Effortful responding and behavioral contrast

Georgann Zachary

The University of Montana

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EFFORTFUL RESPONDING AND
BEHAVIORAL CONTRAST

by

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An experiment was conducted in which wheel-running behavior of rats under different effort requirements and schedules of reinforcement was investigated. It was hypothesized that behavioral contrast could be obtained using a wheel-running response and that an increase in effort would result in a change in the level of contrast present. Two computer automated running wheels attached with two tunnels and a central choice chamber were used. Effort was defined as the tangential force required to turn the wheel. Low effort was 20g and high effort was 80g. Results indicated there was significantly less distance run for the high effort group as compared with the low effort group. Negative behavioral contrast was in evidence but not positive behavioral contrast. These results are inconsistent with traditional free-operant responding and suggest a response/species interpretation for behavioral contrast must be considered.
# TABLE OF CONTENTS

ABSTRACT .............................................................. ii

LIST OF TABLES ................................................... iv

INTRODUCTION ......................................................... 1

  Additivity Theory .................................................. 6
  Competition Theory ............................................... 8
  Matching Law ...................................................... 10
  Suppression Theory ............................................... 11
  Species Differences ............................................. 13

CURRENT STUDY ................................................... 14

METHOD ................................................................. 14

  Subjects ............................................................ 14
  Apparatus .......................................................... 15
  Procedure .......................................................... 15

RESULTS ................................................................. 17

DISCUSSION .......................................................... 18

REFERENCES ......................................................... 27
LIST OF TABLES

1. Order of Presentation of Schedule Components ........................................... 16
2. Mean Run Distance (m) as a Function of Phase and Effort Level ..................... 18
When a subject is responding in an operant situation, behavior can and will change as a function of changing reinforcement rates. The level of operant behavior that a given rate of reinforcement will maintain in a situation is usually affected by the amount of reinforcement obtained in other situations. When a subject’s performance, maintained by one condition of reinforcement, is affected by exposure to another, it is suggested that the subject has somehow discriminated between the conditions of reinforcement and altered its performance based on that discrimination. If performance significantly exceeds or is significantly lower than a baseline condition, this observed change in performance is called contrast. Contrast can occur based on a shift from a large magnitude of reinforcement to a small magnitude of reinforcement or visa versa (Crespi, 1942). Crespi termed the increase in running speed exhibited by rats who experienced a sudden increase in their magnitude of reinforcement an “elation effect”. He termed the decrease in running speed of rats who experienced a sudden decrease in their magnitude of reinforcement a “depression effect”. These shifts in performance were later renamed positive and negative contrast effects, respectively. Although contrast effects do not usually persist indefinitely in this situation, they do not depend upon a purely transient after-effect of exposure to one condition of reinforcement. The necessary and sufficient conditions for contrast have not been fully defined. The best generalization is that contrast results from changes in relative reinforcement (Hinson & Staddon, 1978).

Reynolds (1961) observed that a change in behavior during the presentation of one stimulus, as a consequence of changing the schedule associated with a different stimulus, resulted in an interaction. The change in behavior is called contrast when the change in
the rate of responding during the presentation of one stimulus is in a direction away from
the rate of responding generated during the presentation of the other stimulus. Reynolds
termed this change in responding “behavioral contrast”. The term refers to an inverse
relationship between the rate of responding in one component of a concurrent schedule
(when two schedules are simultaneously available) or a multiple schedule (when
schedules are successively alternated) and the conditions of reinforcement in the other
component. Positive behavioral contrast is an increase in first-component responding
with a decrease in second-component reinforcement. Negative behavioral contrast is a
decrease in first-component responding with improvements in second-component
reinforcers (McSweeney & Norman, 1979). Free-operant studies of simultaneous
contrast employing pigeons pecking keys have routinely observed large and reliable
positive and negative contrast effects.

Many factors have a demonstrated influence on behavioral contrast including
relative rate of reinforcement between S+ and S- (Bloomfield, 1967; Dougan et al. 1985;
McSweeney, 1975; Williams, 1983; Williams & Wixted, 1986), decline in response rate
to S- (Flaherty, Clancy, & Kaplan, 1981; Halliday & Boakes, 1971; 1974), duration of
each component of the multiple schedule (Dougan et al. 1985, McSweeney, 1983;
McSweeney, 1982; Williams, 1989), difficulty of discrimination (Bloomfield, 1967;
Blough, 1983; Williams, 1989), discrimination of nonreinforced periods (Marcucella,
1976; Wilkie, 1977; Williams, 1989), stimulus location (Bouzas & Baum, 1976; Farthing,
1975; Hanson & Green, 1986; Hemmes, 1973; Hinson & Higa, 1989; Westbrook, 1973),
response type (Dougan et al. 1989; Hemmes, 1973; King & McSweeney, 1987;

Behavioral contrast tends to be greater when the difference in reinforcement density between S+ and S- is greater (Bloomfield, 1967; McSweeney, 1975). This effect is analogous to reward magnitude effects in simple instrumental contrast. The degree of contrast is a function of relative reinforcement rate in the unchanged component: the greater the relative reinforcement rate, as compared to the alternative schedule, the greater the contrast (Williams, 1983).

