Bitonic Function

in

Multiple Schedules

© Henry Lam

A Thesis
Submitted to the Faculty of Arts
In Partial Fulfillment of the Requirements for
The Degree of Master of Arts

Department of Psychology
Lakehead University
Thunder Bay, Ontario, Canada

Nov., 1981

TABLE OF CONTENTS

ACKNOWLEDGEMENT

I would like to thank Dr. Steve R. Goldstein for his academic guidance, valuable insight and enormous support in the process of completing this research.

I would also like to thank Dr. K. Paul Satinder for his constructive criticisms and comments.

Also, my sincere appreciation goes to Dr. James F. Evans, and Dr. John L. Jamieson who assisted me in the statistical analysis.

The typing of this manuscript and constant encouragement from my wife, Jane, is greatly appreciated.

LIST OF FIGURES

Abstract

The objective of this study was to determine whether changes in the rate of responding in the constant component (S1) of multiple schedules could be expressed as a bitonic function of the length of fixed-interval schedules associated with the variable component (S2).

Four male, Sprague-Dawley rats were trained and tested with a two-component multiple schedule. The constant component was associated with a fixed-interval, one minute schedule (FI-1 min.), whereas the variable component was associated with six different fixed-interval schedules at various stages of the experiment. The dependent variable was expressed as the number of bar presses per minute.

The results indicated significant interaction effects in each subject. A bitonic function was evident between schedules and the rate of response. The results strengthen the position that schedule-induced behavior and interaction effects share a common underlying mechanism.

Introduction

Since the publication of Ferster and Skinner's (1957) Schedules of Reinforcement, the volume of operant research has steadily grown (Appendix 1). Operant methods have contributed to the development of such diverse areas as psychopharmacology (Dew, 1955; Smith, 1964), clinical psychology (Ney, Palvesky, and Markely, 1971; Williams, 1959), educational psychology (Hall, Lund, and Jackson, 1968; O'Leary and Drabman, 1971), and developmental psychology (Madson, Hoffman, Thomas, Koropsak, and Madsen, 1969; Goetz and Baer, 1973).

A fundamental concept in operant research deals with schedules of reinforcement. Schedules, or more generally contingencies, define the relationship among stimuli, responses, and reinforcers. Such relations are believed to play a central role in the emergence and regulation of behavior (Morse and Kelleher, 1970). A particular relationship among these factors ensures both the formation of discrimination and the emergence of adjunctive behavior.

The aim of this thesis is to provide a rationale as well as experimental data to support the notion that discrimination and adjunctive phenomena are related.

The first part of this task is dealt with by considering the defining characteristics and major features of these two phenomena. The second part is dealt with in an experiment which illustrates their interrelationship.

Discrimination Learning

A typical discrimination learning procedure involves two distinct phases, i.e. non-differential reinforcement procedure and differential reinforcement procedure. A non-differential reinforcement procedure is basically used to obtain baseline levels of responding by confronting the experimental subject with two or more stimuli and identical reinforcing choices, while a differential reinforcement procedure is used to establish differential responding by reinforcing the subject in the presence of different stimuli. The stimuli in discrimination learning are referred to as discriminative stimuli (Skinner, 1938), a function of which is to occasion the response under a particular reinforcement schedule. Further, each response pattern is said to be well controlled by a stimulus if, and only if, a change in the property of the stimulus yields a change in the response pattern. For example, the presence and absence of the light producing a different rate of responses indicates that the light, as a stimulus, has acquired the property of controlling the behavior. This phenomenon is called stimulus control.

Two-component Multiple Schedules

When an organism is exposed to a light-on and light-off situation in succession, a two-component multiple schedule is specified. In such a schedule, each stimulus is associated with a reinforcement schedule which defines a single component in multiple schedules (Reynolds, 1961a). At the beginning of the discrimination training, the organism usually responds to both stimuli and their associated reinforcement schedules indiscriminately, that is, the organism responds to two components in multiple schedules as if they were one. As the training progresses, the organism gradually develops a differential response pattern to the stimuli as well as their associated reinforcement schedules. A stable explicit response pattern to each component in multiple schedules over a period of time signifies discrimination.

In conjunction with two-component schedules a Change-Over-Delay (C.O.D.) procedure is frequently used to separate two components so that the schedule in the second component does not adventitiously reinforce the response in the first component (Catania, 1972). A typical C.O.D. spcifies a minimum delay between the change-over from the responding in one component and the next possible reinforced response in the second component. The C.O.D. procedure has been most widely employed in two-component concurrent schedules (Shull and Pliskoff, 1967; Brownstein and Pliskoff, 1968; Stubbs, Pliskoff and Reid, 1977; White, 1979).

Assumption of Independence among Components

When two isolated schedules such as fixed-interval (FI) and fixed-ratio (FR) are combined in multiple schedules, the response rates in both components usually maintain their pre-combination performance pattern. For example, in multiple FI FR schedules, the typical scallop pattern (Blackman, 1974; Reynolds, 1968) is associated with the first component while the FR break-and-run (Cumming and Schoenfeld, 1958) pattern is associated with the second component. Such a differential response pattern seems to suggest that the response rates in these two components are independent of each other. However, the discovery of interaction effects (Reynolds, 1961a) has altered this "independence" notion.

Interaction between Two Components in Multiple Schedules

Reynolds (1961a, 1961b, 1961c) initiated a systematic investigation into the interrelationship of two components in multiple schedules. He reported that the rate of responding during the presentation of one stimulus might be altered by the change of schedules of reinforcement associated with the second stimulus. This phenomenon was referred to as an "interaction effect". Further, he suggested that the necessary and sufficient condition for the occurrence of interaction effects depended upon the change of relative reinforcement frequency associated with the components. In other words, regardless whether the response rate in the variable component (S2) increased, remained constant, or decreased, interaction effects were to take place when changes occurred to the relative reinforcement frequency associated with the components.

The Ambiguity over the Definitinn of Behavioral Contrast for Multiple Schedules

Two theories greatly influenced the classification of interaction effects. The Relative Reinforcement Frequency Theory (Reynolds, 1961a) defined a "positive contrast effect" as an increased rate of responding in the constant component (S1) in relation to a reduction of the frequency of reinforcement in the other component (S2). A "negative contrast effect" was said to have occurred when the rate in the constant component decreased while its counterpart increased. On the other hand, Terrace's Theory of Suppression of Response Rate (1966) suggested that a "positive contrast effect" be defined as an increased rate of responding in S1 in response to a reduction of the rate of responding in the variable component (S2); and "negative contrast effect" as a reduction of response rate in S1 while its counterpart increased. It is apparent that Reynolds tended to focus his attention on relative reinforcement frequency whereas Terrace seemed to concentrate on the differential response rates associated with two components. The following diagram in Figure 1 shows that under Reynolds' Relative Reinforcement Frequency Theory, positive contrast may occur in a number of conditions.

