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TITLE OF THESIS/TITRE DE LA THÈSE

SOME FURTHER Boundary Conditions
Associated with the Production of
BEHAVIORAL CONTRAST IN PIGEONS

UNIVERSITY/UNIVERSITÉ

CARLETON

DEGREE FOR WHICH THESIS WAS PRESENTED/

GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE

Doctor of Philosophy

YEAR THIS DEGREE CONFERRED/ANNÉE D'OBTENTION DE CE DEGRÉ

1977

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SOME FURTHER BOUNDARY CONDITIONS
ASSOCIATED WITH THE PRODUCTION OF
BEHAVIORAL CONTRAST IN PIGEONS

by

William R. Barnes
Department of Psychology

Thesis presented to the Faculty of Graduate
Studies of Carleton University in partial
fulfillment of the requirements for the
degree of Doctor of Philosophy

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Ottawa, April, 1977

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The undersigned recommend to the Faculty
of Graduate Studies acceptance of the Thesis

Some Further Boundary Conditions²
Associated with the Production of
Behavioral Contrast in Pigeons

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ABSTRACT

The effect of a particular reinforcer on behavior is frequently a function of the subject's experience with other reinforcers. A type of successive discrimination procedure in which two or more reinforcement conditions are presented in alternation, each associated with a distinctive stimulus (a multiple schedule), is one paradigm used to study such interaction effects. Behavioral contrast refers to one type of interaction effect in which performance under one component of the multiple schedule changes as a function of alterations in the behavior and its consequences in another component. The purpose of the present studies was to provide further clarification of the boundary conditions associated with the production of behavioral contrast in pigeons.

In the first experiment, two procedures which differed with respect to discriminative context were used to alter the relative reinforcement frequency provided by two components of a multiple schedule. In the standard discrimination procedure, two groups received either an absolute reduction (extinction) or a reduction in the number of reinforcements provided in two additional components. The non-standard procedure involved the addition or deletion of two equally valued components.

The results indicated increased rates of responding in the constant components (positive contrast) as a function of; the introduction of extinction or a lowered frequency of reinforcement in the changed components and the addition of equally valued schedule components. The removal of schedule components produced decrements in responding in the remaining components (negative contrast). However, the relatively weak effects obtained for seven of the twelve subjects constitutes a major limitation of the present results. Finally, those subjects which received a reduction in reinforcements during presentations of the changed components demonstrated differential stimulus control by line orientation in subsequent generalization tests.

The second study investigated the effects of variations in the presentation frequency of conditioned reinforcement (a brief stimulus paired with food) on multiple schedule performance. The result indicated that contrast effects obtained as a function of manipulations in primary reinforcement were larger in effects obtained as a function of similar manipulations in conditioned reinforcement.

The present results were discussed in relation to empirical findings and current theoretical interpretations of interaction effects obtained within discrimination and related paradigms. It was concluded that a variety

of local and overall patterns of behavioral contrast have been produced by a variety of procedures. The diversity of empirical findings and theoretical interpretations suggests that behavioral contrast is not a unitary phenomenon.

ACKNOWLEDGEMENTS

I am indebted to many people for their help and support throughout the course of this research. I thank Dr. Marilyn Marshall for her constructive comments and suggestions; Dr. Jo Tombaugh for her invaluable assistance regarding computer programming, and Roger Sands for his technical assistance in the preparation of graphs. In particular, I am grateful to Dr. Tom Tombaugh for his supervision and patient guidance. Finally, I thank my wife, Barbara, for her continuing support.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Problem	1
General Paradigm	1
Early Empirical Results	7
Theoretical Interpretations	10
Conclusions	26
EXPERIMENT 1	30
METHOD	41
Subjects	41
Apparatus	41
Experimental Design and Theoretical Predictions	42
Procedure	47
RESULTS	51
Behavioral Contrast	51
Generalization	60
Summary	63
DISCUSSION	66
Empirical Considerations	66
Theoretical Considerations	76
EXPERIMENT 2	89
METHOD	92
Subjects and Apparatus	92
Experimental Design and Theoretical Predictions	92
Procedure	96
RESULTS	99
Summary	109
DISCUSSION	112
Empirical Considerations	112
Theoretical Considerations	119
SUMMARY AND CONCLUSIONS	132
REFERENCES	135

LIST OF TABLES

Table	Page
1. Design for Experiment 1	43
2. Summary of Contrast Effects Obtained in Experiment 1	64
3. Original Design for Experiment 2	93
4. Design for Experiment 2	97
5. Summary of Contrast Effects Obtained in Experiment 2	110

LIST OF FIGURES

Figure	Page
1. Mean Rates of Responding for Groups 2-2R ^b and 2-2I.	52
2. Mean Rates of Responding for Groups 4-2E and 4-2D	53
3. Mean Change in Responses Per Minute to the Constant Components During Phase II for Groups 2-2R and 2-2I.	54
4. Mean Change in Responses Per Minute to the Constant Components During Phase II for Groups 4-2E and 4-2D.	55
5. Relative Generalization Gradients for Groups 4-2E and 4-2D.	61
6. Relative Generalization Gradients for Groups 2-2R and 2-2I.	62
7. Mean Rates of Responding to the Vertical (Constant Component) and Horizontal Line Orientations.	100
8. Mean Rates of Responding to the Vertical (Constant Component) and Horizontal Line Orientations.	101
9. Mean Rates of Responding to the Vertical (Constant Component) and Horizontal Line Orientations.	102
10. Mean Rates of Responding to the Vertical (Constant Component) and Horizontal Line Orientations.	103

INTRODUCTION

Problem

The present proposal is concerned with an evaluation of performance under several different stimulus conditions and a determination of the degree to which performance in the presence of one stimulus influences behavior occurring in the presence of other stimulus conditions. The purpose of the present studies was to further investigate the occurrence of behavioral interactions within an operant discrimination paradigm.

General Paradigm

A basic principle in operant conditioning is that the frequency of behavior can be modified by the consequences of the behavior. Environmental events which increase the frequency of behavior which they follow are termed reinforcing stimuli or reinforcers. These stimuli not only increase the probability of the preceeding behavior, but they also contribute by bringing the behavior under the control of environmental stimuli which precede and accompany the reinforced behavior. Those environmental stimuli in whose presence responses are reinforced are called discriminative stimuli. Discriminative stimuli signal that reinforcement will occur and as such, are said to exert stimulus control over behavior. For example, if the presentation of food is made contingent upon responding

in the presence of an exteroceptive stimulus, such as a red light, then the probability of responding in the presence of this stimulus will increase and the red stimulus is said to exert control over responding.

The same response might be reinforced under identical contingencies during the presentation of two or more successively presented exteroceptive stimuli. For example, the pecking response of a pigeon could be equally reinforced during successive presentations of a red and green light. In this example, behavior should be identical in the presence of each of the two stimuli---rate of key peck responding should increase during the presentation of both stimuli. However, key peck behavior would not increase during an interstimulus interval in which there was no light because pecking had not been reinforced under this condition. Thus, the lights whether red or green, are said to exert discriminative stimulus control because the frequency of responding is higher in their presence than in their absence. However, since the pigeon does not behave differentially in the presence of each of the colors it may be said that it does not discriminate between the two stimuli. That is, the two stimuli do not exert differential control over responding.

Differential stimulus control over key peck behavior can be produced in the above example by instituting differential reinforcement in the presence of the two stimuli. If responding during the presentation of red continues to be

reinforced but responding during the green is now non-reinforced, the pigeon will respond differently in the presence of each stimulus. The rate of nonreinforced responding in the presence of green will decrease, while the rate of reinforced responding in the presence of red will tend to increase. The pigeon is said to discriminate between the two stimuli because it behaves differently in the presence of each. The decreased response rate obtained during presentation of the green stimulus is characteristic of behavioral changes which occur following a change in the contingencies from reinforcement to non-reinforcement. However, the increased response rate obtained during the presentations of the red stimulus cannot be explained with reference to the reinforcement contingencies in the red component, since they remain unchanged. In this discriminative situation, the rate of responding during the presentation of the red stimulus (S+) depends upon the consequences of responding in the presence of the green stimulus (S-). The behavior generated under one stimulus condition is not independent of the behavior and its' consequences which occur under an alternately presented stimulus, even though each stimulus presentation is independent of the subject's behavior in the presence of the alternate stimulus. Thus, when the performance under a given condition is partly determined by the performance and its' consequences under other stimulus conditions an interaction effect is said to occur.

In the discriminative situation, four types of interaction effects may be distinguished (Reynolds, 1961b). These refer to the different rates of responding associated with two stimuli where the conditions are changed in one stimulus component and remain unchanged in the other. Cases in which the changes in each of two rates of responding are in opposite directions are referred to as behavioral contrast. Cases in which the changes in each of two rates of responding are in the same direction are referred to as behavioral induction. These interaction effects may be further distinguished according to the direction of the change which occurs in the unchanged stimulus component. If the rate of responding in the unchanged component increases, the effect (induction or contrast) is positive; if the rate in the unchanged component decreases, the effect is negative.

Positive behavioral contrast (PC) typically occurs during the formation of a discrimination between two stimuli. For example, a discrimination between an S+ and an S- could be established by reinforcing responding in the presence of the former but not the latter stimulus. As the rate of responding during the presentation of the changed stimulus (S-) decreases, the rate of responding during the unchanged stimulus (S+) increases over the previously maintained rate. Negative behavioral contrast (NC) often occurs following the abolition of a discrimination. After a discrimination is trained, it can be abolished by reinforcing responding in the presence of each discriminative stimulus. The change

from nonreinforcement to reinforcement in the presence of the former S- stimulus results in an increase in response rate during the changed stimulus (former S-) and a decrease in the response rate during the unchanged stimulus below the previously maintained rate.

There are at least two primary reasons for the experimental study of behavioral contrast. As previously indicated, contrast and induction represent indirect behavioral effects. Thus, despite their relative independence, the extent of behavioral control exerted by a single component is partly dependent upon the conditions associated with other components of the multiple schedule. Therefore, a major interest has been the determination of the behavioral processes responsible for these interaction effects. At an empirical level, a number of investigators have attempted to delineate those stimulus conditions which are always present when contrast is obtained as well as those conditions which always result in the occurrence of contrast (see reviews by Dunham, 1968; Freeman, 1971). That is, the purpose of these studies was to specify the necessary and sufficient conditions, respectively, for the production of contrast.

A second related interest concerns the role of behavioral contrast in a general theory of discrimination learning. Behavioral contrast is one of several generalized effects that may be obtained during the establishment of a discrimination (Terrace, 1972). In his early theoretical

considerations of discrimination learning, Spence (1936) postulated that the primary effects of differential reinforcement were negative. That is, the development of inhibition associated with a discriminative stimulus (S-) correlated with extinction or a relatively poor schedule of reinforcement should produce a generalized decrement in responding to other stimuli. However, PC refers to an enhancement of responding in the presence of the unchanged stimulus component (S+). Therefore, a major interest is the determination of how contrast, once generated, influences subsequent discrimination performance.

Behavioral contrast is typically studied within an operant discrimination paradigm. The general procedure employed in these investigations is as follows. Training is given on a single response manipulandum (eg: bar press or key peck response). Two exteroceptive stimuli, each associated with a particular reinforcement schedule are alternately presented to the subject. This paradigm is referred to as a multiple (mult.) schedule. Initially, responding to each stimulus component is reinforced under identical schedules of reinforcement. Thus, red and green stimuli might be successively presented on a single key with responding reinforced under a variable-interval¹ 1 minute (VI-1) schedule in the presence of the red stimulus

¹ an intermittent reinforcement schedule in which a specified period of time must elapse before a response can be reinforced. The period of time separating reinforcement availability is determined by a random series of intervals having a given mean and lying between arbitrary extreme values.

and under a VI-1 minute schedule in the presence of the green stimulus. This schedule would be termed a mult. VI-1, VI-1. This procedure is employed in order to generate equal rates of responding and reinforcement during each stimulus component. This phase is continued until the rate of responding under each schedule component has stabilized. The stable behavior serves as a baseline from which to measure the effects of subsequent experimental manipulations. In the contrast phase, a discriminative condition associated with one component of the multiple is changed while the other component remains unchanged. For example, in the above situation, non-reinforcement or extinction (ext) might be instituted during presentations of the green (changed) stimulus. The VI schedule would continue to be in effect during presentations of the red (unchanged) stimulus. As previously described, this procedure yields a positive contrast effect; as rate of responding during presentations of the green (changed) stimulus decreases, the rate of responding during the red (unchanged) stimulus increases over the rate maintained during the initial or baseline phase even though reinforcement conditions remained the same in this component.

Early Empirical Results

Positive Contrast. Positive contrast has been obtained with a number of different schedule combinations and variations in the general mult. schedule paradigm

previously described. Early studies of PC employed an absolute reduction in reinforcement frequency by instituting extinction during the changed component (Reynolds, 1961a,d,e; Smith and Roy, 1954). Subsequent investigations have demonstrated PC by introducing a schedule of reinforcement during the changed component which merely programs fewer reinforcements than the previous schedule (Findley, 1958; Nevin and Shuttleworth, 1966; Reynolds, 1961c). For example, in Reynolds' study (1961c) a decrease in reinforcement frequency was produced by changing a mult. VI-1, VI-1 schedule to a mult. VI-1, VI-3 schedule. PC has also been obtained by combining several different reinforcement schedules within the multiple paradigm. Dews (1958) reported a PC effect when a mult. FI, FI² was changed to a mult. FI, FR³ schedule in which reinforcement frequency was lower during the FR component. Reynolds (1961b) and Reynolds and Catania (1961) reported similar effects when reinforcement frequency was varied under mult. VI, FR and mult. VI, FI schedules respectively.

In the above studies, PC was produced by reducing both the frequency of reinforcement and the rate of responding in the changed component. The above results suggest that

²an intermittent reinforcement schedule in which the first response which occurs after a constant (or fixed) interval of time is reinforced.

³an intermittent reinforcement schedule in which a response is reinforced upon the completion of a constant (or fixed) number of responses counted from the preceding reinforcement.

any procedural operation which lowers reinforcement frequency and decreases response rate in the changed component of a mult. will produce PC.

Negative Contrast. While demonstrations of negative contrast (NC) are not as numerous as those showing PC (Freeman, 1971), a tentative conclusion is that this phenomenon also occurs under a wide range of conditions. Reynolds (1961b) obtained a NC effect following a change from ext. to the original VI schedule which was in effect during the changed component (mult. VI, ext.; mult. VI, VI). NC has also been obtained when the mean value of a VI schedule was decreased during the changed component, thus increasing the frequency of reinforcement associated with this component (Nevin and Shuttleworth, 1966; Reynolds, 1961c, 1963). In the Nevin and Shuttleworth study, a mult. VI-5, VI-5 schedule was changed to a mult. VI-5, VI-1. An increase in the response rate was obtained during the changed component (VI-1) with a corresponding decreased rate occurring during the constant component (VI-5).

NC has also been found with a combination of several different reinforcement schedules. Shuster (1959) obtained NC in rats following a change in a mult. FR 20, FR 20 schedule to a mult. FR 20, FR 10. Bloomfield (1967a) and Reynolds (1961c) obtained NC following a schedule change from VI to FR with a greater reinforcement frequency associated with the FR component. Reynolds (1961c) also obtained a NC effect after a schedule change from an FR to

a VI in which reinforcement frequency increased.

In the above studies, NC was produced by increasing both the frequency of reinforcement and the rate of responding in the changed component. A tentative conclusion that may be drawn from the above results is that any operation which increases reinforcement frequency and raises response rate in the changed component of a mult. schedule will produce NC.

Theoretical Interpretations

There are four major theoretical interpretations of behavioral contrast. Reynolds' (1961) relative reinforcement hypothesis is a descriptive account of the relationship between responding and reinforcement frequency in multiple schedules. Terrace (1972) postulates that contrast is a product of emotional behavior generated by reductions in rate of responding, while the additivity theory of Gamzu and Schwartz (1973) assumes that reinforcement alterations produce their effects through Pavlovian conditioning processes. The fourth hypothesis relates contrast to the development of an increased preference for the constant component (Bloomfield, 1969) or increased aversiveness in the changed component of a multiple schedule (Premack, 1969).