Studies have shown that a decline in response rate is neither a necessary nor sufficient condition for the occurrence of contrast in S+ (Flaherty, Clancy, & Kaplan, 1981; Halliday & Boakes, 1971). Halliday & Boakes (1971) trained pigeons on a VI 1-minute VI 1-minute schedule then shifted one schedule to a VT 1-minute (reinforcement is not contingent upon a response). Responding decreased on the VT schedule but there was no corresponding increase on the VI schedule, hence no behavioral contrast. Halliday & Boakes (1974) demonstrated that behavioral contrast could be obtained without a decline in responding to S-. Contrast was produced by a decline in reinforcement frequency without a decline in response rate.

Contrast is greater when component duration is short and the two schedules alternate rapidly and often (McSweeney, 1982); the absolute size of positive and negative behavioral contrast varied inversely with component when key pecks produced the reinforcer. This effect was hypothesized to occur because the subject had
an enhanced opportunity to compare the two reinforcement schedules. Williams (1989) hypothesized that contrast effects varied inversely with the component duration of the target component but contrast effects were smaller the shorter the alternative component duration.

Contrast seems to be greater when the discrimination is difficult for the animal (Bloomfield, 1972; Blough, 1983). This may be because similar stimuli enhance the degree of comparison of one reward schedule to another. Marcucella (1976) and Wilkie (1977) proposed that the critical variable in behavioral contrast was the occurrence of discriminated periods of nonreinforcement. Wilkie changed a multiple VI VI to a multiple VI FI, and a multiple VI VT to a multiple VI FT, so that the FI and the FT schedules provided equivalent average reinforcement rates to the VI VT schedules that preceded them. The result in both cases was a substantial contrast effect in the unchanged VI component. Williams (1976) has provided strong evidence against this controlling variable. Subjects trained on a VI VI schedule with alternating 90 second components were shifted to a VI FI schedule, such that one reinforcer was delivered during each 90 second component. Results showed no consistent contrast effects in responding to the unchanged component. Further evidence against this proposed controlling variable comes from the recognition that contrast does not always occur when signaled reinforcement is employed (Griffin & Stewart, 1977; Gutman & Fenner, 1982; Williams, 1980).

Although several studies (Redford & Perkins, 1974; Schwartz, 1974; 1975) have failed to find contrast when the discriminative stimuli were located off the response key
(a house light or tone), this generalization is not without conflicting evidence. Contrast studies with rats provides one major source of conflicting evidence since all of them used discriminative stimuli located off the response lever with bar pressing being the typical response, and either a house light or tone was the discriminative stimulus (Bouzas & Baum 1976; Farthing, 1975; Hemmes, 1973; Westbrook, 1973). Given that behavioral contrast was found in these studies implies that stimulus location is not a crucial variable in behavioral contrast.

Response type was believed to be a controlling variable in behavioral contrast because early research demonstrated contrast only when the operant response is the same as the consummatory response associated with the reinforcer (Hemmes, 1973; Westbrook, 1973). More recent studies substituting treadle-pressing for keypecking have provided evidence against this generalization (Davison & Ferguson, 1978; McSweeney, 1983). Robust contrast effects do occur with bar pressing, and there is no reason to believe that it is any different from treadle pressing in pigeons (Williams, 1983).

Transitions from S- to S+ signal the associated schedule of reinforcement. Is the elevated responding that occurs in S+ due to a comparison with the preceding S- period? Rachlin (1973) indicated that the transitions from S- to S+ may be an important locus of one aspect of contrast. Williams (1981) indicates quite strongly that it is the following S- period, not the preceding S- period, that is the major contributor to contrast. Williams (1983) reported that responding in the first component was more effected by changes in the middle component than was responding in the third component. These results support earlier research (Bacotti, 1976; Farley, 1980).
Behavioral contrast has been observed when subjects respond during both concurrent and multiple schedules (McSweeney, 1975; Reynolds, 1961). Herrnstein (1970) suggests that all schedule effects may be accounted for by a coherent system of equations which state that the absolute rate of any response is proportional to its associated relative reinforcement. Others attribute behavioral contrast in concurrent and multiple schedules to qualitatively different mechanisms (Rachlin, 1973). Theories of schedule performance would be simplified if similar factors governed behavior on the two schedules. Some data suggest that multiple-schedule contrast is more difficult to produce than concurrent-schedule contrast (McSweeney, 1975; 1978), but these comparisons are made across studies. The two types of contrast were examined in the same study with McSweeney et al. (1988). Contrast was reported consistently for concurrent schedules but not for multiple schedules.