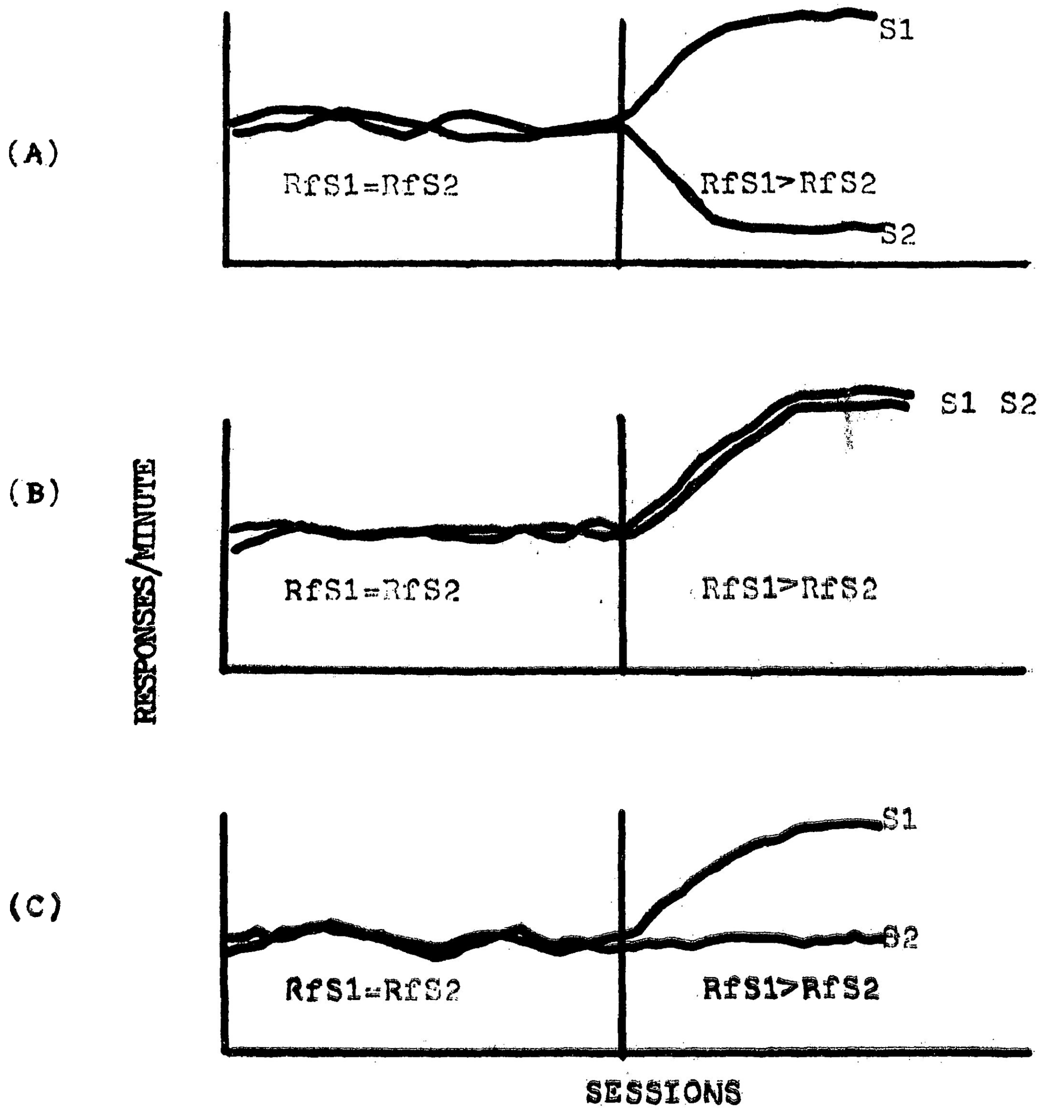


Figure 1 Positive contrast may occur in three modes in Reynolds' Relative Reinforcement Frequency Theory (Reynolds, 1961a).

Induction

In a two-component operant situation, induction is one type of interaction. According to Skinner (1938) and Terrace's theory, positive induction is said to have occurred when the change in rate in the constant component is in the direction towards the increased rate of responding in the variable component. Negative induction is said to have occurred if the rate of responding in both components reduces below their original baseline levels.

In view of the possible combinations under which interaction effects can occur, the existing classification system seems inadequate to define certain types of interaction. For example, if interaction occurs, the response rate in S1 increase due to a reduction of reinforcement frequencies in S2. However, the response rate in S2 could either decrease, remain unchanged, or increase. Should this latter phenomenon be defined as positive contrast or positive induction?

Three Major Characteristics of Interaction Effects

Contrast effects take place whenever the rate in the constant component (S1) of multiple schedules varies with the reinforcement frequency in the S2 component (Reynolds, 1961a; Nevin, 1968; Halliday and Boakes, 1971; Wilkie, 1972). Secondly, positive contrast effects normally occur when the condition of the variable component changes to S-, i.e. extinction, low reinforcement frequencies, time-out, punishment, or reinforcement of a low rate of responding (DRL) (Crespi, 1942; Amsel and Roussel, 1952; Reynolds, 1961a; Reynolds and Catania, 1961; Brethower and Reynolds, 1962; Gutman, Sutterer, and Brush, 1975; Innis, 1978). Thirdly, the change of the response rate in the constant component is reversible. In other words, should the reinforcement frequency in the variable or changing component be brought back to the pre-discrimination phase, the rate of responding in the constant component would eventually return and stablize around the pre-discrimination baseline level (Reynolds, 1961c).

Interaction Effects Related Phenomena

In the peak shift phenomenon (Hanson, 1959), discrimination was first established and then a spectrum of stimuli were presented under extinction conditions. Contrary to expectation, the peak level of responding did not occur directly over the S+, i.e. the stimulus on which subjects were trained. The maximum rate of response did not occur to S+ but instead shifted in a direction away from S- (stimulus which the subjects were trained not to respond).

During a discrimination training task in a three-armed maze, Goldstein (1971) demonstrated that spatial shift was accompanied by the introductinn of S- (non-reinforcement in one of the close arms). The direction of spatial shift moved away from the S-.

Theories Accounting for Interaction Effects

Various theories have been developed to account for interaction effects. Relative Frequency of Reinforcement Theory (Reynolds, 1961a) maintains that the change of the response rate in the first component is influenced by the relative reinforcement frequency associated with the second component. Frustration Effect Theory (Terrace, 1966; Amsel, 1958) states that the inhibition of responding (response suppression) in the S2 component generates an emotional element which in turn produces contrast in the first component (S1). Additivity Theory (Brown and Jenkins, 1968; Westbrook, 1973) suggests that inhibition of responding is not sufficient for contrast to occur: rather, it is the excitatory stimulus-reinforcer relation that produces contrast. In short, positive contrast occurs when responses elicited by a stimulus-reinforcer association are added to those maintained by response-reinforcer contingencies.

Despite the fact that all these theories are supported by empirical evidence (Weisman, 1969; Rilling, Askew, Ahlskog, and Kramer, 1969; Jenkins and Boakes, 1973; Keller, 1974; Redford and Perkins, 1974; Whipple and Fantino, 1980), the precise underlying causes of contrast have not been identified.

Adjunctive Behavior

Falk (1961) was the first to observe excessive drinking in rats when they were trained under an intermittent schedule of reinforcement with water concurrently available. A large quantity of water above their daily baseline level was consumed in a few hours (Clark, 1962; Falk, 1966a, 1966b, 1967; Schaeffer, Diehl, and Salzberg, 1966). This excessive drinking is known as polydipsia. More recent studies (Burkes, 1970; Hymowitz, Freed, and Lester, 1970; Wayner and Greenberg, 1973; Yoburn and Cohen, 1979; Alferink, Bartness, and Harder, 1980; Poling, Krafft, Chapman, and Lyon, 1980) have confirmed these findings.

Other apparently related forms of adjunctive behavior include excessive wheel running induced by intermittent schedules (King, 1974); attacks produced by intermittent reinforcement (Hutchinson, Azrin, and Hunt, 1968); schedule-induced air licking behavior (Mendelson and Chillag, 1970); and schedule-induced pica (Villarreal, 1967).

All these phenomena share a common denominator, namely, an intermittent schedule. Falk (1971) called such classes of behavior "adjunctive" or "schedule-induced" behavior.

From the discrimination learning perspective, adjunctive behavior can be viewed as a two-component operant situation. For example, schedule-induced polydipsia consists of an intermittent schedule component and a drinking component; schedule-induced aggression, an intermittent schedule component and an aggressive behavior component; and the schedule-induced wheel running, an intermittent schedule component and a wheel running component.

In short, these examples suggest that the intermittent schedule component and the schedule-induced behavior component as expressed in adjunctive behavior may be functionally analogous to the variable component and the constant component respectively in two-component multiple or concurrent schedules.

Four Major Characteristics of Adjunctive Behavior

Schedule-induced behavior takes place as the schedule component changes typically from a continuous reinforcement schedule to an intermittent schedule (Falk, 1966a; Flory, 1969; Wayner and Greenberg, 1973). Schedules commonly employed for studying polydipsia are fixed-time (FT), fixed-interval (FI), and variable-interval (VI) schedules (Keehn and Colotla, 1971; Falk, 1961, 1966b). Due to the fact that the reliability of ratio schedules in producing polydipsia is not comparable to that of FT, FI, and VI schedules (Schaeffer, Diehl, and Salzberg, 1966; Carlisle, 1971), fixed-ratio schedules have been used more in the study of induced aggressive behavior (Gentry, 1968; Knutson, 1970) than in polydipsia studies. Second, the excessive behavior usually occurs when the schedule component becomes less rewarding in comparison to the continuous reinforcement schedule, provided that such behavior can occur in a given environment (Falk, 1961, 1966a). Third, the excessive behavioral outcome is usually reversible, that is, when the schedule component is brought back to the appropriate baseline level, the excessive behavior disappears (Falk, 1966a, 1966b). Fourth, the excessive behavior usually occurs during the post-reinforcement pause period (Villarreal, 1967; Hutchinson, Azrin, and Hunt, 1968; Poling, Kraft, Chapman, and Lyon, 1980).

These adjunctive phenomena are puzzling because there are no obvious reasons for their occurrence. The adventitious reinforcement of water consumption by food delivery has been suggested as a possible explanation, but it has not been supported by subsequent research findings (Falk, 1966a, 1967, 1969). Observations have indicated that adjunctive behavior occurs in the post-pellet interval and before the food delivery. Similarly, Stricker and Adair (1966) have demonstrated that tissue water deficit is not a determinant to the occurrence of polydipsia. In fact, in nearly all the polydipsia studies, subjects are usually not deprived of water.