Reinforcement Rate Hypothesis. Reynolds (1961a) hypothesized that rate of reinforcement is the critical variable in producing contrast effects. Specifically,

Reynolds stated that the relative, rather than absolute rate of reinforcement is responsible for contrast. According to Reynolds (1961a), "rate of responding in the presence of a given stimulus is determined by the rate of reinforcement in the presence of that stimulus relative to the reinforcement rate during all other stimuli controlling the organism's behavior". For example, in a two component mult. schedule, where each component is reinforced on a VI-2 min. schedule, the absolute number of reinforcements received per hour would be 30 for each stimulus condition. Therefore, the relative rate of reinforcement would be 50% under each component ($30/30 + 30 = 50\%$). If this mult. VI-2, VI-2 schedule were now changed to a mult. VI-2, VI-6 schedule, the absolute number of reinforcements received during the changed component would decrease to 10 while remaining the same (30) during the unchanged component. The total number of reinforcements received throughout the session would decrease from 60 to 40. Thus, the relative rate, or number of reinforcements received during the unchanged component would increase to 75% ($30/30 + 10 = 75\%$). As a result of the increased relative reinforcement rate, Reynolds would predict a corresponding increase in the response rate obtained during the unchanged component. That is, positive contrast would be predicted. If the same mult. VI-2, VI-2 schedule had been changed to a mult. VI-2, VI-1 schedule, the total number of reinforcements received throughout the

session would increase from 60 to 90. The absolute number of reinforcements received during the changed component would increase from 30 to 60 while remaining at 30 during the unchanged component. Thus, the relative reinforcement rate received during the unchanged component would decrease to approximately 33% ($30/30 + 60 = 33\%$). As a result, a decreased rate of responding during the unchanged component (negative contrast) would be predicted. Reynolds' account of contrast phenomena remains at a descriptive level, since he does not elaborate on the assumed process by which an organism is able to discriminate and compare different reinforcement rates associated with different stimulus conditions.

There is substantial experimental evidence which indicates a functional relation exists between the relative rate of reinforcement in the unchanged component and the magnitude of the contrast effect, either PC or NC (Bloomfield, 1967; Catania, 1963; Reynolds, 1963). As the magnitude of the difference in the relative reinforcement rate increases or decreases from the baseline conditions, there is a corresponding change in the magnitude of the PC or NC effect.

However, despite the functional relationship described above, there is evidence which indicates that variations in the relative reinforcement rate are not always a sufficient condition for the production of PC or NC effects. For example, Reynolds, (1963) reported that neither PC

nor NC occurred when responding in the unchanged component was maintained by a very high or low rate of reinforcement, respectively. That is, even though the relative rate of reinforcement during the unchanged component was increased from 50% to 100% (mult. VI, ext.), PC did not occur when 38 reinforcements per hour were programmed in the unchanged component. Reynolds also reported that when the relative reinforcement rate was decreased from 50% to 10% in the unchanged component by increasing the absolute number of reinforcements obtained in the changed component from 1 to 10 per hour, positive induction rather than NC occurred.

Results from several other investigations indicate that a reduction in the rate of reinforcement is not a necessary condition for PC to occur. These studies have employed a variety of experimental contingencies during the changed component of the mult. schedule in an attempt to maintain the same reinforcement frequencies associated with each component of the mult. schedule. Reynolds (1961b) employed a procedure in which the experimental chamber was completely darkened for a specified interval of time. He obtained PC by simply alternating these dark periods between successive presentations of a stimulus correlated with a VI-1 min. schedule. Brownstein and Hughes (1970) and Brownstein and Newsom (1970) employed cueing procedures during the presentation of the changed stimulus component in order to maintain a constant reinforcement rate. In this procedure a cue signalling reinforcement availability was added during

the changed component. The pigeon learned to respond in this component only during the presentations of the discriminative cue. Thus, rate of responding decreased in the presence of the changed component, while relative rate of reinforcement remained constant for both stimulus components. PC was obtained in both investigations. Wiseman (1970) employed a schedule change in which reinforcement was obtained for not key pecking during the changed component of a two-component mult. schedule. This schedule involved differential reinforcement of behavior other (DRO) than responding on a specific manipulum. Thus, a mult. VI, VI schedule was changed to a mult. VI, DRO in which the S was reinforced for not key pecking during presentations of the DRO component. Wiseman obtained PC despite the fact that the DRO schedule maintained a constant reinforcement frequency.⁴

Response Rate Hypothesis. Terrace (1972) proposed that a reduction in the rate of responding in the presence of a discriminative stimulus that was required by the schedule in effect (such as the extinction and DRO schedules previously discussed) should produce behavioral contrast. That is, contrast is a consequence of requiring an organism

⁴Wiseman maintained equal reinforcement rates in the DRO and VI components by adjusting the duration of the DRO requirement as a consequence of reduced responding in the DRO component. Two previous investigations of DRO reinforcement (Reynolds, 1961a; Nevin, 1968) reduced the rate of responding to a stimulus correlated with DRO by increasing the rate of DRO reinforcement. However, behavioral contrast was not obtained in either of these investigations.

to learn to respond at a lower rate in the presence of one of two alternating stimuli. Terrace suggested that these reductions in the rate of responding were characterized by "an active holding back" or forced reduction in responding and were accompanied by emotional responses.

At a hypothetical explanatory level, Terrace relates the occurrence of emotional behavior to the development of frustration generated by nonreinforcement. Amsel (1962) postulated that frustration generated by nonreinforcement was a negative drive. The drive of conditioned frustration is held to be functionally similar to other negative drives in that the organism will attempt to diminish the intensity of the conditioned frustration drive. As a result of the development of frustration, Terrace postulates that responses which are incompatible with the previously reinforced operant are strengthened, presumably by the avoidance of frustration. Further, Terrace states that the development of these incompatible response tendencies during presentations of the changed or S- component are indicative of conditioned inhibition. Contrast is presumed to be an after-effect of conditioned inhibition which occurred during the changed component. Thus, Terrace considers contrast to be a by-product of one type of discrimination learning that results in frustration and conditioned inhibition.

A discrimination established under a mult. VI, ext. schedule results in the development of frustration, due to

nonreinforced responding in the presence of the extinction component, and therefore conditioned inhibition, according to Terrace (1972, p. 253). As previously indicated, PC is typically obtained during the formation of a discrimination under a mult. VI, ext. schedule. However, since a reduction in both the rate of responding and the rate of reinforcement occur during the extinction component, the results from these studies do not conclusively indicate that response reduction in the changed component is a sufficient condition for the production of contrast.

Two procedures have been employed to decrease response rates in the changed component without altering reinforcement frequency in this component. Terrace (1968) and Wiseman (1969) employed a schedule that differentially reinforced long inter-response times. That is, reinforcement was contingent upon a predetermined period of time elapsing between successive responses. This contingency generates a relatively low response rate and, therefore is termed differential reinforcement of low rates (DRL). In the above investigations the inter-response interval in the DRL schedule was manipulated in order to equate the reinforcement frequency provided in each component of a mult. VI, DRL schedule. In these studies PC was obtained under the mult. VI, DRL schedule. In the previously cited study by Wiseman (1970), a PC effect was obtained under a mult. VI, DRO schedule in which the reinforcement frequency was the same in both schedule components. The results from

these investigations indicate that a reduced rate of responding may be a sufficient condition for the production of contrast.

However, the failure to obtain PC in several other investigations (Halliday and Boakes, 1971; Wiseman and Ramsden, 1973; Wilkie, 1972) which produced reductions in response rate indicate that this variable is not a sufficient condition for the production of contrast. In each of these studies, a variable interval response-dependent schedule (VI) was changed to a variable interval response-independent schedule, termed a variable time schedule (VT) by Zeiler (1968). In a VT schedule, reinforcers are scheduled independently of responding. In the studies cited above, when one component of a mult. VI, VI schedule was changed to a VT schedule, the rate of responding in this component was reduced without reducing the reinforcement frequency. However, no increase in responding was obtained in the constant component VI schedule.

Moreover there is some experimental evidence which indicates that response reduction is not a necessary condition for the production of behavioral contrast. In two investigations of the effects of delaying reinforcement presentations in the changed component of a multiple schedule (Richards, 1972; Wilkie, 1971) some subjects showed behavioral contrast without a corresponding response reduction in the delay component. Hemmes and Eckermann (1972) produced response rate increments in the changed component

of a multiple schedule by differentially, or selectively reinforcing high rates of responding. This type of contingency has been termed a differential reinforcement of high rates schedule (DRH). These investigators reported that such a procedure also resulted in increased response rates to the constant VI component. Thus, an increase in constant component response rates occurred despite a corresponding increased rate of responding in the changed component.

Additivity Hypothesis. Brown and Jenkins (1968) reported a method for the automatic shaping of key pecking in pigeons. In their procedure, labelled "autoshaping", when a response key was illuminated several seconds prior to response-independent presentations of food, experimentally naive pigeons began to peck the key. This procedure may be compared to that of classical or respondent conditioning; the food and the pecking response that it elicits correspond to the unconditioned stimulus (UCS) and the unconditioned response (UCR); the lighted key and the response of pecking the key correspond to the conditioned stimulus (CS) and conditioned response (CR). Williams and Williams (1969) reported that key pecking was maintained under a modified autoshaping procedure in which pecks prevented food presentation. This finding was interpreted as indicating the importance of the stimulus-reinforcer contingency in maintaining key pecking. That is, the fact that pecking was directed at the illuminated key was

attributed to the key's predictive value with respect to food. In summarizing the substantial recent research on autoshaping and related phenomena, Schwartz (1975) concluded that key pecking can be established and maintained if a differential predictive relationship exists between response-key illumination and the presentation of food.

Gamzu and Schwartz (1973) suggested that demonstrations of the control of key pecking by a stimulus-reinforcer (respondent) contingency in the absence of a response-reinforcer (operant) contingency has implications for situations in which both types of contingencies are present. For example, in a mult. VI, ext. schedule, reinforcement depends upon both the key peck and the presence of the stimulus correlated with the VI schedule. The operant contingency should continue to maintain a given response rate in the VI component. In addition, the differential stimulus-reinforcer contingency may also produce a given rate of pecking. The positive contrast effect obtained under this schedule might be dependent upon independent contributions to the rate of key pecking by both operant and respondent contingencies. That is, contrast might simply be the result of the addition of elicited pecking to an operant baseline of responding. Gamzu and Schwartz provided initial support for an additivity interpretation of contrast effects in multiple schedules. They employed a two-component multiple schedule of variable-time (response-independent) reinforcement. The components

contained either identical reinforcement frequencies (mult. VT, VT) or different frequencies (mult. VT, ext.) in successive experimental phases. An increase in key pecking was obtained in one component only when the component signalled a higher reinforcement frequency. Thus, the establishment of a differential stimulus-reinforcer dependency was sufficient to increase key pecking.

Several investigators (eg: Keller, 1974; Schwartz, 1975) have evaluated the effects of stimulus-reinforcer contingencies on the occurrence of contrast by attempting to experimentally separate operant and elicited pecks. These studies employed a modified multiple schedule in which the stimuli signalling the components (VI or ext.) were located on a second response key. Pecks on this signal key had no effect in producing reinforcement, while responses on the constant key, always illuminated by the same stimulus, produced reinforcement during a VI component. Keller and Schwartz reported that constant key responding typically decreased in the VI component of a mult. VI, ext. schedule, while signal key responding to the VI component increased. However, combining the responding obtained on both the constant and signal keys did yield positive contrast as predicted by the additivity theory.

One prediction derived from an additivity theory is that positive contrast is not an inevitable consequence of all multiple schedule procedures. According to this

theory the occurrence of contrast depends upon the procedural coincidence that both stimulus-reinforcer and response-reinforcer relations direct behavior toward the response key. If a differential stimulus-reinforcer contingency were signalled by stimuli not located on the response key, responding controlled by this contingency should not be directed toward the key. Therefore, if key pecking were maintained by a response reinforcer contingency, the behavior controlled by these two types of contingencies would not summate to produce a positive contrast effect. Redford & Perkins (1974) and Schwartz (1975) have obtained results which support this assumption. These investigators found no evidence of positive contrast when a houselight or tone served as the discriminative stimulus in a mult. VI, ext. schedule. An additivity interpretation would also predict that positive contrast should not be obtained if the operant response is dissimilar to the behavior elicited by the respondent contingency. In this situation the introduction of a differential stimulus-reinforcer contingency should generate and maintain key pecking. However, if the required operant is not key pecking, then the joint effect of these two types of contingencies would not result in an increase in operant responding. This explanation would account for the failure to obtain positive contrast in pigeons when treadle pressing was the operant response (Hemmes, 1973; Westbrook, 1973).

The evidence cited above indicates substantial empirical support for an additivity theory of positive behavioral contrast.

However, at the present time, there are at least two limitations with respect to this theory. The results from a recent study indicate that the spatial separation of respondent and operant contingencies does not necessarily eliminate their interaction. Schwartz, Hamilton and Silberberg (1975) employed a two key multiple schedule procedure similar to the one used by Keller (1974) and Schwartz (1975), previously described. In addition, Schwartz, et al, employed a contingency which prohibited the reinforcement of operant key pecks that closely followed signal key pecks. This changeover delay (COD) procedure was included in order to prevent the adventitious reinforcement of a signal key response which was temporally contiguous with a reinforced operant key response. These investigators reported that the summation of signal and operant key responses did not yield a positive contrast effect, due to the relatively low rate of signal key responding. These results indicate that the adventitious reinforcement of signal key responses partially controlled the frequency of such responses, and therefore the occurrence of positive contrast, in previous investigations which did not employ a COD procedure. In its' present formulation, the additivity theory does not account for the possibility that pecking generated by a respondent contingency can be subsequently reinforced by an operant contingency. Therefore, as Schwartz, et al, suggested, the additivity theory may not be a sufficient account of positive contrast.

In the present paper, positive contrast has been described as an increase in the overall session rate of responding in the unchanged component. The overall changes in response rate may also be accompanied by particular patterns of responding within these components. Numerous studies (eg: Boneau and Axelrod, 1962; Nevin and Shettleworth, 1966; Rachlin, 1973) have shown that immediately after the transition from a multiple schedule component with less frequent reinforcement to one with more frequent reinforcement, there is a temporary increase in responding which gradually declines as the component continues. These demonstrations of local positive contrast effects support a general assumption of the additivity theory. As previously indicated, this theory assumes that positive contrast results from the addition of key pecks that are elicited by the signalled change from a low to a high density of reinforcement.⁵ However, Terrace (1966) reported evidence for both a local contrast effect, and an additional contrast effect that was independent of the prior multiple schedule component. Further, two investigations (Boneau and Axelrod, 1962; Nevin and Shettleworth, 1966) reported an overall contrast effect for a number of sessions after local contrast had disappeared. These findings indicate that, while local contrast may be closely related to overall contrast,

⁵Gamzu and Schwartz (1973) made no prediction concerning the locus of elicited pecks within a component. Rachlin (1973) proposed a similar account of contrast which did predict that elicited pecks would be concentrated immediately after the transition from a low to a high density of reinforcement. However, Buck, Rothestein and Williams (1975) concluded that neither of these accounts can adequately explain the local positive contrast phenomena.

the two effects are not identical. Several authors (Buck, Rothestein and Williams, 1975; Schwartz et al, 1975) have suggested that due to the relative independence of these effects, the additivity theory accounts primarily for local contrast, rather than overall contrast.

Preference Hypothesis. Bloomfield (1969) advanced the hypothesis that behavioral contrast results from a "worsening of conditions" during the altered component of a multiple schedule. The introduction of this less-preferred condition results in the increased conditioned (secondary) reinforcement value of the constant component (Bloomfield, 1970). Premack (1969) postulated a similar interpretation. He stated that contrast results if there is a change in the "aversiveness" associated with one of the multiple schedule components.

As previously indicated, contrast has been obtained in multiple schedules in which reinforcement frequency is reduced in the changed component (eg: Reynolds, 1963) as well as schedules requiring low (DRL schedule, Terrace, 1966) or high (DRH)(Hemmes and Eckermann, 1972) rates of responding in the changed component. A preference account of contrast would predict that each of the above conditions should be less preferred than the constant component comprising the multiple schedule.

Investigations of "preference" for two schedule components typically employ a concurrent schedule.⁶ In this situation preference is measured by the time allocated to

⁶In a concurrent schedule two or more independent reinforcement schedules are programmed on typically different response keys (Catania, 1966).

one of the available schedules. Investigations of differential reinforcement within a concurrent schedule paradigm indicate that pigeons prefer frequent as opposed to infrequent reinforcement (eg. Catania, 1966). Pantino (1968) presented some evidence which indicates that pigeons prefer schedules that do not require a low rate of responding and that pigeons also prefer FI to DRH schedules when these schedules were equated for reinforcement frequency. In addition, Wilkie (1972) reported no contrast effects in a multiple VI, VT schedule. In subsequent concurrent schedule responding no preference was obtained for either component.