The following is an examination of the proposed theories that have been postulated in order to explain behavioral contrast. The major theoretical explanations of behavioral contrast include: additivity theory, competition theory, matching theory, and the suppression by reinforcement theory (inhibition theory).

The Additivity Theory of Behavioral Contrast

Additivity theory implies that contrast in multiple schedules has little to do with contrast and matching in concurrent schedules because contrast in multiple schedules is mediated entirely by stimulus-reinforcer contingencies. The additive theories proposed by Gamzu and Schwartz (1973), Hearst and Jenkins (1974), and Rachlin (1973) differ
minimally in specific details but all state that contrast only occurs when at least two processes or variables interact. One variable, the response-reinforcer relationship, controls a type of responding that is called instrumental responding. Another variable, the stimulus-reinforcer relationship controls a type of responding called additive responding. According to all three theories, positive contrast occurs when responses controlled by the stimulus-reinforcer relationship facilitate or add to the responses controlled by response-reinforcer relationship. According to Hearst & Jenkins (1974) and Rachlin (1973), negative contrast occurs when responses controlled by the stimulus-reinforcer relationship interfere with or subtract from responses controlled by the response-reinforcer relationship. Contrast does not occur if one of the relationships is absent or if they both occur but do not interact. The three accounts do have differences and are labeled accordingly as the weak, moderate, and strong versions of additivity. A weak version of additivity theory distinguishes between additive and instrumental responses on the basis of the environmental relationships that control them. Positive contrast occurs when both environmental relationships are present and their effects on behavior sum. Negative contrast occurs when both are present and their effects at least partially cancel. No contrast occurs if only one relationship is present or if both are present but do not interact. Only the weak version of the theory is currently testable. To test the weak version of additivity theory each relationship would have to be independently established, but test results have been ambiguous (Bradshaw, Szabadi, and Bevan, 1978; Hearst and Gormley, 1976; McSweeney, Ettinger, and Norman, 1981). Williams (1983) stated that given the formal problems faced by the additivity theory, and
the lack of any definitive evidence in its favor, it seems time to abandon it in favor of more promising alternatives.

The moderate version of the additive theory attributes additive and instrumental responses to fundamentally different theoretical mechanisms, usually operant and classical conditioning. The question of whether operant and classical conditioning are different forms of control over responding has not be satisfactory answered so this version of the theory cannot be tested (Hearst & Jenkins, 1974; Williams, 1990; 1992).

The strong version of the theory would be easiest to test if one could distinguish between additive and instrumental responses based on their physical characteristics. Schwartz (1977) attempted to distinguish these responses on the basis of their duration with additive responses having a duration shorter than 30 msec and instrumental responses longer than 40 msec. However, these duration differences have not been supported in subsequent experiments (Moore, 1973; Williams, 1983; Woodruff et. al. 1977).

**Competition Theory of Behavioral Contrast**

Hinson and Staddon (1978) observed that the magnitude of behavioral contrast increased when an alternative to operant responding was made available. Rats' food-reinforced responding on a multiple schedule showed more contrast when a wheel-running response was available than when it was not. According to the competition theory of behavioral contrast (Ettinger and Staddon, 1982; Hinson and Staddon, 1978; Staddon, 1982), contrast results from reduced competition between operant responding
and alternative (interim) responding in the contrast component. When the rate of reinforcement in the changed component is reduced, interim responses are re-allocated to that component, making them less competitive with the instrumental responding in the other, constant component. Additional support for the competition theory of behavioral contrast comes from White (1978), who argues that contrast is due to an increase in time allocation to the operant response, rather than an increase in the actual rate of response. King & McSweeney (1987) studied multiple schedule contrast with topographically different response requirements and their results were partially consistent with the competition theory of behavioral contrast. Three major criticisms have been levered against the competition theory of contrast. First, attempts to replicate contrast with other interim responses (licking) have failed to produce contrast, suggesting competition theory is an insufficient model (Dougan and Eacker, 1982; Dougan et al., 1985; Jacquet, 1972). Second, Hinson and Staddon's (1978) two groups, one with the running wheel available and the other without the running wheel, differed not only in the occurrence of contrast, but also in the degree of discrimination that was achieved. Rather than merely offering a competing response, the running wheel may have increased discrimination, which is strongly associated with contrast. Finally, Hinson and Staddon (1978) used rats as subjects which have not been shown to produce contrast effects as consistently as pigeons. If contrast is conceptually dissimilar for rats and pigeons, than the generality of Hinson and Staddon's results is called into question.
Matching Law Explanation of Behavioral Contrast