The Rationale for the Synthesis of Interaction Effects and Adjunctive Beheavior

Schedule induced situatinns implicitly program two conditions of reinforcement, that is, the formal operant-reinforcement relation and the adjunctive response-reinforcement relation. On the other hand, discrimination situations explicitly program two conditions of reinforcement correlated with S1 and S2. In both cases, the rate of response in the S1 component increases as the S2 component becomes less rewarding. The excessive or "over-shooting" behavior manifest in the S1 component is believed to be caused by the schedule in the S2 component.

Under the schedule induced situation, conditions of reinforcement are simultaneously provided, that is, subjects are allowed to switch from one reinforcement conditon to another. This arrangement is often referred to as a concurrent schedule. Whereas in the S1 and S2 successive situations, subjects are successively presented with components, the choice of which is programmed. This latter arrangement is referred to as multiple schedules which have been discussed earlier.

Concurrent schedules are by and large used to generate schedule-induced behavior while multiple schedules are used to induce contrast effects. However, studies have indicated that contrast effects can also occur in concurrent-scheduled situations (Catania, 1961; Eisenberger, Frank, and Park, 1975); and schedule-induced behavior in multiple-scheduled situations (Allen and Porter, 1975; Jacquet, 1972). In addition, contrast effects have been demonstrated on schedule-induced polydipsia in multiple-schedule situations (Porter and Allen, 1977). These findings suggest that schedule-induced behavior and contrast effects are not only functionally analogous, but they may be generated by the same set of conditions, i.e. concurrent or multiple schedules. Therefore adjunctive behavior and contrast effects may be homologous.

It is therefore not by accident that similar theoretical accounts have been used to explain contrast and adjunctive behavior. For example, the notion of emotionality has been used by some investigators (Terrace, 1966; Thomka and Rosellim, 1975) to account for the occurrence of adjunctive behavior as well as contrast effects. Both phenomena were said to have been caused by frustration or the aversive effects generated by intermittent schedules. However, the usefulness of emotionality as an explanatory concept has been questionable and pointed out to be untestable (Freeman, 1971; Falk, 1971).

Given the importance of intermittent schedules to both contrast effects and adjunctive behavior, it is logical to investigate the relationship of the magnitude of schedules to the "excessive" pattern of behavior. Falk (1966a) found that there was a consistent and reliable relation between intermittent schedules and schedule-induced behavior. He observed that polydipsia was a bitonic function of the length of fixed-interval food schedules. That is, polydipsia increased up to approximately FI-3 minutes, and gradually fell off at lower reinforcement values (Fig. 2).

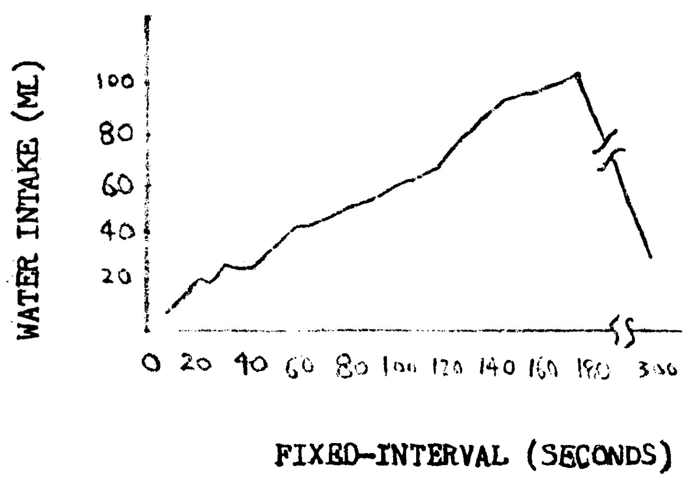


Fig. 2 Polydipsia as a function of the length of food fixed-interval schedules (Falk, 1966a, p. 38).

A bitonic function was also observed by Flory (1969) in a schedule-induced aggression study where attacks were induced by fixed-time feeding schedules. As the intervals of reinforcement increased from 15 seconds to 960 seconds, attacks increased up to a point then gradually dropped to lower levels at the longer interval values (Fig. 3).

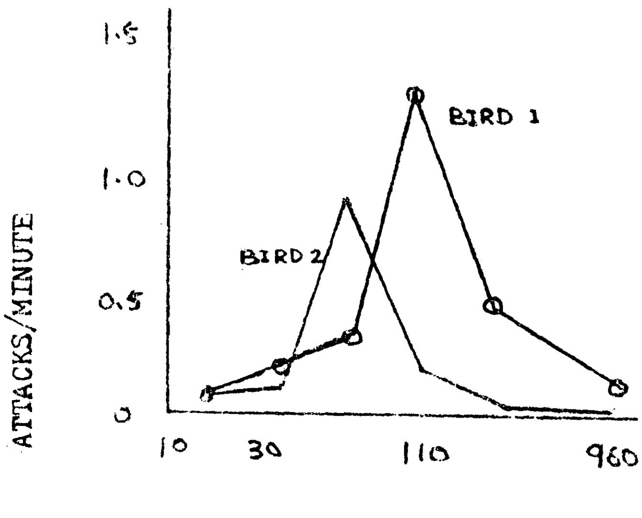


Fig. 3 Schedule-induced aggression as a function of the length of minimum inter-food interval schedules in seconds (Flory, 1969, p. 826).

Similarly, bitonic functions between schedules and behavioral outcomes have been reported in other areas. Wayner and Greenberg (1973) demonstrated that the number of bar presses was a bitonic function of fixed-time schedules. In other words, lever pressing occurred independently of food reinforcement, and it reached a peak performance at 4 minutes of the fixed-time schedules. Although the total number of bar presses was very small, the presence of the function is evident (Fig. 4).

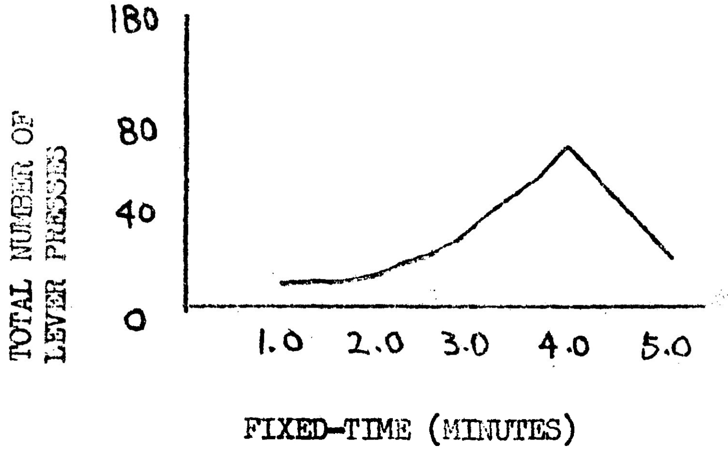


Fig. 4 Mean total number of lever presses as a function of different fixed time interval schedules (Wayner and Greenberg, 1973, p. 966).

Studying the conditions under which contrast and induction occurred, Reynolds (1963) found that the highest rate of pecking in the constant component occurred at VI 8 minutes in the variable component, rather than VI extinction (Fig. 5). A bitonic function between the rate of pecking in one component and the VI schedule of reinforcement in the other was therefore suggested.

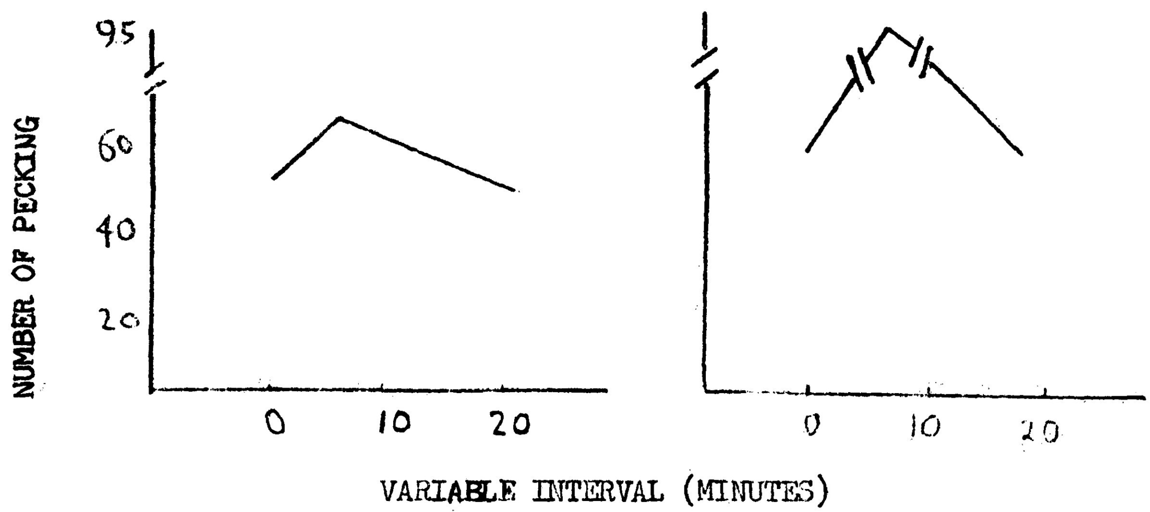


Fig. 5 Rate of pecking in the constant component as a function of the length of variable interval schedules associated with the variable component (Reynolds, 1963, p. 134).