The above findings provide substantial evidence for a preference interpretation in that many of the conditions which have been shown to produce contrast are also less preferred. However, Wilkie (1973) failed to obtain the proposed relationship between contrast and preference with a procedure which signalled reinforcement availability in the changed component. While contrast was obtained under this procedure, pigeons showed no preference for non-signalled versus signalled reinforcement in a concurrent schedule. These results suggest that the development of a preference for the constant multiple schedule component may not be a necessary condition for the production of contrast.

Conclusions

The results previously discussed, in addition to evidence presented in two reviews of the behavior contrast literature (Dunham, 1968; Freeman, 1971), indicate the following empirical conclusions. Discrimination procedures that produce reductions in reinforcement frequency and/or response rate in the altered component of a multiple schedule reliably produce behavioral contrast. Further, there is a direct relation between the magnitude by which reinforcement frequency is altered and the magnitude of the resulting contrast effect, over a wide range of reinforcement frequency manipulations. However, every study which has obtained this relationship has allowed concomitant change in; (1) response rate during the changed component, and (2) the absolute density of reinforcement. Thus, the relationship between reinforcement frequency and the magnitude of behavioral contrast cannot be unequivocally related to variations in reinforcement frequency. In addition, Reynolds (1963) reported that contrast effects were not obtained when a relatively high (38 reinforcements per hour) reinforcement frequency maintained constant component responding, or when reinforcement frequency in the altered component was slightly increased from a low value (1 to 10 reinforcements per hour). Thus, alterations in relative reinforcement frequency may not be a sufficient condition for the production of contrast. Additional evidence

indicates that a reduction in the rate of reinforcement is not a necessary condition for contrast occurrence.

A variety of procedures have been employed in obtaining contrast effects without corresponding alterations in relative reinforcement frequency. Thus, cueing reinforcement availability in the altered component (Brownstein and Hughes, 1970), introduction of a DRO schedule

(Wiseman, 1970), delaying reinforcement presentation in the altered component (Richards, 1972) and simply separating successive presentations of a VI component by black-out or time-out (Sadowsky, 1973) have produced positive contrast without corresponding changes in reinforcement frequency.

There is also a rather extensive body of literature relating to the reduction of responding in the altered component and the production of positive contrast in the constant component. However, in several experiments (Halliday and Boakes, 1971; Weisman and Ramsden, 1973; Wilkie, 1972) response rates have been reduced in the altered component by introducing a variable-time reinforcement schedule and positive contrast was not obtained. Thus, response reduction is not a sufficient condition for the production of contrast. In addition, there is some experimental evidence indicating response reduction is not a necessary condition for contrast to occur. Thus, Hemmes and Eckerman, (1972) produced a positive interaction (increased responding in the constant component) by

increasing response rates in the altered component. In two investigations (Richards, 1972; Wilkie, 1971) of delayed reinforcements, some, but not all subjects showed behavioral contrast without a reduction in responding during the delay component.

In summary, these results indicate that alterations in relative reinforcement frequency and reductions in response rate are neither sufficient nor necessary for the production of contrast effects. Therefore, the major limitations of both the relative reinforcement (Reynolds, 1961) and the response rate reduction (Terrace, 1972) interpretations is their inability to adequately account for all of the experimental findings.

A third account of behavior contrast relates its occurrence to the development of a differential stimulus-reinforcer dependency resulting from a discriminative change from a low to high density of reinforcement. This dependency elicits key pecks which are added to key pecks maintained by response-reinforcer relations resulting in increased rates (positive contrast) in the constant component (Gamzu and Schwartz, 1973; Rachlin, 1973). However, it may be argued that an additivity theory is only relevant to the development of transient contrast effects (Buck, et al 1975) and there is some evidence (Scull et al, 1970) which suggests that an exteroceptive discrimination is not a necessary condition for such effects.

A fourth hypothesis relates the occurrence of contrast to the introduction of a condition that is "less-preferred" than the constant condition (Bloomfield, 1969; Premack, 1969). There is considerable empirical support for this position in that some conditions which result in contrast are less-preferred when measured by time spent in an alternate component of a concurrent schedule. The major limitation with this theoretical account is the lack of operational definitions regarding the antecedent conditions necessary to render a stimuli "aversive" or "less-preferred".

In summary, more recent experimental findings appear to substantiate the conclusion reached by Dunham (1968) and Freeman (1971) that at the present time there is no single adequate explanation of all types of contrast.

EXPERIMENT 1

The introduction provided a selective review of the literature relevant to one type of interaction effect (behavioral contrast) that can occur between independently programmed reinforcement conditions. This review was restricted to investigations that employed one type of discrimination procedure (a multiple schedule) in which two or more schedules of reinforcement are presented in succession, each associated with a distinctive stimulus. Typically, responding in multiple schedules is characteristic of the simple schedules that comprise them (Ferster and Skinner, 1957, p. 503). That is, the pattern of performance in a particular component of the multiple schedule is almost identical to the type of performance obtained when that schedule is the only one in force. Despite this relative independence in the pattern of behavior, a change in the response rate in one component is obtained as a consequence of a change in certain conditions in another component. Skinner (1938, p. 175) first used the term "contrast" to refer to a type of interaction effect where changes in responding in two components were opposite in direction. The term contrast emphasized the fact that there was a divergence in response rates, rather than a covariation in responding.

Reynolds (1961) subsequently demonstrated that contrast was a reliable effect that accompanied the formation

(positive contrast) and the elimination (negative contrast) of a discrimination between two stimuli. His descriptive definition of contrast, typically adopted by other investigators, requires a divergent alteration in response rates in two components. Reynolds (1961, p. 57) stated that contrast occurs, "....when the change in 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". As noted by Hemmes and Echerman (1972), Reynolds' definition implies that response rate in the changed component may be a determinant of changes in responding in the constant component. As previously indicated (Introduction pp. 27-28), reductions in responding in the changed component constitute neither a necessary nor a sufficient condition for the production of increments in responding in the constant component. That is, the positive effects obtained in the constant component are not dependent upon divergent alterations in responding in the changed component. This finding suggests that changes in rate of responding in the constant component should be named independently of rate alterations in the changed component. Any change in the rate of responding in the constant component, which occurred as a consequence of the changed conditions in another component, might be labelled "contrast". Further, the term "positive contrast" would describe constant component rate increases, and

"negative contrast" would describe constant component rate decreases. The proposed definition of behavioral contrast still indicates that the constant component effects are indirect, that is, attributable to the changed conditions in a second component. However, this definition does not require information regarding the direct effects obtained in the changed component. Information regarding responding in the changed component could be provided in the description of the independent variables directly manipulated by the experimenter.

The modified definition proposed above essentially defines behavioral contrast as a change in responding to one discriminative stimulus following a change in the reinforcement conditions associated with a second discriminative stimulus. The present definition emphasizes the similarity between behavioral contrast and related phenomena which may be collectively referred to as "contrasted conditions of reinforcement". Several authors (Scull, Davies and Amsel, 1970; Terrace, 1972) have discussed the similarity between positive contrast and the frustration effect. The frustration effect refers to the increase in rats running speed in the second compartment of a two-part runway following the omission of reinforcement on half the trials in the first compartment. Thus, despite differences in procedure and the type of response studied, both the frustration effect and positive contrast refer to a facilitation in responding following the start of discrimination training. Scull, et al and Terrace also indicate

that these phenomena share a number of common properties with respect to their sequential nature, their permanence and their generality across a number of operant conditioning paradigms.

Dunham (1968) discussed the functional similarity between the phenomena labelled "behavioral contrast" and those labelled as "incentive contrast". As in investigations of behavioral contrast, incentive contrast has been frequently investigated within a successive differential (discriminative) conditioning paradigm. In one procedure rats are exposed either alternately or randomly to two distinctly different runways, each associated with a different quantity or magnitude of reinforcement. Incentive contrast is demonstrated if the performance asymptotes of subjects exposed to differential reinforcement are higher (positive contrast) or lower (negative contrast) than the performance of control subjects receiving either the larger or smaller magnitude of reinforcement in both runways. While Dunham does indicate that these two different methodological approaches to contrast phenomena entail a variety of differences in operational procedures, he concludes that these effects are related at an empirical level.⁷ Thus, the contrast effects obtained in these

⁷Dunham (1968) provides a comparison of a number of procedural differences between these approaches including the method of evaluation (between versus within subject), the type of reinforcement schedule employed (continuous versus intermittent) and the reinforcement parameters manipulated (magnitude versus frequency). Black (1968) also provides a selective review of the incentive contrast literature related to variations in solid food reinforcement.

discrimination paradigms are not a function of the absolute reinforcement in one discriminative condition, but represent the indirect effects of the reinforcement provided in a second condition.

Contrast effects have also been obtained in a successive instrumental conditioning paradigm which does not involve discrimination training. In this procedure, first reported by Crespi (1942), the reinforcement conditions associated with a single stimulus-response event are changed between successive experimental phases. Contrast is obtained if the performance level of subjects experiencing a change in reinforcement conditions exceeds the performance level of control subjects maintained by the post-change reinforcement condition. This type of contrast effect has been termed an interaction since the changes (either increments or decrements) in performance level exceed those maintained by the absolute post-change reinforcement condition (Dunham, 1968). However, this type of incentive contrast effect differs from behavioral contrast in that the former effect can be attributed directly to the change in reinforcement conditions. These comparisons can best be made by a description of the effects obtained as a function of the reduction in reinforcement conditions in each paradigm. In the nondifferential procedure, rats traverse a straight runway for a given magnitude of reinforcement. In the discriminative procedure pigeons peck a response key successively illuminated either red or green, with

identical but independent frequencies of reinforcement provided in each stimulus condition. This baseline phase of training is continued until responding has stabilized, at which time the reinforcement conditions are changed.

In the nondifferential procedure the magnitude of reinforcement is reduced, resulting in immediate decrements in the speed of transversing the runway. Further, these performance decrements exceed the performance levels of subjects maintained by the lower magnitude of reinforcement throughout both experimental phases. That is, a reduction in reinforcement magnitude in the nondifferential procedure produces a negative contrast effect. In the discriminative procedure reinforcement is no longer provided in the presence of one of the discriminative stimuli (extinction procedure), resulting in an increased rate of responding to the remaining stimulus. That is, the withdrawal of reinforcement associated with one discriminative condition produces a positive contrast effect in a second discriminative condition. To reiterate, both of these effects may be termed interactions with respect to performance under a given condition of reinforcement and the previous reinforcement conditions. However, the negative contrast effect (nondifferential procedure) can be attributed directly to the reduction in reinforcement conditions, while the positive effect (discriminative procedure) is indirect, attributable to the reduction in reinforcement conditions in a second discriminative stimulus.

Several authors have made similar comparisons in discussing the relationship between the contrast effects

obtained within discriminative and nondifferential conditioning paradigms. Dunham (1968) suggested that an important distinction between these two areas was the difference in contrast operations employed. He concluded that operations involving quantity or reinforcement magnitude were not antecedents for the same process as alterations in reinforcement and nonreinforcement. The results from several investigations which contrasted the duration of access to food in two components of a multiple schedule provided some support for this conclusion, (Dickson and Thomas, 1963; Mariner and Thomas, 1967; Shettleworth and Nevin, 1965). This duration manipulation essentially constitutes differences in reinforcement magnitude, therefore behavioral contrast was expected. However, the results from these studies indicated no evidence for either positive or negative contrast effects. Dunham (1968) and Mackintosh, Little and Lord (1972) indicate differences in the empirical effects obtained in these areas. While positive contrast is reliably obtained within a discrimination procedure, there are fewer conclusive demonstrations of this phenomenon in non-differential conditioning procedures. Negative contrast has received little experimental attention in the multiple schedule paradigm. In fact several investigators (Bloomfield, 1967; Pear and Wilkie, 1970; Terrace, 1968) failed to obtain evidence for negative contrast.

Finally, while Reynolds (1961a, p. 115) did obtain negative behavioral contrast, he also reported that the decrements in rate of responding associated with negative contrast were not as pronounced as the rate increments which characterized positive contrast. These findings question the assumption that positive and negative contrast effects reflect the same general process. Terrace (1972) also stated that the "Crespi effects" appeared to resemble the behavioral contrast effects. However, he concluded that due to the essential difference in conditioning paradigms employed it was premature to classify these phenomena together.

The definitive resolution of these and related issues would require the direct experimental comparison of the discriminative and nondifferential contrast paradigms. This general approach has at least two implications for the study of behavioral contrast. First, such comparisons might provide some clarification of the boundary conditions under which these indirect contrast effects are obtained. As indicated in the introduction, behavioral contrast has been obtained in a variety of discrimination procedures. In addition to a number of schedule combinations, behavioral contrast can occur with a number of variations in the general multiple schedule paradigm. Thus, at the present time, the limitations regarding the indirect interactions between two reinforcement conditions are overly broad. A second, related implication of this comparative approach

is the possible delineation of alternative variables that affect behavioral contrast. As indicated in the conclusion of the introduction, recent investigations have not provided an adequate determination of the variables responsible for the production of behavioral contrast. Indeed, given the variety of procedures and the different types of behavioral contrast effects reported in the literature, several authors concluded that it was not surprising that, at present, there is no adequate explanation of behavioral contrast (Buck, et al, 1975; Dunham, 1968; Freeman, 1971; Mackintosh, et al, 1972; Premack, 1969; Scull, et al, 1970).

The present study represents an initial attempt to provide evidence relevant to the above two issues. The two contrast paradigms presently under discussion differ along a number of dimensions. However, attempts to generalize empirical results and explanatory concepts across these two methodologies requires initial investigations of the differences in reinforcement parameters manipulated. The purpose of the present study was to provide further evidence relevant to this variable by examining two different procedural variations in reinforcement frequency within a multiple schedule. The basic distinction between these manipulations can be illustrated by a description of the procedures employed to decrease reinforcement frequency. In an initial phase, subjects were exposed to a four component multiple schedule providing an equal but independent number of reinforcements in each component. In one group the absolute number of

reinforcements provided by the multiple schedule was subsequently reduced by instituting extinction procedures in two of the four components. These procedures closely approximate those of a "standard" multiple schedule discrimination. In a second group the absolute number of reinforcements provided was reduced by deleting two of the four components from the multiple schedule. The two components common to both groups (constant components) in the second experimental phase continue to provide the same absolute frequency of reinforcement provided in the first phase. In addition, the relative reinforcement frequency provided by these components increases in the second phase. However, the groups differ with respect to the discriminative context in which the change in relative frequency occurs. As opposed to the extinction procedure, the change in relative frequency produced by deleting schedule components is not associated with other schedule components which provide both a lower relative and absolute frequency. In a third group, the relative reinforcement frequency provided by two schedule components was subsequently decreased by the addition of two components providing identical frequencies of reinforcement. In this group the change in relative frequency produced by adding schedule components is not associated with other schedule components which provide both a higher relative and absolute frequency of reinforcement. Thus, while the addition and deletion of equally valued components produced changes in

relative reinforcement frequency, unlike standard multiple schedule procedures these changes were not associated with alterations in absolute reinforcement frequency in other components.

The present study sought to determine if behavioral contrast would occur as a function of the addition and deletion of equally valued schedule components. In addition to providing a clarification of the boundary conditions associated with the production of behavioral contrast, the present study is also relevant to current theoretical interpretations of contrast which stress the importance of the discriminative context in which the phenomena occur.

METHOD

Subjects

Twelve naive male White Carneaux pigeons, approximately one year old, purchased from the Palmetto Pigeon Farm served as Ss.

Apparatus

Four standard Lehigh Valley operant-conditioning chambers were used. Each apparatus (15 in. x 12 in. x 15 in. high, 38.1 cm x 30.5 cm x 38.1 cm high) was housed in a second chamber (3 ft. x 2 ft. x 2 ft. high, .90 M x .60 M x .60 M) constructed of 3/4 in. (1.91 cm) plywood and sound insulated with acoustical ceiling tile. Masking noise and ventilation were provided by two 100-CFM Dayton blowers located on the left side wall and back wall, respectively of each apparatus and holding chamber. Visible to the bird was a single translucent (Perspex) response key 1 in. (2.54 cm) in diameter with its center 8½ in. (21.6 cm) above the floor on the vertical center of the apparatus' side wall. Pecks with a minimum force of 15g (0.14N) constituted a response and were reinforced by presentations of mixed grain at a 2 in. (5.08 cm) square aperture located directly below the response key. When in the raised position, the grain hopper is flush with the bottom of the aperture.

Presentations of the grain hopper were independently signalled by illumination of a 6-W bulb positioned 1 in. (2.54 cm) behind the center of the aperture. Stimuli were projected on the reverse side of the translucent key by In-Line Digital Display Units. The stimuli consisted of 1/16 in. (0.06 cm) wide lines on a dark background. The lines were 1 in. (2.54 cm) long and could be presented at seven different orientations to the horizontal (0°) in $22\frac{1}{2}^{\circ}$ steps. Diffuse general illumination was provided by a 6-W bulb (house light) located $2\frac{1}{2}$ in. (6.35 cm) above the center of the response key. All experimental contingencies and response measures were programmed and recorded by a PDP-8 digital computer located in a separate room.