Herrnstein (1970) focused on the context of reinforcement and stated that the relative rate of reinforcement determines behavior in simple schedules, multiple schedules, and concurrent schedules. In fact, with very short components in the multiple schedule, the context of reinforcement becomes functionally equivalent to a concurrent schedule (Herrnstein & Loveland, 1974; Nevin, 1974; Shimp & Wheatley, 1971). Herrnstein amended matching law to change the context of reinforcement to represent the average rate of reinforcement in the situation, rather than the sum of reinforcement rates. Matching law has been extended to situations in which qualitatively different reinforcers are delivered from two alternatives (Hollard & Davison, 1971; Miller, 1976). In virtually all of the research conducted on matching, the responses required to produce reinforcement have been topographically the same as the alternatives. Hanson & Green (1986) demonstrated that the matching law can also account for choice behavior involving topographically different responses. This is important given that in more naturalistic settings an organism must often allocate its behavior between rather different responses, such as scratching and pecking. Matching law predicts that increases in reinforcement from unscheduled sources will decrease the magnitude of contrast. However, the addition of an alternative source of reinforcement can increase the magnitude of contrast (Dougan et al., 1986; Hinson & Staddon, 1978).

The derivation of the matching law requires that an assumption be made concerning the control of behavior (Timberlake, 1982). Herrnstein (1970) predicted that changes in component duration would change the magnitude of contrast but he had to add
a parameter (m) which Timberlake suggested was not a critical component of the theory. Studies failing to show a component-duration effect still support the matching law interpretation of contrast with an increased responding in the changed component and no decrease of responding in the constant component (Dougal et al., 1985).

Inhibition by Reinforcement (Suppression) Theory of Behavioral Contrast

According to Catania (1973), responding maintained by a simple VI schedule is controlled by two separate effects, an excitatory effect, which is directly proportional to the rate of reinforcement and an inhibitory effect, which also increases with rate of reinforcement. The excitatory effect is given in an equation that states the given frequency of a response is equal to the product of the units of reinforcer/time by reinforcement \( f(E) = KR \). The inhibitory effect is given by the equation that states the frequency of inhibition is equal to the inverse of all sources of reinforcement in the given situation divided by units of reinforcer over time \( f(I) = 1/(1+\Sigma R/C) \). The two effects are assumed to interact multiplicatively to determine the actual response rate. Catania’s (1973) analysis may be extended to multiple schedules by the additional assumption that the inhibitory effects of reinforcement are proportional to the average rate of reinforcement in the situation, not just the reinforcement occurring during a particular component of the multiple schedule. This theory is supported by McSweeney et al. (1986) who found that positive and negative contrast generally increase with increases in the baseline rates of reinforcement when pigeons pecked keys. McSweeney (1987) argues that multiple-schedule behavioral contrast occurs because delayed reinforcers
suppress behavior. Some reinforcers delivered in the second component of a multiple schedule suppress responding during the first component because they follow that responding after a delay. Removing second-component reinforcers removes suppression from the first component and response rates rise, creating positive contrast. Adding second-component reinforcers adds suppression and response rates fall, creating negative contrast. Negative contrast has been reported following delays in reward (Maxwell et al., 1976; Shanab, Domino, and Melrose, 1977).

While numerous theories have been proposed to account for behavioral contrast, none seems to provide a generally accepted explanation of behavioral contrast. These theoretical failures may be a result of attempts to explain behavioral contrast in terms of a single causal factor. It is possible that contrast is controlled by several factors including one or more of the theories presented. At the very least, a multidimensional theory of behavioral contrast seems necessary. In support of this idea, Dougan, McSweeney, and Farmer (1985) have shown that competition theory and matching theory may both be correct, depending on the situation. The effects of baseline reinforcement rate and component duration on contrast behavior and re-allocation of interim behavior in rats had results consistent with the theory of contrast based on matching law but matching law failed to provide a general model for contrast. They hypothesized that a general model might be more obtainable using a behavioral competition theory if there is a consistent decrease in interim behavior in the presence of the constant component.
Species Differences in Behavioral Contrast