In short, these cited studies concerning the interaction effects and adjunctive behavior seem to point to two common findings. First, the peak performance appears between 2 minutes and 8 minutes; second, an inverted U-shape function occurs in both contrast and adjunctive phenomena.

In light of the bitonic function evident in a variety of adjunctive and contrast situations, it seems logical to think that these two areas share common determinants, dynamic properties and controlling variables despite the complexity of the nature of both phenomena.

The specific experimental objective of this study was to determine whether changes in the rate of responding in the constant component of multiple schedules was a bitonic function of the length of fixed interval schedules associated with the changing component.

The second objective of this study was to seek more evidence to determine whether schedule-induced behavior and contrast effects share a common origin. This study did not attempt to provide any model or theoretical framework but rather focused itself on the empirical evidence to show that the two domains of behavior may be overlapping. It was hoped that a better understanding and appreciation of the underlying mechanism may be achieved, and that further theoretical postulations and investigations may be continued.

Method

Subjects

Four experimentally naive Sprague-Dawley (black and white hooded) male rats, 180 days old, were the subjects used in the study. These animals were bred in the laboratory and were from the same litter. Each animal was individually housed and was kept under a constant room temperature of $70^{\circ}F \pm 2^{\circ}F$ and humidity of 16%.

Apparatus

The apparatus consisted of a single-lever standard operant training chamber. A white pilot light was mounted above the lever. With the food cup being located on the right side of the lever, standard 45-mg Noyes pellets were delivered into the magazine by a Ralph Gerbrands model D-1 pellet dispenser.

The training chamber was enclosed by Opaque paper to minimize external visual stimuli during experimental sessions. In order to reduce the extraneous noise level, the chamber was placed 10 meters away from the rest of the apparatus (Fig. 6(b)).

The fixed-interval (FI) schedules associated with both components were generated by the BRS multi-schedule programmer Model 2901. In addition, a Hunter Time Interval Delay Unit was installed to extend the fixed-interval maximum time from a limit of 60 seconds to 120 seconds. From 2 minutes up to 8 minutes, the Hunter Unit was replaced by a reset switch.

A light associated with the variable component was switched on by a timing device and designated as S2. The light was turned off every 15 minutes by the same device and remained off for 15 minutes.

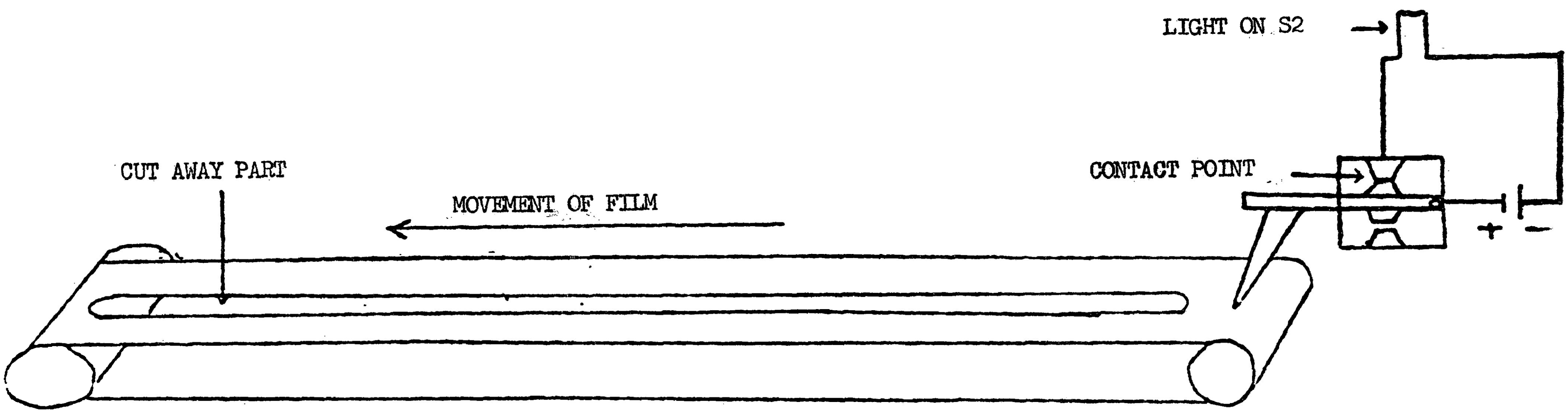


Fig. 6(a) Schematic representation of the timing device.

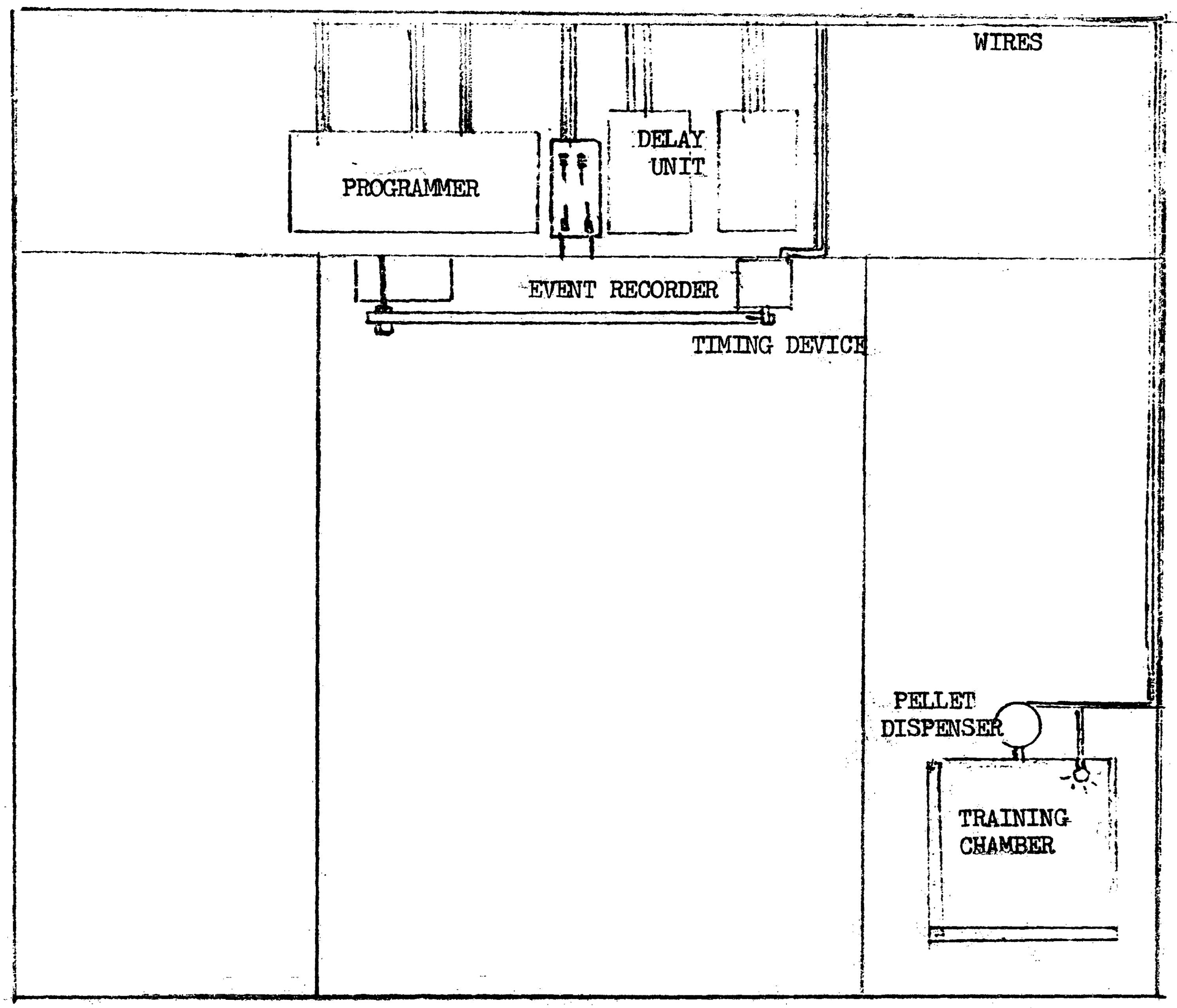


Fig. 6(b) Top view of the apparatus and their relative positions.