Experimental Design and Theoretical Predictions

The experimental design is presented in Table 1. In Phase I, two groups were distinguished on the basis of the number of components comprising the multiple schedule. The numbers of parentheses indicate the absolute number of reinforcements received per session in each component.

In Phase II each of the two groups in Phase I are further divided into two groups. In one group (2-2I) two identical VI components were added to the multiple schedule, while in a second group (2-2R) the added components

TABLE 1
Design for Experiment 1

	<u>S1</u>	<u>S2</u>	<u>S3</u>	<u>S4</u>
<u>Phase I</u>				
Group 2	VI 1 (20)	VI 1 (20)		
Group 4	VI 1 (20)	VI 1 (20)	VI 1 (20)	VI 1 (20)

<u>Phase II</u>				
Group 2-2I	VI 1 (20)	VI 1 (20)	VI 1 (20)	VI 1 (20)
Group 2-2R	VI 1 (20)	VI 1 (20)	VI 2 (10)	VI 2 (10)
Group 4-2E	VI 1 (20)	VI 1 (20)	Ext.	Ext.
Group 4-2D	VI 1 (20)	VI 1 (20)		

Phase III - Generalization tests

provided lower frequency of reinforcement than the existing components. In a third group (4-2E) responding continued to be reinforced in only two of the original four components. In the fourth group (4-2D) two of the four components were deleted from the multiple schedule.

In Phase III all subjects received two generalization tests. Eight line orientation values were employed in each of these tests.

The changes in reinforcement conditions in Phase II associated with two of the multiple schedule components for groups 2-2R and 4-2E occur in relation to two other (constant) components. In addition, two of the four components provided lower frequency of reinforcement in each of these groups. Therefore, each of the four current theoretical interpretations of contrast would predict the occurrence of positive contrast in groups 2-2R and 4-2E. Reynolds' relative reinforcement hypothesis would attribute these effects to the fact that two schedule components in each of these groups provide a higher relative reinforcement frequency than the remaining components in Phase II. Predictions derived from Terrace's response rate hypothesis are based upon the assumption that a less frequent reinforcement schedule will produce a lower rate of responding. The aversive qualities (ie: frustration) associated with a lower rate of responding are presumed to be responsible for positive contrast. Likewise, the presence of components providing less frequent reinforcement should constitute a

"worsening of conditions" associated with these components of the multiple schedule and therefore, positive contrast according to a preference theory (Bloomfield). Finally, the differential reinforcement frequencies provided by components of the multiple schedule should establish differential stimulus-reinforcer relations which should produce positive contrast according to the additivity theory of Gamzu and Schwartz.

The changes in reinforcement conditions in Phase II associated with two of the multiple schedule components for groups 2-2I and 4-2D do not occur in relation to other components. The addition of two equally valued schedule components results in an increase in the number of reinforcements received per session for group 2-2I. This change also results in a decrease in the relative reinforcement frequency provided by the two (constant) components common to each phase. However, this decrease occurs between successive experimental phases; within Phase II each of the four components provide identical absolute and thus, relative frequencies of reinforcement. Therefore, neither of the four theories under discussion would predict the occurrence of contrast in this group. Reynolds stated that the change in reinforcement frequency in the presence of a particular stimulus relative to the reinforcement frequency during other stimuli controlling behavior was partly responsible for the occurrence of contrast. Therefore, the decrease in relative frequency produced by

the present procedure should not result in contrast for group 2-2I. The addition of two equally valued components would not be expected to produce a decrease in responding to any of the four components, therefore, Terrace would also predict that contrast would not be obtained in this group. Further, as the addition of equally valued components would not constitute a "worsening of conditions" associated with the multiple schedule in Phase II, preference theory would also predict that contrast will not be obtained. Finally, as there is no basis for the establishment of a differential stimulus-reinforcer relation an additivity theory would not predict the occurrence of contrast.

The deletion of two equally valued schedule components in group 4-2E produced a decrement the number of reinforcements received per session, but an increase in the relative frequency of reinforcement provided by the remaining (constant) components in Phase II. However, based upon similar considerations as those described above, none of the current theoretical accounts would predict the occurrence of contrast in this group. As the increase in relative reinforcement frequency produced by the present manipulations did not occur in relation to the reinforcement conditions prevailing in other components, Reynolds would not predict the occurrence of contrast in group 4-2D. Similarly, the failure of the present procedure to produce a decrement in responding,

a "worsening of conditions" or a differential stimulus-reinforcer relation would lead to the same prediction according to the response rate, preference and additivity interpretations.

Procedure

Maintenance and preliminary training. Upon receipt from the supplier, all birds were individually caged and placed on ad libitum food and water for approximately one month. For an approximate four week period the Ss were handled daily and reduced to 75% of their free-feeding weight. All Ss were maintained at this weight throughout the experiment. Any S more than $\pm 15g$ of its' 75% body weight prior to the start of an experimental session was not run that day.

Preliminary training. The Ss were adapted to the experimental chambers and trained to eat from the food hoppers over the first four experimental sessions. Forty reinforcements were given each session. A 4 sec. presentation of mixed grain constituted a reinforcement throughout the experiment. General illumination was provided by the houselight with the hopper light illuminated during reinforcement presentations. The response key was darkened during this phase.

On the fifth experimental day the Ss were trained to peck the response key by the automatic key peck training

method of Brown and Jenkins (1968). In the present procedure the response key was illuminated by white light for a period of 8 sec. A reinforcement was presented for key-pecks which occurred during this interval or at the completion of this interval if no response occurred. The response key was darkened for 60 sec. following the presentation of a reinforcement under either of the above contingencies. A session terminated following the presentation of forty reinforcements. Two Ss (#5 and #12) failed to consistently respond after four sessions under this procedure and were manually shaped to peck the key.

Four sessions were then given under an increasing multiple FR schedule, Mult.FR 5, 10, 20, 40. The response key was alternately illuminated by horizontal (0°) and vertical (90°) lines. A 5 sec. interstimulus interval, during which time only the houselight was illuminated, separated successive stimulus presentations. A session terminated following the attainment of twenty reinforcements in the presence of each stimulus.

Phase I. Six Ss were randomly assigned to one of the two experimental groups. One group continued to receive presentations of the 0° and 90° line orientations while a second group also received presentations of the $22\frac{1}{2}^{\circ}$ line orientation and its' mirror image.

Phases I and II involved multiple VI schedule training. The mean inter-reinforcement intervals for each schedule are presented in Table 1. The range of different inter-

reinforcement intervals generated under these schedules approached infinity with a lower boundary of 5 sec. Such a distribution of intervals insured that reinforcement occurred with a given probability that remained constant as a function of time since the last reinforcement.

Component durations were 2 min. in length. A reinforcement programmed at the completion of a component, but not obtained, was cancelled. Stimulus presentation order was randomly determined with the restriction that over a block of four presentations each stimulus was presented an identical number of times.

Phase II. The two phase I groups were further divided into two groups in this phase. In two of these groups two additional VI components were added to the two component multiple schedule. In group 2-2R the added components were reinforced under a VI-2 minute schedule while responding in the two existing components continued to be maintained under a VI-1 minute schedule. In group 2-2I responding in the added components was reinforced under an identical VI-1 minute schedule to that effect during the existing components.

The group responding under the four component schedule in Phase I was also divided into two groups during Phase II. In group 4-E reinforcement never occurred in the presence of two of the four components. In group 4-2D two components were deleted from the multiple schedule in Phase II.

Phase III. This phase involved two generalization tests in extinction for each subject. Eight different white line orientations were used as stimuli: 0° , $\pm 67\frac{1}{2}^{\circ}$, $\pm 45^{\circ}$, $\pm 22\frac{1}{2}^{\circ}$ and 90° . The stimuli were presented 10 times a session in eight randomized blocks for 30 sec. presentation periods. A 5 sec. blackout (no illumination) separated successive presentations.

RESULTS

Behavioral Contrast

In order to provide a definition consistent with all procedural manipulations employed in the present study, behavioral contrast was defined as changes in response rate during the constant components independent of response rate alterations in the "changed" components. In evaluating the rate changes in the constant components during Phase II, the following criterion was employed for labelling such changes as contrast. For each subject, contrast was said to occur only if the mean responses rate in the constant components during any six consecutive Phase II sessions was greater than two standard deviations from the mean response rate in these component during the last six baseline (Phase I) sessions.

Figures 1 and 2 show absolute response rates, averaged over two-day blocks, for each subject during the last six days of baseline and the twenty-two days of Phase II training. Response rate was defined as the number of responses emitted in the presence of a given stimulus divided by the time spent in the presence of that stimulus, excluding reinforcement time. Figures 3 and 4 show the absolute change in responses per minute to the constant components during the twenty-two days of Phase II training. These measures were obtained by

Fig. 1. Mean rates of responding for groups 2-2R (left column) and 2-2I. The 0° and 90° line orientations were correlated with VI 1-min schedules in both phases.

BLOCKS OF TWO SESSIONS

Fig. 2. Mean rates of responding for groups 4-2E (left column) and 4-2D. The 0° and 90° line orientations were correlated with VI 1-min schedules in both phases.

2 VI 1 → 2 VI 1 2 VI 2

2 VI 1 → 4 VI 1

RESPONSES PER MINUTE

BLOCKS OF TWO SESSIONS

Fig. 3. Mean change in responses per minute to the constant components during phase II for groups 2-22 (left column) and 2-21. The dashed horizontal lines indicate ± 2 standard deviation values from the terminal response rate in phase I.

Fig. 4. Mean change in responses per minute to the constant components during phase II for groups 4-2E (left column) and 4-2D. The dashed horizontal lines indicate ± 2 standard deviation values from the terminal response rate in phase I.

calculating the difference between the mean daily response rates in Phase II and the mean terminal rates, last six sessions, during the baseline phase.

Group 2-2R (2 VI 1; 2 VI 1, 2 VI 2). The data for the three subjects in this group are presented in the left column of Figures 1 and 3. All three subjects were responding at approximately equal rates in the two components at the completion of baseline training (left panels in Figure 1).

The right panels in Figure 1 show response rates following the introduction of the two VI 2 components. Response rates in the two VI 1 and two VI 2 components did diverge with continued discrimination training. A clear separation in response rates between these components, defined as a difference of 10 responses per minute, was shown by all subjects after approximately sixteen to eighteen discrimination sessions. The mean response rates in the two added VI components over the last six sessions of Phase II were between eight and ten responses per minute lower than the constant component rates over the same period of baseline training.

The mean response rate increments to the constant components over the last six Phase II sessions in comparison to the baseline mean, varied between ten and thirteen responses per minute. As shown in Figure 3 (left column), the mean constant component rate increments were greater than two standard deviations from the baseline mean for

subjects #5 and #15. Thus, positive contrast was obtained in two of the three subjects in this group.

Group 2-2I (2 VI 1; 4 VI 1). The data for the three subjects in this group are presented in the right hand columns of Figures 1 and 3. As shown in Figure 1 (left panels), all three subjects were responding at approximately equal rates to the two components at the completion of baseline training.

The introduction of two additional VI 1 components (right panels) resulted in an initial increase in response rates to all components, in comparison to the constant components baseline mean, for subjects #1 and #11. The mean rate over the last six Phase II sessions in the added components was ten and six responses per minute above the constant components baseline rate for subjects #1 and #11, respectively. Subject #7 showed an initial separation in response rates between an added and a constant component and the two remaining components, followed by an increase in rate to all components. The mean response rate in the added components at the completion of Phase II was approximately forty responses per minute higher than the mean baseline constant component rate for subject #7.

As shown in Figure 3 (right column), the mean constant components rate increment over the last six Phase II sessions was greater than two standard deviations from the mean baseline value in these components for

subjects #1 and #7. Therefore, positive contrast was obtained in two of the three subjects in this group.

Group 4-2E (4 VI 1; 2 VI 1, 2 Ext.). The data for the three subjects in this group are presented in the left columns of Figures 2 and 4. Inspection of Figure 2 (left panels) indicates that daily response rates appeared stable and approximately equal to all four components for subject #3 at the completion of baseline training. However, subject #6 showed rate differences of approximately twelve responses per minute in one or more stimulus components and subject #12 showed differences of approximately thirty responses per minute in daily response rates over this period.

The introduction of extinction in two of the four components resulted in differential responding for all three subjects. Inspection of Figure 2 indicates that subjects #6 and #12 showed a clear separation in response rates (a difference of ten responses per minute) between the VI and extinction components by the sixth Phase II session. However, subject #3 does not show a clear separation in rates to these components until the tenth Phase II session. Responding in the extinction components did reach a relatively low level for all three subjects at the completion of Phase II. The mean extinction components response rate over the last six Phase II sessions was ten or fewer responses per minute for all three subjects.

The general pattern of constant component responding in Phase II is also similar for subjects #6 and #12. As shown in Figure 4 (left column), responding in the 0° (horizontal) stimulus component is higher than in the 90° (vertical) component for these two subjects. That is, higher response rates were obtained in the S+ value with the greatest physical similarity to the S- values ($+22^{\circ}$ from the horizontal line). In addition, response rates to the 90° orientation reached a "peak" or maximum rate after six or eight Phase II sessions for subjects #12 and 6, respectively. The response rates in this component then demonstrate a general tendency to return to the mean baseline rate.

Inspection of Figure 2 indicates that no subject in the present group maintained increments in responding to the constant components greater than two standard deviations from the baseline mean. Thus, no subject in this group demonstrated positive contrast according to the present criterion.

Group 4-2D (4 VI 1; 2 VI 1). The data for the three subjects in this group are presented in the right hand columns of Figures 2 and 4. As can be seen in Figure 2 (left panels), at the completion of baseline training daily response rates appeared stable and approximately equal to the four components for all three subjects. The removal of two of the original VI components resulted in a general decrease in response rates to the remaining (constant) components over the first eight to twelve

Phase II sessions. Inspection of Figure 4 indicates that the terminal Phase II constant components response rate for subject #14 decreased below two standard deviations from the baseline mean. Thus, negative contrast was obtained for only one subject in this group.

Generalization

The results of the generalization tests are presented in Figures 5 and 6. The relative generalization measures shown are proportional indices based upon the total number of responses to a particular stimulus in relation to the total number of responses emitted. The steepness of the gradient slopes and the height of "peak" responding was employed in evaluating the degree of differential stimulus control exerted by the line tilt continuum.

The gradients obtained for the three subjects in group 4-2E are presented in Figure 5 (left column). Inspection of these Figures indicates that the gradients obtained for each subject in this group are steep with bi-modal peaks in responding occurring to the two S+ values.

The gradients obtained for each subject in group 4-2D are shown in the right column of Figure 6. The gradients for each subject in this group are relatively flat and non-peaked. These characteristics indicate little differential stimulus control by the line tilt continuum.

The gradients for group 2-2R are presented in the left column of Figure 6. In general, each of these

Fig. 5. Relative generalization gradients for groups 4-2E (left column) and 4-2D. The multiple schedule in effect in Phase II is indicated at the top of each column.

Fig. 6. Relative generalization gradients for groups 2-2R (left column) and 2-2I. the multiple schedule in effect in Phase II is indicated at the top of each column.

gradients is convex in shape. In addition, all three subjects show bi-modal response peaks to the two stimulus values associated with a higher reinforcement frequency during Phase II.

The gradients for group 2-2I are shown in the right column of Figure 6. The gradients obtained for subjects #1 and #7 are relatively flat and non-peaked, suggesting little differential control by line orientation. As with the comparison between groups 4-2D and 4-2E, the present gradients may be distinguished from those obtained in group 2-2R by the lack of gradient curvature and the failure to obtain peak responding to those stimulus values associated with the multiple schedule in Phase II. The gradient obtained for subject #11 does indicate some curvature and response peaks to two of the four line orientations associated with the multiple schedule in Phase II.

Summary

Table 2 summarizes the effects obtained in Phase II. The subjects listed in the second column of this Table demonstrated contrast according to the present criterion, while those listed in column three demonstrated constant component rate changes indicative of contrast.