Finally, the importance of species differences in relation to contrast must be discussed. Extant research suggests that behavioral contrast in rats may be a different phenomenon from behavioral contrast in pigeons when the same variables are manipulated in a standard contrast paradigm (Dougan et al., 1985; 1986; Reynolds, 1963; Spealman & Gollub, 1974). The existence of reliable contrast only at high reinforcement rates explains why some researchers have argued that contrast does not reliably occur in rats, which typically have much lower reinforcement rates than pigeons (Rachlin, 1973; Schwartz & Gamzu, 1977). If contrast is the same phenomenon in both species, then any observed differences must be due to some uncontrolled variables changed across the test conditions for the two species. Conversely, observed species differences in contrast may actually indicate a completely different phenomenon in rats and pigeons. Dougan et al. (1989) demonstrated that discrimination was relatively poor in rats and relatively good in pigeons and that keen discrimination is commonly assumed to be necessary for contrast to occur (Terrace, 1968; Williams, 1983). Differences in discrimination may explain why contrast was more reliable in pigeons than in rats. Rat levers, pigeon keys, and pigeon treadles have not been shown to be equivalent as response manipulanda or that a 45 mg Noyes pellet is equivalent to 4 seconds of access to grain as a reinforcer. Hemmes (1973) and Westbrook (1973) have reported that when pigeons are required to press a lever rather than peck a key, the development of a discrimination is not accompanied by any increase in rate of responding to the first stimulus. The strong version of the additivity theory does predict for species differences (McSweeney et al., 1981). This version
predicts that contrast will occur when operant and Pavlovian responses have similar topographies, because rats are less likely to press bars during Pavlovian training they would be less likely to show contrast.

The above studies have dealt with pigeons pecking keys or pushing treadles and rats pressing bars, all which are discrete responses that require little effort or low caloric expenditure. Can behavioral contrast be obtained using a complex and more effortful behavior? If so, would the topography of the contrast remain comparable to traditional behavioral contrast? The following experiment examined behavioral contrast using a running wheel preparation in which the effortfulness of the response was varied.

The running wheel allows for continuous responding and, like a treadlepress or barpress, the effort level can be varied. Effort levels in the running can be manipulated by adjusting the amount of tangential force required to turn the wheel. The running response is a full body response requiring more caloric expenditure than a simple response and running can be measured in terms of speed to estimate the subjects level of responding. This is a unique approach to examining behavioral contrast because running has not been used as a primary response. The only other behavioral contrast study to include running was conducted by Hinson & Staddon (1987) in which a running wheel was provided as an interim responding option.

METHOD

Subjects

Twelve male Sprague-Dawley rats, approximately 70 days of age upon arrival,
served as subjects. The subjects were housed in groups of four and maintained on a 12:12 light-dark cycle with ad-libitum access to food and water in their home cages during the first week, and thereafter maintained at 85% of their pre-deprivation weight.

**Apparatus**

Two modified Wahman running wheels, each 36 cm in diameter, were connected by a choice chamber made of plexiglass measuring 23 cm X 23 cm X 30 cm. Two 8 X 12 cm PVC tunnels joined the choice chamber to each wheel. Attached to the front wall of the choice chamber, located equi-distant from both wheels, a feeder cup was mounted for reinforcement delivery. The entire apparatus was housed in a sound-attenuated chamber with exhaust fans to provide ventilation and masking noise. The chamber was illuminated by a single house light. Each wheel was modified to allow computer monitoring of wheel rotation (Haddad et al., 1994; Petree, Haddad, & Berger, 1992; Szalda-Petree et al., 1994). Additionally, each wheel was equipped with a tension bar to control the tangential force required to turn the wheel.

**Procedure**

**Shaping**

The subjects were gradually exposed to the apparatus. During the first phase of the exposure the subjects were placed in the choice chamber, without access to the two tunnels, and received magazine training (45 mg Noyes pellets delivered) on a VT 1 minute schedule. The next phase of shaping increased the exposure by opening one tunnel/wheel and using a FR 56 cm schedule to deliver reinforcement. The tunnel and
wheel made available was alternated daily until reliable running was achieved for each wheel. The final phase of shaping allowed the subject access to both tunnels and wheels simultaneously, with each wheel delivering reinforcement using concurrent FR 56 cm schedules.

