. *Journal of the Experimental Analysis of Behavior, 6,* 131–139.

Reynolds, G. S., & Limpo, A. J. (1968). On some causes of behavioral contrast. *Journal of the Experimental Analysis of Behavior, 11,* 543–547.

Sadowsky, S. (1973). Behavioral contrast with timeout, blackout, or extinction as the negative condition. *Journal of the Experimental Analysis of Behavior, 19,* 499–507.

Schwartz, B. (1975). Discriminative stimulus location as a determinant of positive and negative behavioral contrast in the pigeon. *Journal of the Experimental Analysis of Behavior, 23,* 167–176.

Scull, J., & Westbrook, R. F. (1973). Interactions in multiple schedules with different responses in each of the components. *Journal of the Experimental Analysis of Behavior, 20,* 511–519.

Selekman, W. (1973). Behavioral contrast and inhibitory stimulus control as related to extended training. *Journal of the Experimental Analysis of Behavior, 20,* 245–252.

Sokolov, Y. N. (1963). *Perception and the conditioned reflex.* (S. W. Waydenfeld Trans.). Oxford, England: Permagon Press.

Solomon, R. L., & Corbit, J. D. (1974). An opponent-process theory of motivation: I. Temporal dynamics of affect. *Psychological Review, 81,* 119–145.

Spealman, R. D. (1976). Interactions in multiple schedules: The role of the stimulus-reinforcer contingency. *Journal of the Experimental Analysis of Behavior, 26,* 79–93.

Spealman, R. D., & Gollub, L. R. (1974). Behavioral interactions in multiple variable-interval schedules. *Journal of the Experimental Analysis of Behavior, 22,* 471–481.

Swithers, S. E., & Hall, W. G. (1994). Does oral experience terminate ingestion? *Appetite, 23,* 113–138.

Swithers-Mulvey, S. E., Miller, G. L., & Hall, W. G. (1991). Habituation of oromotor responding to oral infusions in rat pups. *Appetite, 17,* 55–67.

Taus, S. E., & Hearst, E. (1970). Effects of intertrial (blackout) duration on response rate to a positive stimulus. *Psychonomic Science, 19,* 265–267.

Terrace, H. S. (1966). Behavioral contrast and the peak shift: Effects of extended discrimination training. *Journal of the Experimental Analysis of Behavior, 9,* 613–617.

Terrace, H. S. (1968). Discrimination learning, the peak shift, and behavioral contrast. *Journal of the Experimental Analysis of Behavior, 11,* 727–741.

Thompson, R. F., & Spencer, W. A. (1966). Habituation: A model phenomenon for the study of neuronal substrates of behavior. *Psychological Review, 73,* 16–43.

Thorpe, W. H. (1966). *Learning and instinct in animals.* Cambridge, MA: Harvard University Press.

Vieth, A., & Rilling, M. (1972). Comparison of time-out and extinction as determinants of behavioral contrast: An analysis of sequential effects. *Psychonomic Science, 27,* 281–282.

Wagner, A. R. (1976). Priming in STM: An information-processing mechanism for self-generated or retrieval-generated depression in performance. In T. J. Tighe & R. N. Leaton (Eds.), *Habituation: Perspectives from child development, animal behavior and neurophysiology* (pp. 95–128). New York: Wiley.

Weatherly, J. N., McSweeney, F. K., & Swindell, S. (1995). On the contributions of responding and reinforcement to within-session patterns of responding. *Learning and Motivation, 26,* 421–432.

White, K. G. (1995). Action at a temporal distance: Component transition as the relational basis for successive discrimination. *Journal of the Experimental Analysis of Behavior, 64,* 185–213.

White, K. G., Pipe, M., & McLean, A. P. (1984). Stimulus and reinforcer relativity in multiple schedules: Local and dimensional effects on sensitivity to reinforcement. *Journal of the Experimental Analysis of Behavior, 41,* 69–81.

White, K. G., Pipe, M.-E., McLean, A. P., & Redman, S. (1985). Temporal proximity and reinforcement sensitivity in multiple schedules. *Journal of the Experimental Analysis of Behavior, 44,* 207–215.

Wilkie, D. M. (1972). Variable-time reinforcement in multiple and concurrent schedules. *Journal of the Experimental Analysis of Behavior, 17,* 59–66.

Wilkie, D. M. (1973). Signalled reinforcement in multi-