The introduction of two additional components, regardless of whether they provided a lower reinforcement frequency (group 2-2R) or the same frequency (group 2-2I)

TABLE 2
Summary of Contrast Effects Obtained in Experiment 1

<u>Type of Contrast</u>	<u>Subjects Demonstrating Effects</u>	
	<u>Experimental Criterion</u>	<u>Directionality of Response Rates</u>
Group 2-2I Positive	1, 7	11
Group 2-2R Positive	5, 15	8
Group 4-2E Positive		3, 6, 12
Group 4-2D Negative	14	4, 9

as the existing schedule components, produced positive contrast in two of the three subjects in each of these groups. The introduction of extinction in two of the four schedule components (group 4-2E), while producing a general increase in response rates in both constant components, failed to produce positive contrast, according to the present criterion. However, the removal of two components comprising the multiple schedule (group 4-2D) produced a general decrement in responding to the remaining components. These decrements met the present criterion defining negative contrast for one of the three subjects in this group.

The generalization gradients obtained for each subject in group 4-2E indicated the development of differential stimulus control by line orientation. The gradients obtained for the subjects in group 2-2R showed qualitatively similar characteristics to those of group 4-2E. However, the gradients obtained for subjects in groups 4-2D and 2-2I were relatively flat and non-peaked, suggesting little differential control by line orientation.

DISCUSSION

Empirical Considerations

The contrast effects obtained in the present study extend the variety of procedures by which contrast has been produced. However, the nature of the effects produced by the addition or deletion of schedule components indicate that they cannot be accounted for by differential stimulus characteristics associated with exteroceptive discriminative stimuli. The addition of two identical variable interval components (group 2-2I) produced positive contrast in two subjects, despite the fact that in Phase II there was a decrease in the relative reinforcement frequency in the schedule components common to each phase. Positive contrast has typically been obtained within a two component multiple schedule when relative reinforcement frequency increases in the constant components (Introduction, pp. 7-8). The deletion of two components (group 4-2D) in Phase II resulted in general decrements in responding to the remaining components for all three subjects, and negative contrast for one subject. This procedure produced an increase in the relative reinforcement frequency in the two components common to each phase. Negative contrast has typically been obtained following a decrease in the relative reinforcement frequency in the constant component of a two component multiple schedule (Introduction,

pp. 8-9). Thus, the present procedures used to vary relative reinforcement frequency produced contrast effects that were opposite in direction to those obtained following variations in reinforcement frequency within a standard two component multiple schedule.

The present procedures are similar to those employed in investigations of responding under the same variable interval schedule in isolation and in a multiple schedule context (Spealman and Gollub, 1974, Experiment 2; Terrace, unpublished, described by Herrnstein, 1970, p. 265 and Rachlin, 1973, p. 229). In the Terrace study, pigeons were first exposed to a single variable interval schedule. After response rates were judged stable, a second identical variable interval component was added (mult. VI, VI). Terrace found that response rates in the component common to both phases were on the average 30% lower in the multiple schedule. However, Spealman and Gollub (1974) reported that response rates maintained by a VI schedule in isolation were similar to rates maintained by the same schedule in a two component multiple schedule. These results suggest that the addition or deletion of schedule components in the present study should have produced either no differences in responding in the schedule components common to each phase (Spealman and Gollub, 1974) or lowered rates in the two as compared to the four component schedule combinations (Terrace, unpublished).

The discrepancies between the results obtained by Terrace, Spealman and Gollub and the present findings are

probably not due to differences in the variable interval schedules employed. Terrace and the present study used a mean inter-reinforcement interval of 60 sec., while Spealman and Gollub used intervals which bracketed this value (30 and 180 sec.). However, one major procedural difference in the present study was the variation in two equally valued components as opposed to one. That is, the multiple schedule was comprised of at least two equally valued components. It might be argued that in the present procedure the reinforcement event as a stimulus exerted greater control over responding than did the exteroceptive stimuli associated with the multiple schedule components. Partial support for this assumption is provided by the fact that subjects in groups 4-2D and 2-2I showed essentially equal rates of responding in each component of the multiple schedule in Phases I and II and to all line orientations presented in the generalization test. Further, it might also be assumed that the performance of subjects in these groups in Phase II was under the control of the direction of change in the reinforcing event in Phase II. In this phase there was a change in the absolute number of reinforcements received per session. This interpretation suggests that the increase in the number of reinforcements per session in Phase II produced a general enhancement in responding for the subjects in group 2-2I. Correspondingly, the reduction in the number of reinforcements per session may have produced the general decrements in responding for

subjects in group 4-2D. Thus, the contrast effects obtained in groups 2-2I and 4-2D were inversely related to alterations in relative reinforcement frequency associated with the two components common to each phase, but were directly related to the change in absolute number of reinforcements received per session. The present interpretation emphasizes the stimulus properties of differential reinforcement (absolute number of reinforcements) rather than the stimulus properties of discriminative stimuli that are correlated with different reinforcement conditions (relative reinforcement frequency).

Several investigations employing a multiple schedule paradigm have reported effects similar to those obtained in groups 2-2I and 4-2D. Arnett (1973) reported an increase in local response rates immediately after food presentations in the variable interval component of a mult. VI ext. schedule. He concluded that this local positive contrast effect indicates that reinforcement presentations produce comparable effects to other distinct exteroceptive stimuli in multiple schedules. Indeed similar local contrast effects are obtained following the transition to a schedule component signalling a higher density of reinforcement (Arnett, 1973; Nevin and Shettleworth, 1966; Rachlin, 1973). Boakes, Halliday and Poli (1975, Experiment 1) obtained positive contrast when response independent reinforcements were added to one component of a mult. VI 2, VI 2 schedule.

That is, contrast was obtained when the absolute number of reinforcements received per session increased in one component of the multiple schedule. Further, Boakes, et al (1975) reported that the removal of these additional reinforcements produced a decrease in response rates in this component. That is, a reduction in the absolute number of reinforcements per session produced a negative contrast effect.

The general response patterns associated with the constant component stimuli for two subjects (6 and 12) in group 4-2E, suggest a functional relation between the physical difference in component stimuli and the magnitude of contrast. These subjects consistently demonstrated higher rates of responding in the positive stimulus value (horizontal line) more adjacent to the stimulus values correlated with extinction ($+22^{\circ}$ from horizontal). Similar effects have been reported in several investigations which employed line orientation (Farthing, 1974; Malone, 1975). These authors reported that the maximum rate of responding typically occurred to an orientation value more nearly adjacent to the negative (S-) set as opposed to those values most distant from the S- set. Therefore, portions of the present data support the conclusion that contrast is greater with a relatively small or moderate physical separation between the S+/S- values than with a relatively large difference in these values (Farthing, 1974; Malone, 1975).

The general pattern of responding in the horizontal orientation shown by subjects 6 and 12 is also similar to an effect termed "peak contrast", which has been obtained in several studies employing a mult. VI ext. schedule (eg: Bloomfield, 1966; Sadowsky, 1973). This phenomenon is exhibited when, after reaching an initially high (peak) rate, responding in the positive stimulus returns toward the baseline level. Bloomfield (1966) attributed the occurrence of peak contrast to the use of a "correction" procedure in the extinction component, where any responding toward the end of this interval postponed the onset of the variable interval component. Sadowsky (1973) indicated that the use of a correction procedure basically results in a more rapid reduction of responding in the extinction component than if no such contingency was used. He suggested that the occurrence of peak contrast in studies which did not employ a correction procedure might be attributed to the rapid decrement (first few discrimination sessions) in responding in the extinction component. The peak rate effects shown by subjects 6 and 12 are also associated with an earlier reduction in responding in extinction than found for subject 3, which did not show peak rate effects. Thus, the present findings provide further support for Sadowsky's hypothesis regarding the empirical conditions associated with the occurrence of peak contrast.

Positive contrast was obtained in two subjects (5 and 15) following the addition of two new schedule components. Buck, Rothstein and Williams (1975) obtained positive contrast by adding two extinction components to an existing two component multiple schedule. In the present study the added components provided a lower reinforcement frequency than the existing schedule components. The present results extend the reinforcement conditions under which behavioral contrast can be obtained in a multiple schedule paradigm.

The present discussion has indicated several implications regarding the empirical specification of interaction effects obtained within a multiple schedule paradigm. However, one limitation of the present results is the magnitude of the contrast effects obtained. There are at least two explanations for the relatively weak effects obtained in the present study; the schedule of reinforcement in the constant components, and the length of non-differential or baseline training. The results from several investigations indicate that the magnitude of contrast may be higher for behavior maintained by less frequent reinforcement in the constant component of a multiple schedule (Reynolds, 1963; Spealman and Gollub, 1974, Experiment 1). Reynolds reported that contrast was larger when responding in the constant component was maintained by 20 reinforcements per hour as opposed to 38 per hour. Spealman and Gollub also reported that the magnitude of contrast, in terms of absolute rate change,

was higher with a VI 3 min. schedule in the constant component as compared to a VI 30 sec. schedule in this component. The VI 1 min. schedules used in both constant components in the present study provided a frequency of approximately 48 reinforcements per hour. Thus, the present values closely approximate those which have been shown to produce relatively weak contrast effects. The present findings support the conclusion that the magnitude of contrast appears to be inversely related to the frequency of reinforcement that maintains responding. In addition, these findings suggest that this relationship can be extended to multiple schedules employing more than one constant component.

Spealman and Gollub (1974) also suggested that differences in the magnitude of contrast may in part depend upon the baseline rate of responding. In general, rates of responding maintained by less-frequent reinforcement are usually lower than those maintained by more frequent reinforcement (eg: VI 5 min. as opposed to VI 1 min.). Therefore, the magnitude of contrast may be determined in part by the on-going rate of responding independent of reinforcement frequency. Spealman and Gollub reported evidence which indicated that the magnitude of contrast was inversely related to the ongoing rate of responding in the constant component. The relatively high rates of responding obtained in the four component multiple schedules during baseline training in the present study might partially

explain why only one of six subjects in groups 4-2E and 4-2D demonstrated contrast, according to the present criterion. However, in the present study as in the Reynolds and Spealman and Gollub studies, the frequency of reinforcement and the rate of responding in the constant component covaried. Therefore, these studies do not provide a direct assessment of the independent effect of these variables on the production of contrast. Reynolds and Catania (1961) did report a rate dependent relation with respect to contrast obtained in the fixed interval component of a mult. FI ext. schedule. Fixed interval responding is characterized by lower rates in the initial portions and higher rates in the terminal portions of the interval. Reynolds and Catania found a proportionally greater increase in responding during the initial as compared to the latter portion of the FI schedule.⁸

A second issue concerning reinforcement frequency is the relatively low ratio between the VI 1 min. and VI 2 min. (two-to-one) components employed in group 2-2R. Wheatley and Thomas (1974) reported that a five-to-one difference in reinforcement frequency between two components (mult. VI 1 min., VI 5 min.) produced a larger contrast effect than did a two-to-one difference between components (mult. VI 2.5 min, VI 5 min.). The relatively

⁸Rate dependent relations have also been reported with other phenomena, such as drug effects (Kelleher and Morse, 1968) and conditioned suppression (Blackman, 1968).

weak effects obtained in group 2-2R may be partially attributable to the low ratio in reinforcement frequencies between the added and existing multiple schedule components.

Several authors have indicated the importance of obtaining asymptotic response measures in order to unequivocally classify response changes as instances of positive contrast and not simply performance increments due to additional training (Dunham, 1968; Gutman, Sutterer and Brush, 1975; Sadowsky, 1973). That is, the failure to insure that responding is asymptotic or stable prior to a change in reinforcement conditions might indicate that the positive effect is an artifact due to insufficient training. In the present study, 40 days of baseline training were required for most subjects to achieve stable response rates, particularly in the four component groups. The present procedures resulted in approximately 65 and 34 hours of exposure to the four and two component schedules, respectively, in Phase I. These values constitute a considerably greater length in nondifferential training than is typically employed in studies of behavioral contrast (15 to 20 hours of VI training; see Sadowsky, 1973). Therefore, the present demonstrations of contrast cannot be attributed to the failure to provide an adequate baseline response rate for comparative purposes. However, the use of an extended period of baseline training may be partially responsible for the relatively small unstable or transient effects

that were obtained. Sidman (1960, p. 176-177) indicated that extended experience with variable interval reinforcement can result in the insensitivity of such a schedule to the effects of other variables. It is possible that in the present study a factor such as "proprioceptive control" or "locked rates" became important as a result of extended training, a factor which essentially weakened control by external stimuli. Gutman, et al, (1975) attributed their failure to obtain stable positive contrast effects in rats to the use of 53 hours of multiple schedule baseline training. Further,, Friedman and Gutman (1963) found that generalization gradients obtained after 30 days of VI training were flatter than those obtained following the more usual 7 to 14 days of such training. Hearst and Koresko (1968) suggested a similar interpretation in terms of locked rates following extended VI training to account for these differences. In summary, the nature of the present results suggests that an important variable determining the occurrence of behavioral contrast is the length of baseline training employed.

Theoretical Considerations

One theoretical issue raised by the present results concerns the differential effects obtained as a function of the discriminative context in which alterations in number of reinforcements occurred. The contrast effects

obtained following the addition or deletion of equally valued components (group 2-2I and 4-2D) were interpreted as a direct function of the absolute change in number of reinforcements received per session. This interpretation is similar to accounts of contrast obtained in nondiscriminative procedures which state that behavior is controlled by the direction of the change in some dimension of the reinforcement event, ie: number or magnitude of reinforcement (Dunham, 1968). The contrast effects obtained in more standard multiple schedule procedures (2-2R and 4-2E) were directly related to properties of different reinforcement conditions correlated with different discriminative stimuli, ie: relative reinforcement frequency. Each of these interpretations indicate that contrast is dependent upon the development of differential stimulus control. However, the present results suggest that the nature of the contrast effect obtained is, at least partially dependent upon the type of stimulus control established.

The present distinction may be relevant to recent discussions regarding the independence of various types of contrast effects obtained in multiple schedules. As previously indicated, several authors (Buck, et al, 1975; Dunham, 1968; Freeman, 1971; Mackintosh, et al, 1972; Premack, 1969; Scull, et al, 1970) have suggested that the different patterns of local and overall contrast may indicate separate, independent interactions. These empirical distinctions might be a function of whether

discriminative control is established by some dimension of the reinforcement event or by another exteroceptive stimulus dimension correlated with reinforcement. As previously mentioned, in addition to the present findings, the results from several investigations suggest that the reinforcement event can function as a discriminative stimulus and that the establishment of control by such stimuli is sufficient for the development of contrast. For example, Pear and Wilkie (1970) and Scull, et al. (1970) obtained positive contrast in a two component sequential schedule that did not have different exteroceptive stimuli correlated with each component (a mixed schedule). Further, Arnett (1973) reported a local positive contrast effect immediately following the presentation of reinforcement in a mult. VI ext. schedule. The present discussion will be primarily concerned with the applicability of the four current theoretical interpretations of behavioral contrast to a number of separate and possibly independent contrast effects obtained in multi-component sequential schedules.

Reinforcement Rate Hypothesis. Reynolds (1961) stated that the rate of responding in the presence of a given stimulus was partly determined by the frequency of reinforcement in the presence of that stimulus relative to the frequency during all other stimuli controlling behavior. Specifically, an increase in the relative frequency associated with one stimulus produces an increase

in rate of responding, while a decrease in relative frequency produces a decrease in rate of responding. That is, according to this descriptive account positive contrast results from an increase in the relative reinforcement frequency in the constant component, while negative contrast results from a decrease in relative frequency in the constant component. This interpretation can account for the positive effects obtained in the modified multiple schedules associated with groups 4-2E and 2-2R. The change from reinforcement to extinction in two components for group 4-2E produced an increase in the relative frequency associated with each of the constant components (Phase I = 20/80 or 25%, Phase II = 20/40 or 50%). Likewise, the introduction of two components which provided a lower absolute reinforcement frequency for group 2-2R also produced a higher relative reinforcement frequency in each of the constant components in Phase II (constant component = 20/60 or 33%, added component = 10/60 or 16%). Thus, in addition to reducing the absolute frequency of reinforcement in components currently comprising the multiple (group 4-2E), the addition of components providing less frequent reinforcement (group 2-2R) also produces positive contrast.

Reynolds' interpretation, in its present formulation, cannot account for the effects obtained in groups 4-2D and 2-2I. The deletion of two components in Phase II resulted in an increase in the relative reinforcement frequency associated with each of the remaining (constant)

components for group 4-2D (Phase I = 20/80 or 25%, Phase II = 20/40 or 50%). Therefore, Reynolds might predict increased response rates or positive contrast in the remaining components. However, response rates generally declined for all three subjects in this group. Conversely, the addition of two identical VI components for group 2-2I resulted in a decrease in the relative frequency associated with each stimulus common to both phases (Phase I = 20/40 or 50%, Phase II = 20/80 or 25%). However, instead of the predicted decrease in response rates or negative contrast, all three subjects showed a general increase in responding to the constant components. These results suggest that the direct relationship between response rates and relative reinforcement frequency predicted by Reynolds is limited to situations in which alterations in relative frequency in the constant components occur in relation to an absolute change in the reinforcement frequency in other schedules that currently control behavior.