When the light was off, it was designated as S1. The relay and film shown in Figure 6(a) illustrate the timing device for the 15 minutes alternating on-and-off cycles.

The frequencies of bar presses and of reinforcements as well as the duration of reinforcement were recorded simultaneously on a 4-channel Gerbrands event recorder.

Experimental Design

A repeated measures design was used. Throughout the entire experiment, the animals were given an identical treatment and trained under two-component multiple schedules. The first component was composed of S1 (no light) and a FI-1 min. reinforcement schedule, whereas the second component was associated with S2 (light) and a FI-X min. schedule (X=1, or 2, or 3, etc.). In both components, the subjects were reinforced by 45-mg Noyes pellets.

Initially, a block design or latin square design was considered in hopes of avoiding the systematic influence from the sequential presentation of fixed-interval schedules. However, two major reasons made this design unnecessary and impractical. First, according to the block design, one of the subjects must be exposed to the highest FI value in the second phase of the experiment. Since FI-8 was the highest value in the present experiment, the design was not adopted lest the subject undergo extinction under this high value. Second, previous studies (Reynolds, 1961a, 1961b, 1961c) indicated that the order of presentations exerted minimal influence on the performance of subjects.

Procedure

In this study, the Change-Over-Delay procedure (C.O.D.) was not incorporated into the experimental design for two reasons. First, each component (trial) was fifteen minutes apart; therefore the reinforcement schedule or stimulus associated with the second component was unlikely to exert significant influence on the responding associated with the first component. Secondly, it has been demonstrated that contrast effects occur without having to incorporate C.O.D. procedures in the experimental design (Reynolds, 1961a, 1961b).

Every subject was carefully weighed for five consecutive days before a deprivation schedule was put into effect. In doing so, the free feeding body weight of each subject was calculated and an 80% body weight was determined. Then the number of food pellets for each subject was gradually reduced from ten to two full-sized rat chow pellets. As soon as the 80% body weight was achieved, any deviation from the 80% weight was compensated by either increasing or decreasing the quantity of food pellets given in the previous day. Figure 7 showed the average weight of each subject across the six phases of the experiment.

Magazine and lever-press training. Through the successive approximatinn technique (Ferster and Skinner, 1957), each subject was given one training trial (15 min.) per day to press the lever. Five days of continuous reinforcement training (CRF) were given, followed by a shift to the fixed-interval (FI) 5 seconds. At the end of the eighth day, the subjects were placed under the fixed-interval FI-20 seconds schedule. Meanwhile, the total number of trials for each subject was increased to two trials per day.

Two-component multiple schedules pretraining. The subjects were presented with S2 (light) while the fixed-interval (FI) schedule was

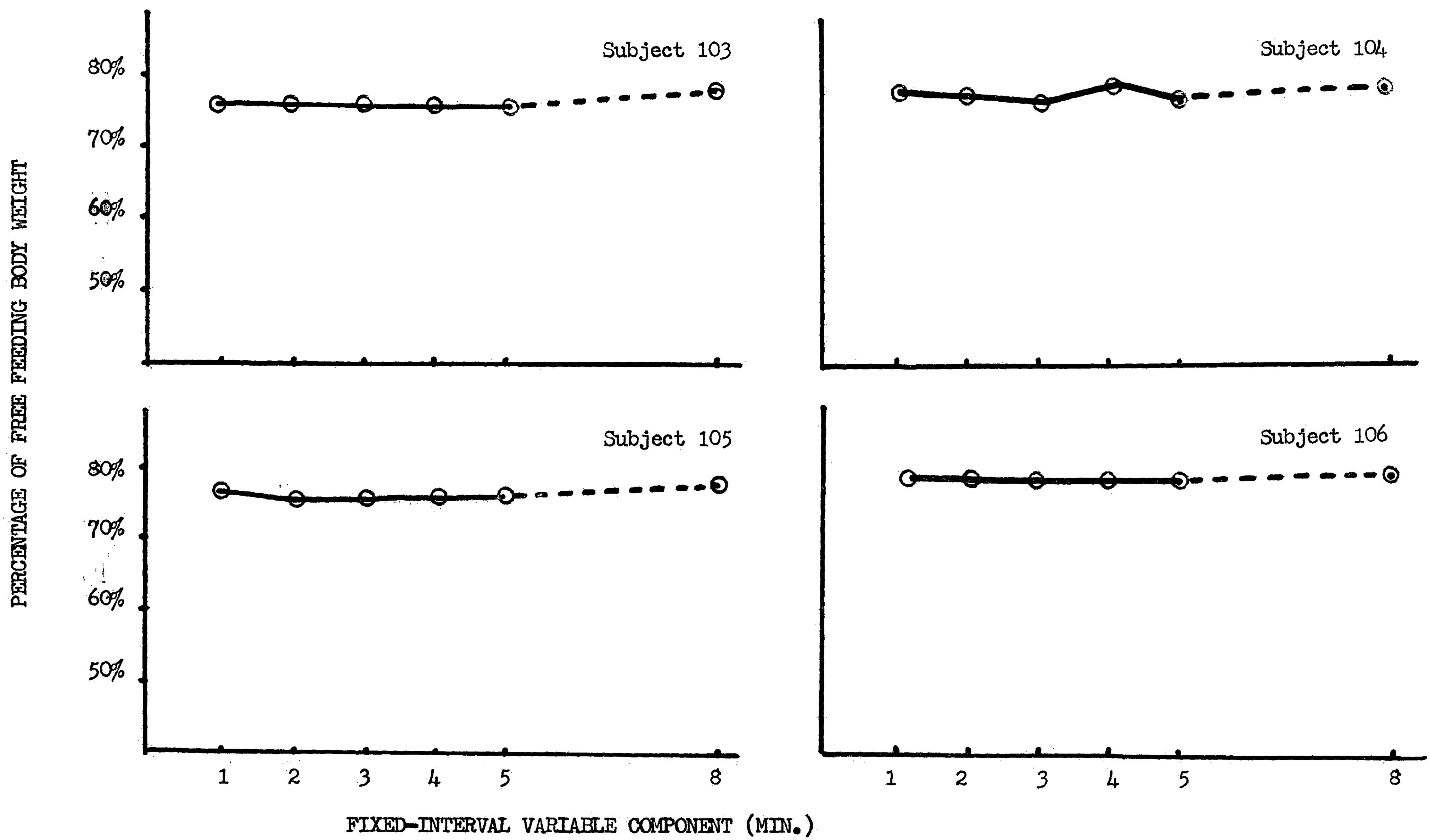


Fig. 7 The percentage of free feeding body weight of all subjects

increased to 35 seconds. The first component continued for 15 minutes before the second component was introduced. The light was switched off (S1) for 15 minutes under the same fixed-interval (FI) 35 seconds schedule. In the following 5 days, the fixed-interval schedule was gradually extended to 60 seconds. Under this training there were two trials per session daily for each subject, and the duration of each trial was 15 minutes.

Multiple FI-1 minute schedules baseline training. The subjects were given four trials per session with two alternating presentations of S2 and S1 in each session. The duration of each presentation was 15 minutes which constituted a trial. Both stimulus S1 and S2 were associated with a FI-1 min. schedule. The criterion for the baseline rate was a stable performance of 5 consecutive days, determined by a visual inspection of the operant curve (Appendix 2). It took 15 sessions for all the subjects to achieve the baseline rate. This relatively stable performance over 5 consecutive days was also used as the criterion for the subjects to change over to phase two.

Discrimination training. After the subjects achieved a stable performance for five consecutive days, the FI-1 min. schedule associated with stimulus S2 was replaced by a FI-2 min. schedule. Similarly, when the subjects exhibited a stable performance over a period of five days, the FI-2 min. schedule associated with stimulus S2 was replaced by a FI-3 min. schedule. To ensure that the performances of the subjects were controlled by each stimulus rather than the order of presentations, a probe technique was introduced in this phase. Each subject was assigned a reverse order of presentations of stimuli in two consecutive sessions and one single session. If the subjects were under the control of the stimuli, the reversal would have caused a reversed response rate immediately after the switch. By the same token, if the subjects were controlled by the order of presentations, the reversed stimuli should have brought about no effect on the rate of responding in S1 and/or S2. After a stable performance over a period of 5 days, the FI-3 min. was replaced by a FI-4 min. schedule. The same discrimination training procedure and criterion of stable performances applied to FI-4 min., FI-5 min., and FI-8 min.