Subjects were then randomly assigned to two groups based on grams of tangential force, 20 or 80 grams, required to turn the running wheel. Both groups received the same schedule configurations and order of shifts (see table 1).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Order of Presentation of Schedule Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI 2 min</td>
<td>VI 2 min</td>
</tr>
<tr>
<td>VI 2 min</td>
<td>VI 15 sec</td>
</tr>
<tr>
<td>VI 2 min</td>
<td>VI 5 min</td>
</tr>
<tr>
<td>VI 2 min</td>
<td>VI 2 min</td>
</tr>
</tbody>
</table>

To avoid any possibility of a wheel bias, the schedules were pseudo-randomized, such that no single wheel was associated with a given schedule of reinforcement for more than two consecutive daily sessions. Daily sessions were 45 minutes in duration. Each phase continued until stable running distances were achieved. Stable running distances were defined as no upward or downward trend in running speeds across three consecutive days.
RESULTS

A oneway ANOVA was conducted on distance run for the three baseline phases and revealed no significant differences ($E(2,20) = .96, p < .400$). As such, the three baseline phases were collapsed for the remaining analyses. A 2 (effort) by 3 (phase) split plot ANOVA was conducted on distance run for the unchanged schedule component and revealed a main effect for effort ($E(1,11) = 8.72, p < .014$), a main effect for phase ($E(2,20) = 37.83, p < .000$), and an effort by phase interaction ($E(2,20) = 7.13, p < .005$).

Multiple comparisons tests (Tukey HSD at the .05 alpha level) revealed significantly less distance run for the low effort group in the negative phase compared with the baseline phase, indicating a negative contrast effect. There was no significant difference in distance run between the positive phase and the baseline or the negative phase, indicating no positive contrast effect. The results for the high effort group were identical to the low effort group. There was significantly less distance run in the negative phase compared with the baseline phase, indicating a negative contrast effect and there was no significant difference in distance run between the positive phase and the baseline or negative phase, indicating no positive contrast effect. In all phases of the experiment there was significantly more distance run by the low effort group compared to the high effort group (see table 2).
Table 2  
Mean Run Distance (m) as a Function of Phase and Effort Level

<table>
<thead>
<tr>
<th>Effort Level (g)</th>
<th>Baseline (VI2:VI2)</th>
<th>Negative (VI2:VI .25)</th>
<th>Positive (VI2:VI5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 (n=6)</td>
<td>284.82 (38.22)</td>
<td>140.23 (16.23)</td>
<td>320.27 (42.79)</td>
</tr>
<tr>
<td>80 (n=6)</td>
<td>168.78 (31.55)</td>
<td>77.52 (11.17)</td>
<td>138.32 (21.78)</td>
</tr>
</tbody>
</table>

Note. SEM in parentheses.

DISCUSSION

The present results demonstrate a strong negative contrast effect while showing no positive contrast. Additionally, while the effort manipulation resulted in lowered response rates, no differences in the type or degree of contrast effects were revealed between the two effort levels. The current results are partially consistent with the typical findings of behavioral contrast. Traditionally, both positive and negative behavioral contrast are readily apparent in a free-operant preparation using pigeons keypecking (Gamzu & Schwartz, 1973; Hemmes, 1973; Hearst & Jenkins, 1974; McSweeney, 1978; Rachlin, 1973; Westbrook, 1973; Williams, 1997; Williams & Wixted, 1986). While traditionally pigeons were thought to be the only species that could exhibit behavioral
contrast, the current results lend support to the growing body of research that has reported behavioral contrast effects in rats (Beninger, 1972; Blough, 1980; Dickinson, 1972; Dougan et al., 1985; Flaherty, Clancy, & Kaplan, 1981; Mackintosh et al., 1972; McHose & Moore, 1978; Williams, 1992) and with other species including humans (Rovee-Collier & Capatides, 1979; Tinklepaugh, 1928; Waite & Osborne, 1972; Williams, 1983).

The current results are only marginally consistent with extant explanations of behavioral contrast. Additivity theory of behavioral contrast postulates that contrast only occurs when at least two processes or variables interact. These variables are divided into two classes of responding, instrumental responding based on a response-reinforcer relationship, and additive responding based on a stimulus-reinforcer relationship. Positive behavioral contrast is the result of these two types of responding facilitating or adding to one another and negative behavioral contrast results when these two types of responding interfere with or subtract from each other. Contrast does not occur if one type of responding is absent or they both occur but do not interact. Support for the additivity theory comes primarily from studies in which the operant response is the same as the consummatory response, such as pigeons pecking keys (Williams, 1983). Studies which oppose the additivity theory include studies where rats press bars for food and brain stimulation (Bradshaw, Szabadi, & Bevan, 1978; Gutman, 1977), and studies where pigeons press treadles for reinforcement (King & McSweeney, 1987; McSweeney et al., 1986). Additive theorists have argued that additive responses do not interact with instrumental responses when rats press bars or pigeons press treadles (Rachlin, 1973).
The current results are also inconsistent with an additivity explanation because of the separation of the operant and consummatory responses.