Reynolds does not elaborate on the assumed process by which an organism is able to discriminate changes in relative reinforcement frequency. The present results suggest that such a process is dependent upon differences in absolute reinforcement frequency between components comprising the multiple schedule. The results from several investigations indicate that this process is not dependent upon the presence of exteroceptive discriminative stimuli correlated with different reinforcement frequencies.

Pear and Wilkie (1970) and Scull, et al (1970) obtained positive behavioral contrast in a mixed schedule of reinforcement, a two component schedule in which neither component was correlated with an exteroceptive discriminative stimulus.

Response Rate Hypothesis. Terrace (1972) considers behavioral contrast to be one by-product of the formation of a discrimination between two or more stimuli. The general model of the acquisition of a discrimination proposed by Terrace is similar to an earlier theory of discrimination learning proposed by Spence (1937).

Spence stated that the strength of responding to a stimulus value correlated with reinforcement (S+) was a function of the positive tendency (excitation) generated by this stimulus and the negative response tendency (inhibition) generated by a stimulus correlated with extinction (S-). As a function of the combination of these response tendencies, Spence predicted that at the start of a discrimination there would be a decrease in the strength of responding to S+. That is, Spence's theory would predict that negative contrast (or negative induction according to Reynolds' definition) would be obtained in a mult. VI ext. schedule due to the generalization of inhibition from S- to S+. Thus, Spence's excitation-inhibition theory cannot account for the occurrence of positive contrast typically obtained in a multiple schedule.

Terrace's account of discrimination learning postulates that the generalized effects of extinction are not exclusively negative. Specifically, Terrace considers behavioral contrast to be a by-product of frustration and conditioned inhibition which occur in the presence of the S- or changed component. That is, Terrace considers positive contrast to be an emotion-produced enhancement of responding resulting from the suppression of responding in S-. This interpretation also suggests that the magnitude of the contrast effect will be a function of the difficulty of the discrimination. If it were assumed that the emotion-produced enhancement of responding to a difficult discrimination is greater than that produced by a relatively easy discrimination, then contrast should be greater with a more difficult discrimination. As previously indicated, the results from two studies that employed several S+ and S- values on a continuum and portions of the present data (subjects 6 and 12, group 4-2E) support the conclusion that contrast is greater with a relatively small or moderate physical separation between S+/S- values (Farthing, 1974; Malone, 1975).

Terrace's account of behavioral contrast emphasizes what may be termed the nondiscriminative functions (i.e. frustration) associated with explicit discriminative stimuli. The contrast effects obtained in groups 4-2D and 2-2I were attributed to the differential control exerted by alterations in the absolute number of

reinforcements. Therefore, an interpretation based upon the emotional reactions to the discrimination situation is probably not applicable to the present findings. A somewhat more parsimonious interpretation of these effects is the emotional-motivational account of changes in reinforcement conditions in simple instrumental learning situations (Amsel, 1962; Spence, 1956). Spence postulated that instrumental performance was mediated by an excitatory process termed incentive motivation. The strength of this assumed process was partly determined by the magnitude of reinforcement that maintained responding. Therefore, an increase in the strength of the instrumental response as a function of an increase in the reinforcement magnitude was due to the change in this excitatory process. This explanation might also account for the general increase in responding obtained for group 2-2I following the increase in absolute number of reinforcements. The general decrements in responding produced in group 4-2D by the decrease in absolute number of reinforcements may be the result of disruptive emotional factors. Amsel (1962) postulated that in addition to the process of incentive motivation associated with reinforcement, nonreinforcement (extinction) was associated with an emotional process termed frustration. Further, frustration was assumed to disrupt ongoing behavior by competing with approach responses maintained by incentive motivation. If it were assumed that a reduction in the

number of reinforcements results in similar emotional consequences as nonreinforcement, then Amsel's theory could account for the effects obtained in group 4-2D. That is, the general decrements in responding may have been produced by the competition between instrumental behavior and avoidance tendencies elicited by proprioceptive stimuli associated with frustration.

The interpretation discussed above emphasized similar mechanisms (excitation, frustration) employed by Terrace to account for behavioral contrast in multiple schedules. However, in the present account the changes in behavior were directly related to the assumed alterations in these processes, while in Terrace's account contrast was attributed to the generalized effects produced in an independent reinforcement condition. Finally, the present interpretation is indeed tentative given the current lack of experimental data concerning the comparability of effects produced by various reinforcement parameters (i.e. frequency, magnitude) in both simple instrumental and multiple schedule paradigms.

Preference Hypothesis. Bloomfield (1970) and Premack (1969) hypothesized that positive behavioral contrast results from an increased preference for the constant component of a multiple schedule. The change in the preference value associated with this component is produced by a "worsening of conditions" (Bloomfield) or a change in the "aversiveness" (Premack) associated

with alterations in the reinforcement conditions in a second component. These authors also indicate that both the introduction of extinction and a lower absolute reinforcement frequency associated with the changed component are sufficient conditions for the production of increased preference and therefore, positive contrast in the constant component. The positive effects obtained in groups 4-2E and 2-2I are, therefore consistent with the preference interpretation of contrast.

While a preference theory might account for the contrast effects obtained in groups 2-2I and 4-2D, certain characteristics of these effects pose difficulties for such an interpretation. In group 2-2I there was a general increase in responding to all four schedule components during Phase II. These effects suggest an increase in the preference value associated with this phase. However, the fact that these changes were not restricted to the two components common to each phase indicates that this change was not due to any aversive condition associated with the added components. Therefore, a preference theory cannot account for either the assumed increase in preference or response rates obtained in this group. The interpretation of the general decrements in responding obtained in group 4-2D encounters a related problem. These effects can be accounted for by assuming that the removal of two components constitutes an aversive condition with respect to the two remaining

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components. This account does not require additional assumptions regarding alterations in the preference structure.

Additivity Hypothesis. Gamzu and Schwartz (1973) postulated that positive contrast occurred as a result of the addition of elicited responding generated by a differential stimulus-reinforcer dependency to an operant baseline of responding. In a typical multiple schedule discrimination procedure (eg: mult.VI ext.), the response-reinforcer (operant) contingency will continue to maintain a given response rate in the constant component. In addition, the differential stimulus-reinforcer relation will also generate a given rate of responding. Thus, the combination of these response rates yields a positive contrast effect. In the present study, the introduction of extinction (group 4-2E) and two additional components providing a lower absolute frequency of reinforcement (group 2-2R) constitute two procedures that are sufficient for the establishment of a differential stimulus-reinforcer relation and therefore, the production of positive contrast.

Gamzu and Schwartz assumed that the occurrence of contrast was entirely dependent upon the differential signalling value of stimuli associated with reinforcement. This assumption implies that the magnitude of the effect is inversely related to the difficulty of the discrimination. In other words, an additivity theory might predict the largest increase in constant component rates with a large separation between $S+/S-$ values. As previously indicated

portions of the present data support the conclusion that contrast is greater with a relatively small or moderate separation between S+/S- values.

The positive contrast effects obtained in group 2-2I cannot be attributed to the establishment of a differential stimulus-reinforcer relation. These results suggest that contrast can be obtained as a function of the establishment of a differential response-reinforcer relation.

Additional support for this conclusion is provided by Keller (1974, Experiment 1), Pear and Wilkie (1970) and Scull, et al (1970). In an attempt to separate operant and elicited responding, Keller employed a two key multiple schedule procedure. Stimuli indicating components (VI or ext.) of the multiple schedule were located on one key (signal key), while a second key illuminated by a constant color provided reinforcement during the VI component. Keller reported that all subjects demonstrated contrast on the signal key that provided stimuli correlated with changes in the multiple schedule.

However, two of the three subjects in this study also demonstrated contrast on the constant key. As previously indicated, Pear and Wilkie (1970) and Scull, et al (1970) obtained positive contrast in a sequential schedule that did not have stimuli correlated with the schedule components (mixed schedule). These results suggest that the establishment of a differential stimulus-reinforcer dependency is not a necessary condition for the production of positive contrast.

Schwartz (1975) suggested that when negative contrast is obtained by a procedure that increases the reinforcement frequency in the changed component, the stimulus-reinforcer relation in the constant component becomes inhibitory. For example, if a mult. VI 3, VI 3 schedule were changed to a mult. VI 3, VI 1, the stimulus signalling the less-dense schedule (VI 3) will produce a decrement in responding or negative contrast. The negative contrast effects obtained in group 4-2D might be interpreted as the result of an analogous inhibitory response-reinforcer relation. That is, a reduction in the number of reinforcements per session produced a general suppression in responding to the remaining components.

The interpretations suggested for the effects obtained in groups 2-2I and 4-2D represent extensions in the additivity theory formulated by Gamzu and Schwartz (1973). The adequacy of these accounts requires further investigation of the empirical relationships between negative and positive contrast.

EXPERIMENT 2

The present study was originally designed to investigate the effects of variations in the presentation frequency of conditioned reinforcement on multiple schedule performance. The purpose of the present study was to determine whether variations in conditioned reinforcement would produce behavioral contrast.

As indicated in the introduction, behavioral contrast has been obtained following various types of alterations in the reinforcement schedule in the changed component of a multiple schedule. In these studies the same primary reinforcing stimulus (food) was used to maintain responding in both components. Contrast was obtained by either removing reinforcement (extinction), or altering the schedule of reinforcement in the changed component.

Several investigations of barpress responding in rats have employed different primary reinforcing stimuli in the alternate components of a multiple schedule (Beninger, 1972; Beninger and Kendall, 1975; Premack, 1969). These investigators obtained contrast following the removal of one of these reinforcers from one component of the multiple schedule. For example, Beninger and Kendall (1975) employed a two component multiple schedule in which responding in one component was reinforced by milk and reinforcement in the alternate component consisted of pellets. When responding was extinguished

in one component following the removal of either pellets or milk, positive contrast was obtained in the constant component. These results suggest that the occurrence of positive contrast is not dependent upon the similarity of the primary reinforcers used to maintain behavior. The present study attempted to further investigate this relationship by determining if similar effects could be obtained when conditioned reinforcement was varied rather than two different primary reinforcers. In the present study primary and conditioned reinforcement were independently manipulated in one component of a multiple schedule during successive experimental phases.

There is a rather extensive experimental literature which indicates that pairing a brief exteroceptive stimulus with a primary reinforcer is sufficient to establish it as a conditioned reinforcer. Further, this literature indicates that the scheduled presentation of a conditioned reinforcer can generate patterns and rates of responding similar to those generated by primary reinforcement (eg: DeLorge, 1969; 1971; Zimmerman, 1957; 1969). These general findings have been obtained under a variety of compound schedules, which are combinations of two or more simple schedules.⁹

⁹An extensive review of earlier research findings and experimental techniques is provided by Kelleher and Gollub (1962). A more recent compilation of research in this area is edited by Hendry (1969). Finally, discussions of the experimental literature with respect to specific paradigms are provided by Malagodi, De Wesse and Johnston (1973), comparing three types of second order schedules; Marr and Zieler (1974), comparing the response dependent and independent effects of brief stimuli in a conjoint schedule.

These findings suggest that variations in conditioned reinforcement should produce qualitatively similar contrast effects to those produced by primary reinforcement. The present study represents an initial attempt to determine the degree to which variations in these reinforcement parameters produce comparable contrast effects in a multiple schedule. As the present study is related to the issue concerning the importance of differential reinforcement frequency as a determinant of behavioral contrast, results from this study may have implications for the four current theoretical interpretations of behavioral contrast.

METHOD

Subjects and Apparatus

Twelve naive male White Carneaux pigeons, approximately one year old, purchased from the Palmento Pigeon Farm served as subjects. The four pigeon chambers described in Exp. 1 were modified for the presentation of an auditory stimulus, a 1,000 cps, 80db tone. A 28V dc buzzer, located directly behind a standard 8-ohm speaker mounted on the side wall, generated the tone.

Experimental Design and Theoretical Predictions

The original design for Experiment 2 is presented in Table 3. In Phase I a reinforcement presentation in both components of the multiple schedule consisted of food (primary reinforcement) paired with tone (conditioned reinforcement). In Phase II tone was no longer presented in the changed (S2) component. This manipulation constitutes the removal of a stimulus that formerly comprised a compound reinforcing event. Further, if this manipulation were interpreted as a reduction in the overall frequency of reinforcement maintaining responding, then each of the four theories previously discussed would predict the occurrence of positive contrast in this phase. A reinforcement rate hypothesis (Reynolds) would attribute this effect to the relative increase in stimuli maintaining responding

TABLE 3

Original design for Experiment 2
 Presentations of the tone were either paired
 with food or presented independently of food.

Stimulus Components

<u>Phase/Subjects</u>		<u>S1</u>	<u>S2</u>
I	All	VI 1 food, VI 1 tone(paired)	VI 1, food VI 1, tone(paired)
II	All	" "	VI 1 food
III	G ₁ n = 3	" "	VI 1 food VI 1 tone(paired)
	G ₂ "	" "	VI 1 food VI 2 tone(paired)
	G ₃	" "	VI 1 food VI 1 tone(independent)
	G ₄	" "	VI 1 food VI 2 tone(independent)

in the constant component. An additivity theory (Gamzu and Schwartz) would attribute the occurrence of positive contrast to the differential stimulus (conditioned) reinforcer relation established in this phase. The removal of conditioned reinforcement would result in a "worsening of conditions" (Bloomfield) or "aversiveness" (Premack) associated with the changed component and therefore, positive contrast according to the preference theory. Finally, the removal of the tone might be expected to produce a reduction in responding during the changed component. A response rate hypothesis (Terrace) would predict positive contrast, based upon the presumed aversive qualities associated with this decrease in responding.

In the original design for the present study, the tone was to be reintroduced during Phase III. Four groups were to be distinguished in this phase, with respect to the procedure by which tone was presented (paired vs independent) and the frequency of tone presentations (VI 1 or VI 2). The reintroduction of the tone, under each of the four procedures was designed to increase the frequency of reinforcing stimuli in the changed component. Therefore, each of the four theories presently under discussion would predict the occurrence of negative contrast in each of the four groups. Reynolds would attribute this effect to the decrease in relative reinforcement frequency provided by the constant component. Gamzu and Schwartz would attribute the

occurrence of negative contrast to the elimination of the differential stimulus (conditioned) reinforcer relation that produced positive contrast in the preceding phase. Likewise, a preference account would attribute these effects to a decrease in the aversiveness associated with the changed component and thus, a decrease in preference for the constant component. Finally, Terrace would predict that the removal of the aversive properties associated with the changed component that produced positive contrast in the preceding phase would result in negative contrast in Phase II.

The purpose of the proposed variation in the frequency of tone presentations (VI 1 vs VI 2) was to determine the existence of a functional relationship between the relative rate of conditioned reinforcement and the magnitude of the negative contrast effect. The purpose of the variations by which tone was presented (paired vs independent) was to determine if different levels of contrast would be obtained as a function of two operations which defined an increase in conditioned reinforcement frequency.

The rationale for the Phase III manipulations was based upon the assumption that a reliable positive contrast effect would be obtained in Phase II. However, only four of the twelve subjects demonstrated positive contrast with respect to the present criteria by the completion of six sessions in Phase II. Therefore, the original

design was altered in an attempt to simply determine the comparability of effects produced by the independent removal and subsequent reintroduction of tone and food. These design alterations are presented in Table 4. In Phase III food was no longer presented (extinction) in the changed component. This manipulation, as that employed in Phase II with respect to the tone, was intended to produce positive contrast. The tone and food paired with the tone were reintroduced in Phases IV and V respectively. It was predicted that each of these manipulations would result in the production of negative contrast.

Procedure

Maintenance and Preliminary Training. All procedural details regarding subject maintenance were identical to Experiment 1. The procedure in each phase of preliminary training was the same as that employed in Experiment 1, with the exception of reinforcement presentations. In the present study, a tone preceded each reinforcement presentation by one-second and terminated at the completion of the four second reinforcement duration.

Phase II. This phase involved training under identical VI schedule components. The VI schedules were constructed in the same manner employed in Experiment 1. As in all

TABLE 4
Design for Experiment 2

Stimulus Components

<u>Phase/Subjects</u>		<u>S1</u>	<u>S2</u>
I	All	VI 1 food, VI 1 tone (paired)	VI 1 food, VI 1 tone (paired)
II	All	"	VI 1 food
III	All	"	Ext.
IV	All	"	VI 1 tone
V	1,3,4 7,9,12	"	VI 1 food, VI 1 tone (paired)

subsequent phases, component duration was two minutes and the two components alternated in a semi-random order that specified a maximum of two successive repetitions of either component. A five-second black-out separated successive component presentations. A session was terminated following the presentation of twenty reinforcements (food & tone) in each component. All subjects received twenty-six sessions of Phase I training.