Results

Data analysis was based upon 81 consecutive days of performances, or a total of 324 trials per subject. The responses per minute for S1 and S2 were defined as the total responses of S1 or S2 divided by 30 minutes. Six response rates were obtained for each subject in each phase. Data were evaluated by repeated measures analysis of variance and polynomial.

The baseline rate of response was determined by the last 5 consecutive days in phase one. The average response rate for each phase was taken from the first 5 consecutive days since the rate of response had a tendency to decrease gradually as the session continued (see also Terrace, 1966; Nevin and Shettleworth, 1966); also contrast effects tend to occur early in discrimination and sometimes disappear with prolonged training (Terrace, 1966; Nevin and Shettleworth, 1966). Therefore, the first 5 sessions was used as an indicator of interaction effects.

In phase 1 baseline training, 15 sessions were required to achieve the criterion of a stable performance. It took another 15 sessions to achieve the same criterion in phase 2 (FI-2 min.) discrimination training. In phase 3 (FI-3 min.) a probe technique was employed. The reversed rate of responding in each component immediately after a reversal of stimuli was evident in three out of the four subjects (Fig. 8). FI-3 min. required 13 sessions to achieve a stable performance. Each of the remaining three phases of discrimination training took 10 sessions to achieve the stable rate.

While the individual contrast curves (Fig. 13) were obtained from the first five consecutive days in each phase, the individual discrimination index curves were gathered from the last eight sessions in each phase (Figs. 9, 10, 11, 12). The former was to show contrast effects whereas the latter was for the purpose of showing the relationship between S1 and S2 across different phases.

The results showed that the response rates associated with both the variable component (S2) and the constant component (S1) increased substantially from their respective baseline rates (Fig. 13). Further, the rate of responses associated with the constant component demonstrated an inverted U shape in response to the reinforcement values associated with the variable component (Fig. 14). The peak reinforcement value for all the subjects was found somewhere between 2 and 4 minutes.

Analysis of variance based upon the average rate of responding over the first 5 consecutive days showed a significant FI schedule effect, $F(5, 15)=13.00$, $p<0.001$ (Appendix 3). Trend analysis by polynomial indicated that the quadratic term just missed reaching the 0.5 level of significance, i.e. $F(1,3)=4.3$, $p=0.057$ (Appendix 6). As to the individual curves (S1) of each subject, subject 105 clearly exhibited an inverted U shape; subjects 104 and 106 demonstrated a similar curve, although to a less degree. Subject 103 failed to show the bitonic curve (Fig. 13).

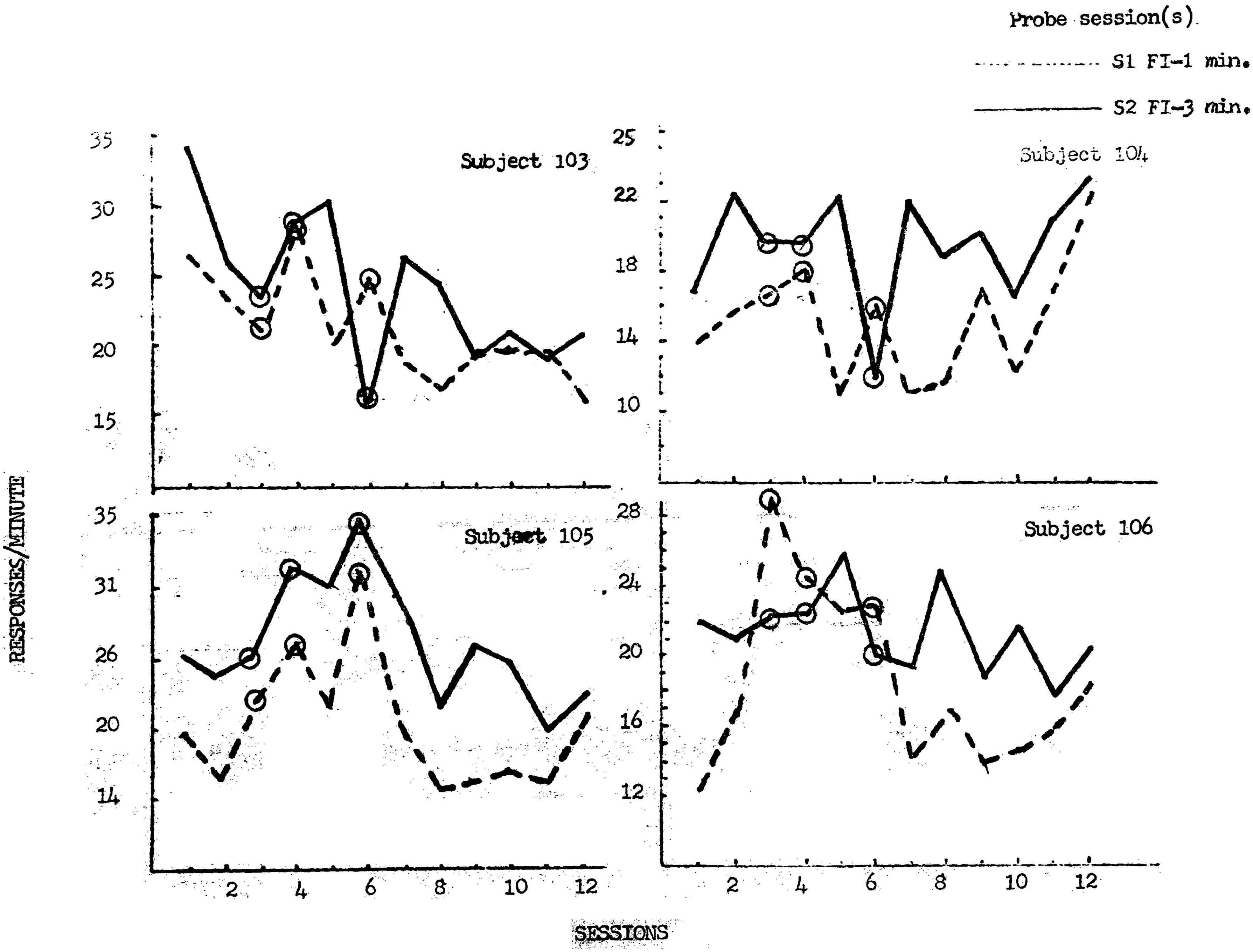


Fig. 8 Differential response rates before, during, and after the probe period.