The competition theory of behavioral contrast is based on the principle that as reinforcement is changed (increased or decreased) interim or alternative responses are re-allocated to the less rewarding component and instrumental responding increases in the more rewarding component. This theory has been tested successfully in rats barpressing with a running wheel available for interim responding (Hinson & Staddon, 1978) and in rats barpressing on two different response levers located on opposite sides of a choice chamber (White, 1978). White’s results indirectly support the competition theory because White argued that contrast is due to an increase in time allocation to the operant response, rather than an increase in the actual rate of response. The current results are not easily explained by the actual rate of responding due to the lack of a specified interim response in the design. There are certain naturally occurring interim responses which could be compared, such as grooming and resting, but there were no records kept on the frequency of these occurrences and which component (wheel) they occurred in. With the use of micro-cameras and surveillance this data could be gathered in future experiments. However, White’s (1978) definition of competition theory which employs a time allocation could be tested by simply measuring time spent in each wheel as well as amount of responding.

The matching explanation of behavioral contrast hypothesizes that the relative rate of reinforcement determines the amount of responding in that component, the denser the reinforcement the more responding allocated to that component. Subjects are typically
using low effort, repetitious responses which can be highly artificial (Shettleworth, 1989). However, several studies have found support for the matching law using a variety of topographically different responses, including key pecking and treadle pressing (Hanson & Green, 1986; McSweeney, 1982); barpressing and licking (Dougan & Eacker, 1982; Jacquet, 1972); wheel running and barpressing (Hinson & Staddon, 1978). The present results are not consistent with this explanation due to a lack of positive contrast and the degree of preference for the denser component in the negative phase. The matching law predicts that the VI-2 m component should receive 11% of the responding, but in the current study 28% of the responding was distributed to the VI-2 m component.

The suppression theory of behavioral contrast maintains that responding in a VI schedule is controlled by two separate and opposing effects, an excitatory and an inhibitory effect (McSweeney, 1987; McSweeney et al. 1986). The excitatory effect occurs in direct proportion to the rate of reinforcement and the inhibitory effect occurs due to a delay in reinforcement. Delay in reinforcement increases inhibitory effects which leads to a suppression of behavior. The current results indicated there was no suppression in behavior when the reinforcement rate decreased in the VI-5m component, but there was a significant increase in behavior when the reinforcement rate increased in the VI-15sec component. While none of the extant explanations can fully account for the present results, suppression theory provides the best overall fit.

The occurrence of behavioral contrast was not the only point of interest in the present study, the effects of effort were observed as well. There has been considerable research regarding the effects of effort, but the results are not conclusive. The general
consensus regarding effort is that as effort requirements increase, overall response rates will decrease (Chung, 1965; Keehn, 1981). Much effort research has focused on the mechanism that is responsible for the decrease in responding. The problem faced by the subjects in the current study is when to leave a wheel and go to the other one in search of reinforcement. This is analogous to patches in the environment and when an animal must decide a patch is depleted and search for a new patch. This experiment varied the effort the subject was required to exert to forage in a patch (run in a wheel) as well as the time spent foraging in that patch (the VI schedule). Mitchell and Brener (1997) examined the foraging behavior of rats using bars requiring an overcoming force to move them downward and manipulated the amount of fixed work that was needed to gain reinforcement. To simulate sudden patch depletion, reinforcement would suddenly be withheld and the amount and time of responding was noted. Results indicated that the traditional variables of giving-up time and giving-up responses were not predictive of patch leaving. It was found that rats left patches only when the work costs of unsuccessful searches exceeded the prevailing work costs of food. These results question the validity of the common practices of using time spent responding or the number of responses performed to estimate the work costs of responding.

Using a caloric expenditure framework it might be hypothesized that high effort would make responding calorically more expensive and the total amount of food acquired to become critically important. If this were the case in the present experiment the subjects should have maximized reinforcement across both schedules resulting in a suppression of behavioral contrast effects. An alternative caloric expenditure framework
is to argue that since a less dense schedule would produce only a small fraction of the
total reinforcement available a more exclusive choice pattern may develop. This would
result in a greatly exaggerated contrast effect and support the position that the degree of
contrast is a function of the relative rate of reinforcement, a magnitude of reinforcement
effect. The results showed no evidence of an exclusive choice pattern and the magnitude
of negative contrast was not significantly lower for the high effort group. This simple
caloric expenditure framework appears incapable of explaining the current results.