Phase II. In this phase the tone was no longer presented with food in the changed component.

Phase III. In this phase food was no longer presented in the changed component. At the completion of ten sessions, six subjects (#2, 5, 6, 8, 10 and 11) continued to show relatively high rates of responding in the changed (extinction) component and three of these subjects (#2, 10 and 11) failed to demonstrate positive contrast. Therefore, these six subjects were given four additional Phase III training sessions.

Phase IV. The tone was reintroduced on a VI-1 schedule during the changed component in this phase. All subjects received ten Phase IV sessions.

Phase V. Food was paired with the tone on a VI-1 schedule during the changed component in this phase. Six subjects (#1, 3, 4, 7, 9 and 12) received eight sessions of Phase V training. The six remaining subjects were not included in Phase V due to experimental time constraints.

RESULTS

Behavioral contrast was evaluated by a similar criterion to that employed in Experiment 1. In Phase II through Phase V, contrast was defined as rate changes in the constant component which exceeded two standard deviations from the mean rate in this component during the terminal sessions of the immediately preceding phase. The number of terminal sessions employed in determining this criterion was based upon the following estimate of stability. In Phases I through IV, responding during a number of sessions was considered stable if each daily rate during this period was less than two standard deviations of the mean rate over the designated sessions. This requirement was met by all subjects for the last six Phase I sessions, the last three Phase II sessions and the last four sessions in Phases III and IV. Therefore, the standard deviation values derived from these sessions were used to evaluate the occurrence of contrast in the immediately subsequent phase.

Figures 7 through 10 show the absolute response rates, averaged over two day blocks, for each subject during the last six Phase I sessions and all sessions in Phases II through V. The dashed lines in these figures indicate the values associated with two standard deviations from the mean rate in the constant component during the preceding phase.

Fig. 7. Mean rates of responding to the vertical (constant component) and horizontal line orientations. The dashed horizontal lines indicate ± 2 standard deviation values from the terminal response rate in the preceding phase.

Fig. 8. Mean rates of responding to the vertical (constant component) and horizontal line orientations. The dashed horizontal lines indicate ± 2 standard deviation values from the terminal response rate in the preceding phase.

Fig. 9. Mean rates of responding to the vertical (constant component) and horizontal line orientations. The dashed horizontal lines indicate ± 2 standard deviation values from the terminal response rate in the preceding phase.

Fig.10. Mean rates of responding to the vertical (constant component) and horizontal line orientations. The dashed horizontal lines indicate ± 2 standard deviation values from the terminal response rate in the preceding phase

Phase I. (VI + tone, VI + tone). At the completion of Phase I, the daily response rates appeared stable and approximately equal in the two components for five subjects (#1, 4, 9, 11, 12). The overall daily response rates continued to increase during this period for three subjects (#6, 8, 10), while four subjects (#2, 3, 5, 7) showed rate differences of approximately fifteen responses per minute in the two components for two or more sessions.

Phase II (VI + tone, VI). Four subjects (#6, 7, 10, 11) demonstrated rate increments in the constant component greater than two standard deviations above the mean terminal Phase I rate. That is, positive contrast was obtained for four subjects in this phase. The data for four additional subjects (#1, 4, 8, 12) showed response increments in the constant component throughout Phase II and a clear separation in rates (differences of ten or more responses per minute) in the two components. Two subjects (#2, 5) demonstrated a general decline in responding in the constant component throughout Phase II, while rates in this component decreased then increased over the last four sessions for the two remaining subjects (#3, 9).

Alterations in the response rates in the changed component were also evaluated in this phase by a comparison with the terminal (last six sessions) Phase I rates in this component. Subject #7 was the only subject that demonstrated both positive contrast and a reduction in

responding in the changed component below two standard deviations of the mean Phase I rate in this component. The production of positive contrast for two subjects (#10, 11) was associated with an increase in responding in the changed component above two standard deviations from the mean Phase I rate. Three of the four subjects (#1, 4, 8) which showed rate increments in the constant component throughout Phase II did produce response decrements in the changed component below two standard deviations from the mean Phase I rate. Finally, while there was a general tendency for lower rates of responding in the changed component during Phase II for the remaining six subjects (#2, 3, 5, 6, 9, 12), only two of these subjects (#2, 3) demonstrated response decrements below the standard deviation criteria and only for the first two sessions. Thus, only four subjects demonstrated positive contrast, and these constant component effects showed no systematic relation to responding in the changed component.

Phase III (VI + tone, ext.). Ten subjects (#12 and 11 were the exceptions) demonstrated increments in the constant component rates greater than two standard deviations above the Phase III mean (last three sessions) for at least six Phase III sessions. That is, ten subjects demonstrated positive contrast in this phase. Subject #2 did show increased rates of responding in the constant component throughout Phase III but not above the two

standard deviation criterion. However, response rates in the constant component for subject #11 decreased below two standard deviations of the mean Phase II rate for ten Phase III sessions. Thus, subject #11 showed negative contrast in Phase III.

All subjects showed overall decrements in responding in the extinction component during Phase III. However, as indicated in the procedure section, two groups may be distinguished with respect to the level of extinction responding at the completion of ten Phase III sessions. Six subjects (#1, 3, 4, 7, 9, 12) emitted twenty or fewer responses in extinction during sessions seven to ten. The remaining six subjects (#2, 5, 6, 8, 10, 11) emitted twenty or more responses in extinction during either sessions seven-eight and/or nine-ten. In addition, three (#2, 10, 11) of these subjects failed to demonstrate an unequivocal positive contrast effect following the completion of ten Phase III sessions. Therefore, six subjects (#2, 5, 6, 8, 10, 11) were given an additional four sessions of Phase III training. The data for these six subjects indicate that, while response rates in the extinction component decreased over the four additional Phase III sessions, these changes had no systematic effect on the constant component rates. For example, rates in the constant component increased over these four sessions for subject #10, producing an unequivocal positive contrast effect.

However, rates in this component decreased over sessions 11-12, then increased during sessions 13-14 for four subjects (#5, 6, 8, 11). Finally, rates in this component increased then decreased over the four additional Phase III sessions for subject #2.

In summary, the change from variable interval primary reinforcement to an extinction condition in the changed component produced positive contrast in ten subjects and negative contrast in one subject.

Phase IV (VI + tone, VI tone only). Five subjects (#1, 2, 6, 7, 10) demonstrated decrements in constant component responding below two standard deviations from the Phase III mean (last four sessions) for at least six sessions in Phase IV. For three of these subjects (#1, 7, 10) responding remained somewhat below (from two to fifteen responses per minute) the deviation criterion throughout Phase IV. Response rates below this criterion were obtained for sessions three to eight, inclusive for subject #6 and the first two and last four sessions for subject #2. The data for six other subjects (#3, 4, 5, 9, 11, 12) indicated a decrement in responding in the constant component over the first two or four sessions of Phase IV, in comparison to rates in this component during the last four Phase III sessions. However, constant component rates generally increased throughout the remaining six to eight sessions for each of these subjects. Finally, the response

rates in this component for subject #8 showed little change, except for the decrement obtained during sessions 5-6.

All subjects showed increased rates of responding in the changed component during the first two to six sessions in this phase. In addition, ten of these subjects (#5 and 7 were the exceptions) showed decreased response rates in this component with continued Phase IV training (last four to six sessions). Responding in the changed component had stabilized over the last six sessions of this phase for subjects #5 and 7.

The reintroduction of the tone in the changed component resulted in negative contrast in five subjects. However, the magnitude of this effect was relatively small for each subject, and somewhat unstable (in terms of the duration of the effect) for two of these subjects.

Phase V (VI + tone, VI + tone). Six subjects (#1, 3, 4, 7, 9, 12) were returned to the original baseline conditions during this phase. Five of these subjects (#1, 3, 4, 7, 12) demonstrated rate decrements in the constant component below two standard deviations from the mean phase IV rate (last four sessions) for at least four sessions in Phase V. Two of these subjects (#7, 12) met the response reduction criterion for negative contrast during all eight sessions. Subject #1 met this requirement for the first four sessions, subject #4 for the last four sessions and subject #3 for sessions 3-4

and 7-8. Although responding did decline over the last four sessions for subject #9, these reductions failed to reach criterion level. The response rates in the constant component remained higher than the rates in the changed component throughout Phase V for five subjects (#1 was the exception). Finally, at the completion of this phase (last four sessions) rates in both components were approximately twenty responses per minute higher than the terminal Phase I rates (last six sessions) for all six subjects.

Summary

Table 5 summarizes the contrast effects obtained in the present study. This table lists those subjects demonstrating contrast according to the present criterion (second column) and those subjects demonstrating constant component rate changes indicative of contrast (third column). Behavioral contrast was obtained as a function of independent manipulations in primary and conditioned reinforcements. These results indicate that qualitatively similar effects can be obtained as a function of manipulations in qualitatively different reinforcers.

However, a fine grained analysis of these results indicates several important distinctions between the effects produced by the present manipulations in primary

TABLE 5
Summary of Contrast Effects Obtained in Experiment 2

<u>Nature of Contrast</u>	Subjects Demonstrating Effects		
	<u>Experimental Criterion</u>	<u>Directionality of Response Rates</u>	<u>Proportion of Subjects</u>
P _{II} Positive	6, 7, 10, 11	1, 4, 8, 12	8/12
P _{III} Positive	1, 3, 4, 5, 6, 7, 8, 9, 10, 12	2	11/12
P _{IV} Negative.	1, 2, 6, 7, 10		5/12
P _V Negative	1, 3, 4, 7, 12	9	6/6

and conditioned reinforcement. As shown in Table 5, four of the twelve subjects (#6, 7, 10, 11) demonstrated positive contrast following the removal of a conditioned reinforcer (tone) in Phase II. Ten of the twelve subjects (#1, 3, 4, 5, 6, 7, 8, 9, 10, 12) demonstrated positive contrast following the removal of primary reinforcement in Phase III. Five of the twelve subjects (#1, 2, 6, 7, 10) demonstrated negative contrast following the reintroduction of the conditioned reinforcer in Phase IV. Five of the six subjects (#1, 3, 4, 7, 12) in Phase V demonstrated negative contrast following the reintroduction of primary reinforcement in this phase. These comparisons indicate that contrast was more reliably obtained following the present manipulations in primary as opposed to conditioned reinforcement. In addition, the present results indicate that the contrast effects obtained following manipulations in primary reinforcement were larger in magnitude and demonstrated greater stability, more consistently maintained, than the effects obtained following similar manipulations in conditioned reinforcement.

DISCUSSION

Empirical Considerations

The present findings complement and extend the results from several studies of multiple schedule interactions using different reinforcers. In the present study, both positive and negative contrast were obtained with pigeons when primary and conditioned reinforcement maintained responding in the constant component and conditioned reinforcement was manipulated in the changed component. This complements the studies of Beninger (1972, 1975) and Premack (1969) who demonstrated positive contrast in rats with qualitatively different reinforcers in the two components of a multiple schedule.

The present results also indicate that contrast effects generated by conditioned reinforcement were generally smaller in magnitude than the effects generated by primary reinforcement. Beninger (1975, Experiment 1) reported that the relative value of the deleted reinforcer was one factor determining the amount of contrast. He concluded that the more valuable the reinforcer that was removed, the greater the positive contrast effect. The differential magnitude of the effects obtained in the present study as a function of the type of reinforcer supports this conclusion.

The fact that conditioned reinforcement produced relatively small contrast effects is consistent with findings from several studies which varied the frequency of conditioned reinforcement in a multiple schedule., (Zimmerman, Hanford and Brown, 1967; Zimmerman, 1969, Experiment 1). In these studies the two components of the multiple schedule provided primary reinforcement under a variable-time, response independent, schedule. Each component also provided conditioned reinforcement under a concurrent but independent variable-interval, response dependent, schedule. Conditioned reinforcement frequency was held constant in one component but varied in the second component throughout successive experimental phases. Zimmerman and his associates reported that response rates in the changed component varied as a function of the conditioned reinforcement frequency provided in this component. In addition, they also reported that constant component response rates sometimes changed in the opposite direction. That is, qualitatively similar contrast effects previously obtained in multiple schedules of primary reinforcement were also found in multiple schedules of conditioned reinforcement. However, these investigators noted that rate changes in the constant component, "were usually small in magnitude compared to x-component (changed) rate changes" and "were inconsistent in direction across birds" (Zimmerman, 1969, p. 97).

Thus, the present findings regarding the interactions between conditioned and primary reinforcement are similar to interaction effects obtained between conditioned reinforcers.

The present findings are also consistent with findings from numerous investigations which have directly compared responding maintained by conditioned and primary reinforcement (eg: DeLorge, 1969; Zimmerman, 1969; also see review by Kelleher and Gollub, 1962). These studies typically report that primary reinforcement maintains higher rates of responding than does conditioned reinforcement at comparable frequencies. DeLorge (Experiment 1) compared responding maintained by primary and conditioned reinforcement in a two component multiple schedule. One component was comprised of a second-order schedule. In this component the behavior specified by a fixed-interval contingency was reinforced by a variable-ratio schedule of conditioned reinforcement (0.5 sec. presentation of feeder light). Primary reinforcement in this component was provided following the completion of the variable-ratio schedule. In the second component all reinforcements were primary and were programed under an identical fixed-interval requirement providing conditioned reinforcement in the second-order component. Thus, while the components provided equal reinforcement frequencies, in the second-order component some reinforcements were primary and some were conditioned.

The conditioned reinforcement component maintained fewer responses per session than did the component providing all primary reinforcement. Zimmerman (1969) reported a similar relationship between responding maintained under a conjoint schedule of primary and conditioned reinforcement. In an initial phase, the conjoint schedule, primary reinforcement was scheduled under a fixed-interval schedule. In addition, a second independent variable-interval schedule, concurrently in effect on the same manipulandum, provided conditioned reinforcement. In a subsequent phase, only primary reinforcement was provided under an identical variable-interval schedule. Zimmerman reported that the rate of responding on the variable-interval schedule in which all reinforcements were primary was higher than the rate on the conjoint schedule in which some reinforcements were primary and some were conditioned. The present results in addition to those reviewed above, indicate that conditioned reinforcers produce weaker effects relative to primary reinforcers over a wide range of schedule parameters.

In addition to being smaller in magnitude, the present effects produced by conditioned reinforcement were relatively unstable, somewhat temporary and were not reliably obtained (according to present criteria) in all subjects. These findings regarding the stability, durability and reliability are not consistent with

results from the conditioned reinforcement literature reviewed above. There are at least two possible procedural explanations for this inconsistency. One explanation is related to the manipulations of conditioned reinforcement employed in the present study. In general, the present procedures may be criticized for their failure to examine conditioned reinforcement under what may be described as "stable chronic conditions" (Zimmerman, 1969). A second explanation concerns the saliency of the exteroceptive stimulus employed (tone).

The removal of the tone in Phase II essentially constitutes an extinction procedure with respect to evaluating prior pairings of the tone and food. In addition, the effects of removing the tone are confounded by the fact that primary reinforcement continued to maintain responding in the changed component during this phase. The reintroduction of the tone alone in Phase IV eliminates the possible confounding effects of primary reinforcement present in Phase II. However, the fact that the tone is never paired with food in the changed component, during this phase, constitutes an extinction procedure. Several authors (eg: Kelleher and Collub, 1962; Zimmerman, 1969; Zimmerman et al, 1969) have commented that the conditioned reinforcement effects obtained under such extinction procedures are relatively transient, that is, restricted to initial sessions. Thus, the absence of powerful conditioned reinforcement effects in the present study, in terms of replicability,

stability and durability, can be at least partially accounted for by the use of the present procedures.

In the conditioned reinforcement studies cited above, the brief exteroceptive stimulus continued to be intermittently associated with primary reinforcement in each experimental phase. This suggests that had a procedure been employed in the present study that continued to intermittently pair tone and primary reinforcement in the changed component, more powerful effects might have been obtained. The initial design of the present study constitutes one such procedure. In this procedure concurrent but independent presentations of the tone were scheduled in the changed component. Thus, the originally proposed procedure closely resembles the conjoint schedule employed by D.W. Zimmerman and J. Zimmerman. A second possibility is the use of a second-order schedule such as that employed by DeLorge. Finally, a third possibility is the employment of a chained schedule. Kelleher and Gollub (1962) give numerous illustrations of the utility of this schedule in investigating properties of conditioned reinforcement. In each of these compound schedules (and their variations, see Malagodi, et al, 1973) the effects of conditioned reinforcement are investigated under conditions in which the conditioned and primary reinforcers continue to be intermittently paired.¹⁰

¹⁰There are however, several relevant considerations regarding the selection of a compound schedule. For example, certain schedule combinations may be more sensitive to patterning than overall rate effects produced by conditioned reinforcement (Marr & Zieler, 1974).