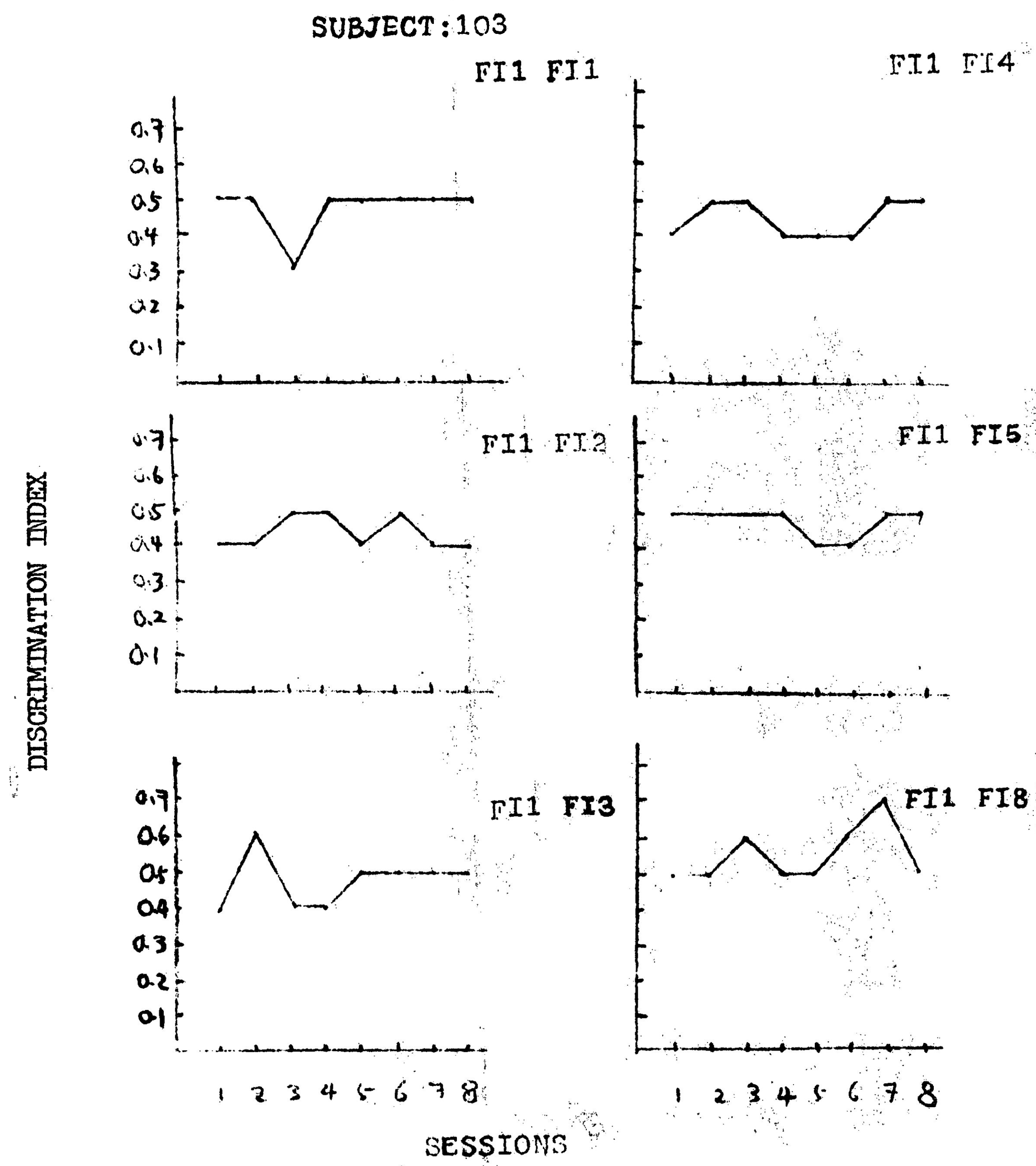


Fig. 9 Individual discrimination index curves across six phases.

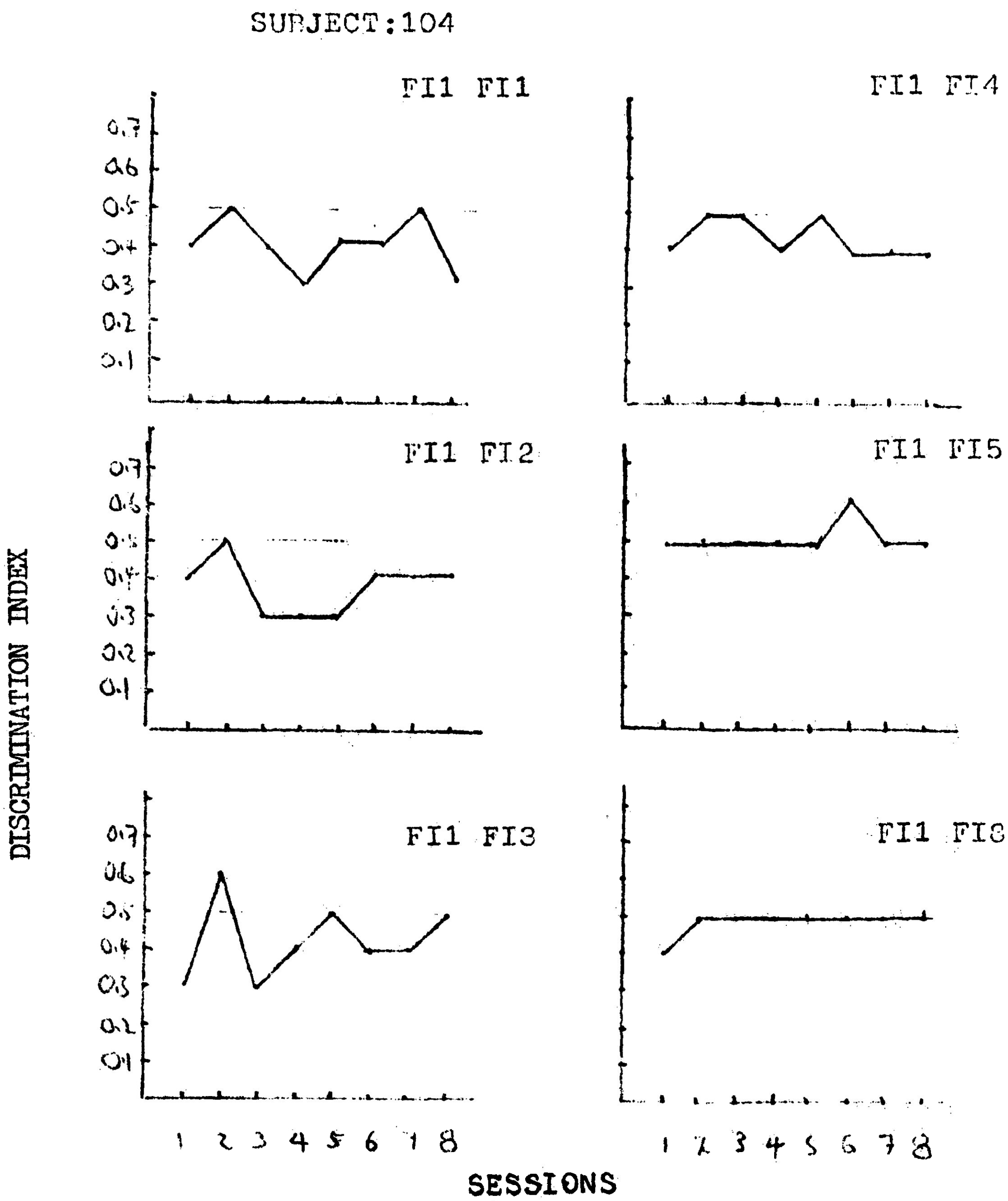


Fig. 10 Individual discrimination index curves across six phases.

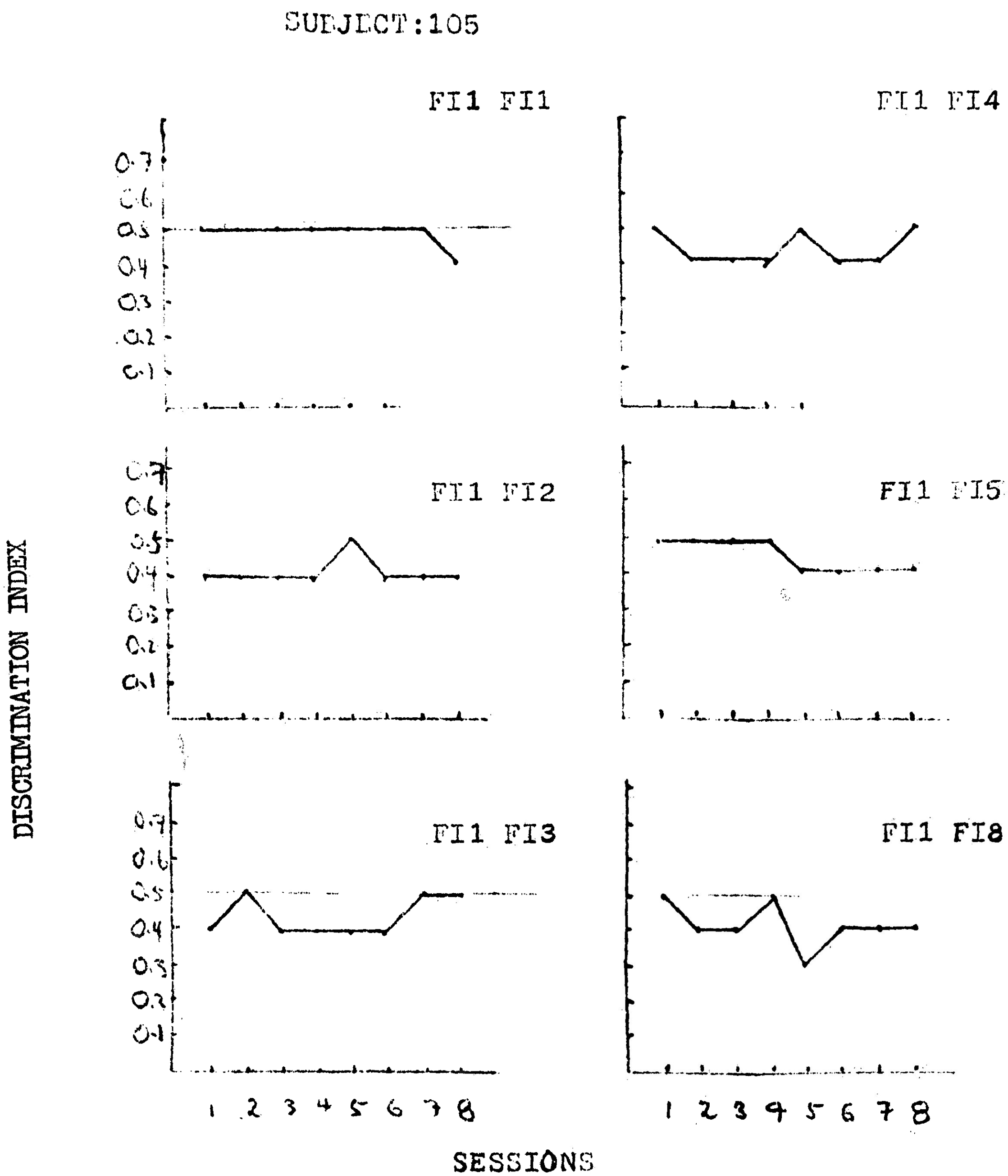


Fig. 11 Individual discrimination index curves across six phases.