Historically, two major preparations have dominated the study of animal behavior:
Operant and Instrumental. The “Skinner box” or operant chamber has been used in
operant conditioning procedures and the maze or runway has been used in instrumental
conditioning procedures. Mellgren and Olson (1983) described a number of dimensions
for comparison between Operant and Instrumental procedures and two of these
dimensions are particularly relevant to the present experiment: response type and species.

Traditional operant preparations are based on the subject engaging in continuous
trials in one location (key pecking or barpressing in an operant chamber) while in
instrumental preparations subjects engage in discrete trials involving spatial locomotion
(running). Operant preparations typically employ pigeons keypecking while instrumental
preparations employ rats running in runways. Extensive study of behavioral contrast has
been limited to pigeons pecking keys and to a much lesser extent, rats pressing bars.
Even with this limited set of species there have been some indications of species specific
response patterns. Behavioral contrast is a very robust phenomenon in pigeons pecking
keys (Williams, 1983; Williams, 1997) and while clearly apparent in rats, contrast is less
robust and some argue may be a different phenomenon altogether (Beninger, 1972: Blough, 1980; Dougan et al. 1989; Mackintosh et al., 1972; McHose & Moore. 1978; Williams, 1990; Williams, 1992). In fact, behavioral contrast is not as readily apparent when using other responses such as pressing levers or treadles, regardless of the species (Hanson & Green, 1986; Mc Sweeney, 1982; McSweeney, 1983).

The current response is of interest because the vast majority of incentive contrast studies use maze running as the response and rats as subjects (Black. 1968; Crespi. 1942; Dunham, 1968; Flaherty, 1982; Williams; 1997). Little contact has occurred between the incentive literature and the growing body of research on contrast in operant procedures with these two separate approaches coexisting for almost 30 years with only minimal contact. This separation has been in part caused by the division of animal learning into an associative learning camp and a behavior analysis camp (Williams, 1997). Incentive contrast can be further divided into two distinct categories: successive contrast and simultaneous contrast. A typical successive contrast preparation employs rat subjects responding on a single runway to one level of reinforcement with a shift occurring to either a higher or lower level of reinforcement then was previously experienced. Subjects that had experienced a previously high level of reinforcement would decrease their responding when shifted to a low level and subjects that had previously experienced a low level of reinforcement would increase their responding when shifted to a high level of reinforcement (Bacotti, 1976; Black, 1968; Crespi, 1942; Dunham, 1968; Flaherty, 1982; Shanab & Spencer, 1978). The decrease in responding is termed successive negative contrast (SucNC) and the increase in responding is termed successive positive
contrast (SucPC). A typical simultaneous contrast preparation employs rat subjects trained to run in two distinct runways, each associated with a certain level of reinforcement. The subjects' rate of responding is then recorded given the runway present during that session. An increase in response to a runway associated with a high level of reinforcement is termed simultaneous positive contrast (SimPC) and a decrease in response to a runway associated with a low level of reinforcement is termed simultaneous negative contrast (SimNC). Compared to the generally robust occurrence of negative contrast in incentive studies, positive contrast has been a much less reliable phenomenon, this is especially true of simultaneous contrast as opposed to successive contrast (Flaherty, 1982). Delay of reinforcement and shifting before the subject approaches asymptote has been demonstrated to produce a more reliable successive positive contrast effect (Shanab & Spencer, 1978; Mellgren, 1972; Schrier, 1967).

Simultaneous contrast is conceptually the same procedure as behavioral contrast studied with multiple schedules. However, the asymmetry between positive and negative contrast in simultaneous contrast does not hold for behavioral contrast, where both positive and negative contrast are easily obtained.

The current study employed rats as subjects running in a wheel. This design blended aspects of operant preparations (continuous responding and little contact with the experimenter) with aspects of instrumental preparations (locomotion through space and rat subjects). The target response, running, produced contrast effects similar to traditional incentive contrast which uses instrumental responding (running) but in a discrete trial preparation. The response, running, may be the key factor because when using an operant
preparation, running produces results consistent with instrumental research. This would lead to the hypothesis that the response is more crucial to the results than the types of preparations used (operant vs instrumental). The present experiment provides a bridge between free-operant and instrumental procedures. Furthermore, the presence of negative contrast without positive contrast suggests the differences between behavioral and incentive contrast are, in part, due to different response classes.
REFERENCES


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