Several investigators (Stubbs and Cohen, 1972; Malagodi, et al, 1973) have referred to the selection of exteroceptive stimuli used in conditioned reinforcement investigations with pigeons. Malagodi, et al, suggested that certain stimuli (eg: offset of houselight or keylight, illumination and activation of the food mechanism) might constitute more salient exteroceptive stimuli for the pigeon than others (change in key color, blackout, tone). However, differences in the saliency of these stimuli and the relation to conditioned reinforcement effects in pigeons has not been experimentally demonstrated. Further, each of the above mentioned stimuli has been previously found to be an effective conditioned reinforcer in second-order schedules (eg: DeLorge, 1967, 1969; Kelleher, 1966). Nevertheless, it is possible that the use of the tone as opposed to a compound stimulus (eg: tone plus offset of houselight or keylight) might have contributed to the failure to obtain more robust effects in the present study.

Theoretical Considerations

The two findings of major import for current theoretical interpretations of contrast are; (1) the demonstration of contrast by some subjects following manipulations in conditioned reinforcement, and (2) the differential magnitude of the interaction effects generated by primary and conditioned reinforcement. The following discussion indicates a possible extension in each of the four previously discussed accounts of contrast which allow these theories to at least partially account for the present effects. In addition, data from related areas are discussed which, in conjunction with the present findings, suggest that an additivity theory is the most viable account of contrast effects currently available.

Reinforcement Rate Hypothesis. Reynolds' (1961) relative reinforcement interpretation can account for the present findings given the following assumptions. First, each reinforcement might be considered a compound event comprised of primary and conditioned reinforcement. Second, the alteration of this compound by either the removal or addition of components constitutes a change in the qualitative frequency of reinforcement. Finally, changes in the qualitative frequency of reinforcement produce effects similar to changes in the quantitative reinforcement frequency associated with the reinforcement schedule. Therefore,

a relative reinforcement interpretation would predict both positive and negative contrast as a result of the increase and decrease in the qualitative reinforcement frequency provided in the constant component during Phases II and IV. As previously indicated, the magnitude of the contrast effect obtained is functionally related to the relative primary reinforcement frequency in the constant component. If it were further assumed that changes in qualitative relative reinforcement (ie: presence or absence of a conditioned reinforcer) were functionally analogous to small changes in quantitative relative reinforcement (ie: change from a VI 1 to a VI 2 schedule) then this theory would also predict the weak effects obtained in Phases II and IV. The small contrast effects obtained by Zimmerman and associates as a function of response dependent conditioned reinforcement frequency provides some support for this last assumption.

Response Rate Hypothesis. Terrace (1972) postulated that the development of inhibitory stimulus control was an essential requirement for the occurrence of behavioral contrast. That is, the introduction of a schedule which requires a lowered response rate to one of two alternate stimuli is a sufficient condition for the occurrence of contrast. However, as previously indicated, alterations in response rate to the changed component were not systematically related to the occurrence of positive contrast in Phase II. Thus, this account of contrast does not appear to be consistent

with the present findings. However, Terrace also indicated that the development of conditioned inhibition was dependent upon the prior occurrence of frustration produced emotional behavior. The fact that primary reinforcement continued to maintain responding in the changed component may have retarded the development of frustration. This explanation suggests that frustration produced emotional behavior became counter-conditioned in this situation due to the fact that key-peck responding continued to be maintained by primary reinforcement. This assumption suggests that any frustration produced effects would be of relatively short duration. That is, the most pronounced effects produced by the removal of the tone on changed component rates and, indirectly on constant component rates should be obtained shortly following the removal of this stimulus. While the present data offer some support for the above assumptions, for the majority of subjects, the maximum effects produced by the removal of the tone did not occur during the initial (first two) sessions of Phase II. A similar interpretation of negative contrast effects obtained in Phase IV, based upon the initial occurrence and subsequent counter-conditioning of frustration produced effects might be proposed. However, the current lack of empirical

evidence regarding the validity of the interpretation with respect to positive contrast precludes the utility of such an interpretation.¹¹

Preference Hypothesis. The fact that conditioned reinforcement produced both positive and negative contrast effects is consistent with a preference interpretation. The removal of the tone in the changed component during Phase II would constitute what Bloomfield (1970) described as a "worsening of conditions" or what Premack (1969) termed a change in the "aversiveness" in this component. This change resulted in an increased preference for the constant component and, according to preference theory, the production of positive contrast. Similarly, the reintroduction of the tone in Phase IV resulted in a decreased preference for the constant component and thus, negative contrast. Premack also postulated that preference itself might undergo changes in the course of a contrast experiment. This assumption implies that if the preference structure underwent changes there might be either elimination or a reversal in initially obtained contrast with continued training. The results from Phase IV provide some support for this assumption.

¹¹The reader is referred to reviews by Dunham (1968) and Freeman (1971) for extensions of frustration theory to negative behavioral contrast. Platt, Senkowski and Mann (1969, p. 44) also discuss contrast in the context of frustrative nonreward theory.

In this phase, a number of subjects demonstrated initial rate decrements in the constant component followed by increments in responding to this component with continued training. Thus, Premack's assumption is consistent with the finding that the tone temporarily acted as a conditioned reinforcer in this phase. A preference interpretation could also account for the present findings regarding the differential magnitude of the contrast effects produced as a function of primary and conditioned reinforcement. These results suggest that conditioned reinforcement should be less preferred than primary reinforcement. The results from several studies previously discussed (DeLorge, 1969; Zimmerman, 1969) indicate that higher rates of responding were maintained by primary reinforcement in comparison to equal frequencies of conditioned reinforcement. These data suggest that primary reinforcement is preferred to conditioned reinforcement. Beninger (1975) also found that qualitatively different reinforcers produced quantitatively different effects. In this study, the removal of milk from one component resulted in larger contrast effects in the solid food component than did contrast produced by the removal of solid food in the milk component. In a subsequent phase, rats demonstrated preference, in terms of time allocation, for milk as opposed to food pellets. Thus, the present results, in addition to findings previously reviewed, indicate substantial support for a preference interpretation.

However, there is a rather large body of experimental literature that cannot be accounted for by the preference hypothesis. In several experiments (Premack, 1969; Wilkie, 1973) the proposed relationship between contrast and preference for the constant component reinforcer was not obtained. Further, several investigations (Dickson and Thomas, 1963; Mariner and Thomas, 1967; Shuttleworth and Nevin, 1965) failed to obtain evidence of contrast in pigeons following a qualitative reinforcement manipulation. In these studies, reinforcement availability per presentation was varied in one component of a multiple schedule. Despite a five-fold difference (2 seconds vs 10 seconds) in duration of access to mixed grain, positive contrast was not obtained. An analogous finding has been reported following a similar qualitative reinforcement manipulation with rats (Barnes and Tombaugh, 1973; Ison and Glass, 1968). These investigators also failed to obtain contrast effects within a non-differential conditioning paradigm following variations in a liquid (sucrose) reinforcer.¹² Finally, two studies

¹²In this paradigm the same discriminative stimulus-response relation exists between successive experimental phases. Thus, rats press a single bar or transverse a single runway throughout all phases. This paradigm differs from a multiple schedule, categorized as a differential discriminative paradigm, in that the multiple has different discriminative stimuli associated with the two or more reinforcement conditions.

(Griffin and Cooper, 1971; Pear and Wilkie, 1971) of multiple schedule responding in rats failed to obtain durable contrast effects in all subjects following manipulations in a liquid reinforcer (sucrose and milk).

These results raise fundamental interpretive issues that are presently not provided by the preference theory. For example, what is the mechanism responsible for changes in the preference structure, emotionality, inhibition? Whatever the mechanism, why is it differentially sensitive to certain types of reinforcement manipulations? Premack (1969) suggested that these and related issues require empirical determination. He indicated one possible procedure for undertaking such an analysis. Prior to and following the investigation of contrast within a standard multiple schedule design the preference for the reinforcer(s) employed should be evaluated. These preference measures would provide the basis for a hierarchy of activities or reinforcers. The establishment of such hierarchies would allow prediction of the occurrence, and possibly magnitude of contrast. These assumptions are consistent with Premack's (1965) more general empirical or relative concept of reinforcement.

Additivity Hypothesis. As previously indicated, the additivity theory states that the occurrence of contrast depends upon the fact that responding generated by the stimulus-reinforcer dependency and responding

maintained by the response-reinforcer dependency are directed toward the same source (Ganz and Schwartz, 1973). Two more basic assumptions, relevant to interpretations of the present results, can be derived from this general statement. These assumptions concern the location of the discriminative stimuli associated with components of the multiple schedule and the relationship between the operant and the consumatory responses. In several investigations (Boakes, 1972; Westbrook, 1973) in which the discriminative stimuli (tone, houselight) were not located on the response key, the contrast effects obtained were small and disappeared, in some subjects, with continued training. In the present study the discriminative stimuli were located on the response key; however, the conditioned reinforcing stimulus (tone) was not. If the location of the reinforcing stimulus were assumed to be as relevant a determiner of contrast as the location of the discriminative stimuli, then an additivity theory could account for the present results. This interpretation suggests that the modality employed as the conditioned reinforcer should influence the nature of the contrast effects obtained in a similar manner to differences in discriminative stimulus modalities.

A second interpretation that can be derived from the additivity theory assumes differences in the nature of consumatory behavior associated with conditioned reinforcement. The results from several studies (Hennes,

1973; Westbrook, 1973) indicate that positive contrast is not obtained when an instrumental response other than key-pecking is employed with pigeons. In these studies the behavior maintained by the response-reinforcer relation (treadle-pressing) was unrelated to the behavior generated by the stimulus-reinforcer relation (pecking). As the behavior controlled by these two relations were not directed toward the same source, contrast did not occur. In Phase II of the present study, the operant maintained by the response-reinforcer relation was pecking, but the conditioned reinforcer (tone) not food, provided the basis for the differential stimulus-reinforcer relation. DeLorge (1971) reported that the behavior of pigeons in the presence of the lighted food aperture (conditioned reinforcer) was similar to behavior initially following the presentation of food. In the present study, the tone should also illicit these "pre-consumatory" behaviors due to the association with food. However, these behaviors should not include pecking as does the actual consumatory response. Thus, it might be argued that the stimulus-reinforcer relation controlled a somewhat different, but related behavior than did the response-reinforcer relation. This difference may account for the fact that not all subjects demonstrated positive contrast and that such effects were small relative to primary reinforcement effects.

An interpretation based upon differences in operant and consumatory behaviors might also account for the results from several studies employing rats as subjects, barpressing as the operant response, and a liquid reinforcer. This interpretation requires the additional assumption that, in rats the consumatory behavior associated with solid food (pellets) and liquid reinforcers is different. Solid food occasions a great deal more manipulation by the fore-paws than does a liquid.¹³ The instrumental bar-press response also requires manipulation by the fore-paws. Thus, the bar-press response in rats is closely related to the consumatory behavior associated with solid food, but somewhat unrelated to behavior associated with liquid reinforcers. Therefore, an additivity theory would predict differences in the nature of the contrast effects obtained in rats as a function of the difference in the relationship between the operant and consumatory responses. The findings reported by Beninger (1975) support this prediction. As previously indicated, he found that contrast effects were larger and more enduring when solid food as opposed to milk maintained responding in the constant component. Two additional studies (Griffin and Cooper, 1971; Pear and Wilkie, 1971) which manipulated liquid reinforcement in a multiple schedule

¹³Numerous observations, performed by the present author, of rats barpressing for solid food and sucrose reinforcement would substantiate this difference.

with rats reported similar findings. That is, contrast did not occur in all subjects and disappeared with continued training in those subjects in which it did occur. Finally, the present interpretations could also account for the fact that contrast was obtained with sucrose pellets (Marx, 1969) but was not obtained as a function of variations in liquid sucrose (Barnes and Tombaugh, 1973; Ison and Glass, 1969).

An explanation of the results obtained following the reintroduction of the tone in Phase IV is based upon a consideration of the stimulus-reinforcer relations in this phase. The reintroduction of the tone removed the differential stimulus-reinforcer relation involving the tone but, continued to maintain a differential relation between the discriminative stimuli and food. The removal of one of these relations (stimulus-tone) suggests that there might be an initial tendency for the development of negative contrast. However, the continued presence of a second relation (stimulus-food) suggests that with continued training positive contrast might occur. Indeed, the majority of subjects did show initial decrements in responding during the constant component, but a subsequent increment during this component with continued training. In summary, the additivity theory can account for the present findings regarding conditioned reinforcement, providing that certain additional empirical assumptions are made.

The present discussion suggests that an additivity theory can account for the results obtained in a number of areas generally classified as studies of contrasted conditions of reinforcement. However, there appears to be at least two restrictions in the applicability of this hypothesis. One limitation previously discussed is the possibility that this theory is restricted to an account of local as opposed to overall contrast effects. Buck et al (1975) concluded that a definitive evaluation of this question requires a systematic analysis of the wide variety of local contrast effects and their relationship to overall behavioral contrast. Further, this theory cannot account for negative contrast effects produced by certain procedural manipulations. The change from unequal to equal reinforcement schedules (as shown in Phase V of the present study) constitutes one procedure for producing negative contrast. The additivity theory can account for negative contrast obtained with this procedure by considering the removal of the differential stimulus-reinforcer relation. However, the production of negative contrast by changes from equal to unequal schedules (ex: mult. VI 1, VI 1 to mult. VI 1, VI 30-sec.) cannot be explained by the same rationale. Schwartz (1975) suggested two possible means of reconciling additivity theory with the production of negative contrast with the latter procedure. One possibility involves the assumption that positive and negative contrast are at

least partially unrelated. The second, and perhaps more logically and empirically consistent suggestion requires the assumption that stimuli signalling less frequent reinforcement become inhibitory.

The present discussion, in addition to evidence presented in the introduction, suggests that an additivity theory represents the most viable interpretation of contrast effects currently available.

While limitations in the current theoretical framework were indicated, this theory offers a possible mechanism for both the interpretation of present findings and the future analysis of interactions between operant and respondent behavior in a number of related areas.

SUMMARY AND CONCLUSIONS

The present results extend the variety of procedures by which contrast has been produced. In Experiment I contrast was obtained by the addition of new schedule components which provided either lower or identical reinforcement frequencies as the existing components as well as the deletion of schedule components. In Experiment II contrast was obtained as a function of alterations in conditioned reinforcement in the changed component.

The different overall patterns of contrast obtained in the present studies complement the findings from other studies of multiple schedule interactions. The general pattern of responding in the constant components for two subjects (6 and 12) in Experiment I was similar to an effect termed "peak contrast" (Sadowsky, 1973). In these subjects responding returned toward the baseline level after reaching an initially high (peak) rate. These subjects also demonstrated higher rates of responding to the positive stimulus more adjacent to the stimuli correlated with extinction. This general response pattern has been termed "stimulus specific contrast" (Farthing, 1974; Malone, 1975). The general pattern of responding shown by other subjects (1, 5, 7, 14 and 15) demonstrating contrast in Experiment I has been termed "maintained or sustained contrast" (Bloomfield, 1966). These subjects

demonstrated relatively stable increments in responding in the constant components after some intermediate level of training.

The negative contrast effects obtained in Phase IV of Experiment II as a function of the reintroduction of the conditioned reinforcer were described as relatively unstable and somewhat transitory. Bloomfield (1976), employing a line tilt discrimination, also failed to obtain reliable negative contrast effects following the reintroduction of primary reinforcement.

The overall pattern of contrast phenomena reported in the present studies cannot be adequately explained by any of the four current theoretical interpretations of behavioral contrast. Relevant modifications or extensions in the present formulation of each theoretical position were discussed. It is suggested, that given the variety of interaction effects subsumed under the term behavioral contrast, local as well as overall, (see Buck, Rothstein and Williams, 1975) at present no single explanation can be offered.

The diversity of both the empirical findings and theoretical explanations suggest at least two, related directions for future research in the area of behavioral contrast. Several authors (eg: Buck, et al, 1975) have indicated the need for a more molecular analysis of what appears to be separate, independent interactions between the components of a multiple schedule. A second approach suggested by Dunham (1968) and a major theme of the present

work, involves the empirical determination of the relationships between behavioral contrast and other methodologies concerned with contrasted conditions of reinforcement. In conjunction, these approaches should produce definitive answers to questions of specific relevance to behavioral contrast, as well as indicating the role of contrast in a general theory of discrimination learning.

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