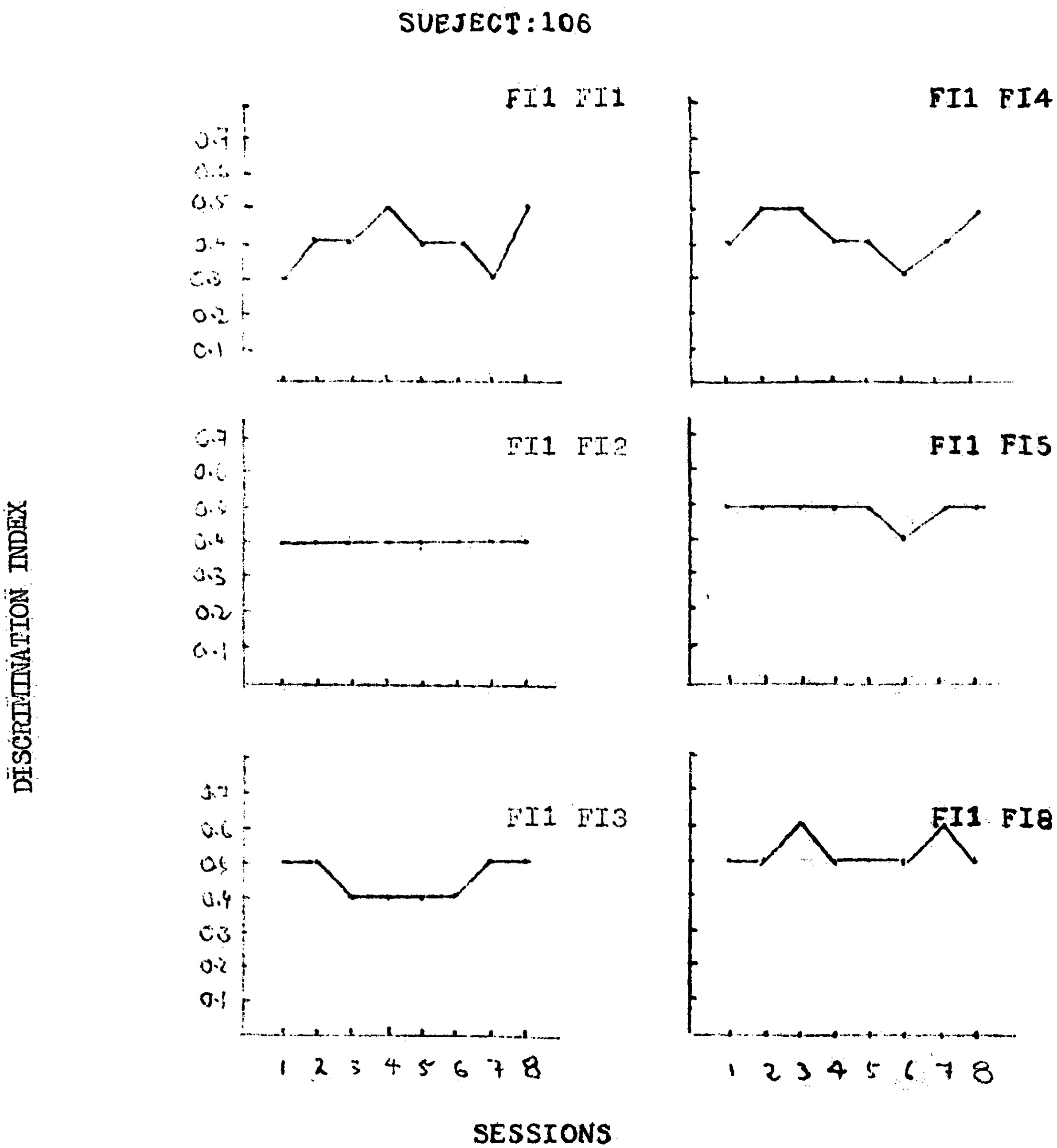


Fig. 12 Individual discrimination index curves across six phases.

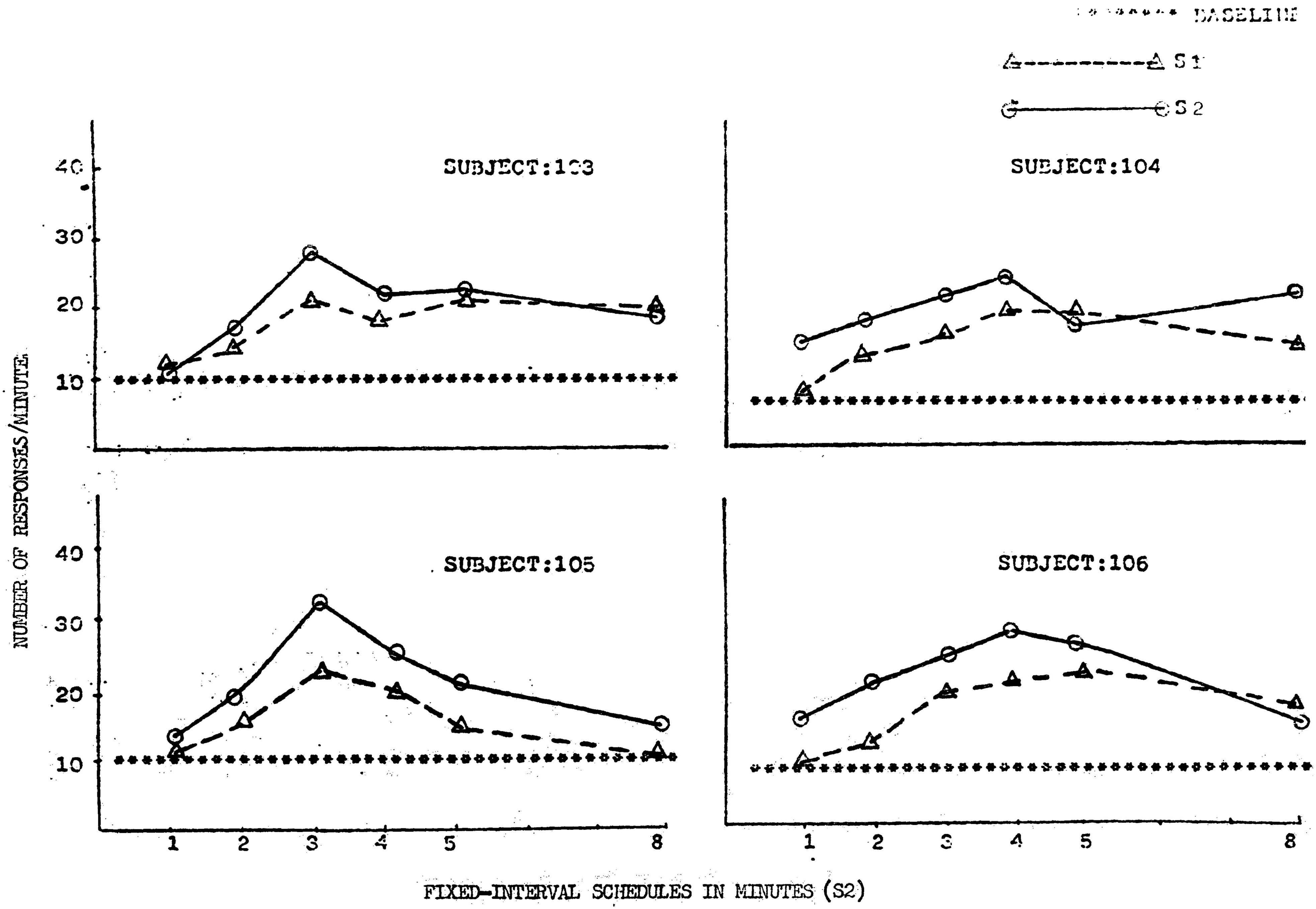


Fig. 13 Mean responses for 5 consecutive days at the beginning of each phase. The baseline rate at FI-1 was obtained from the last 5 consecutive days of phase 1.

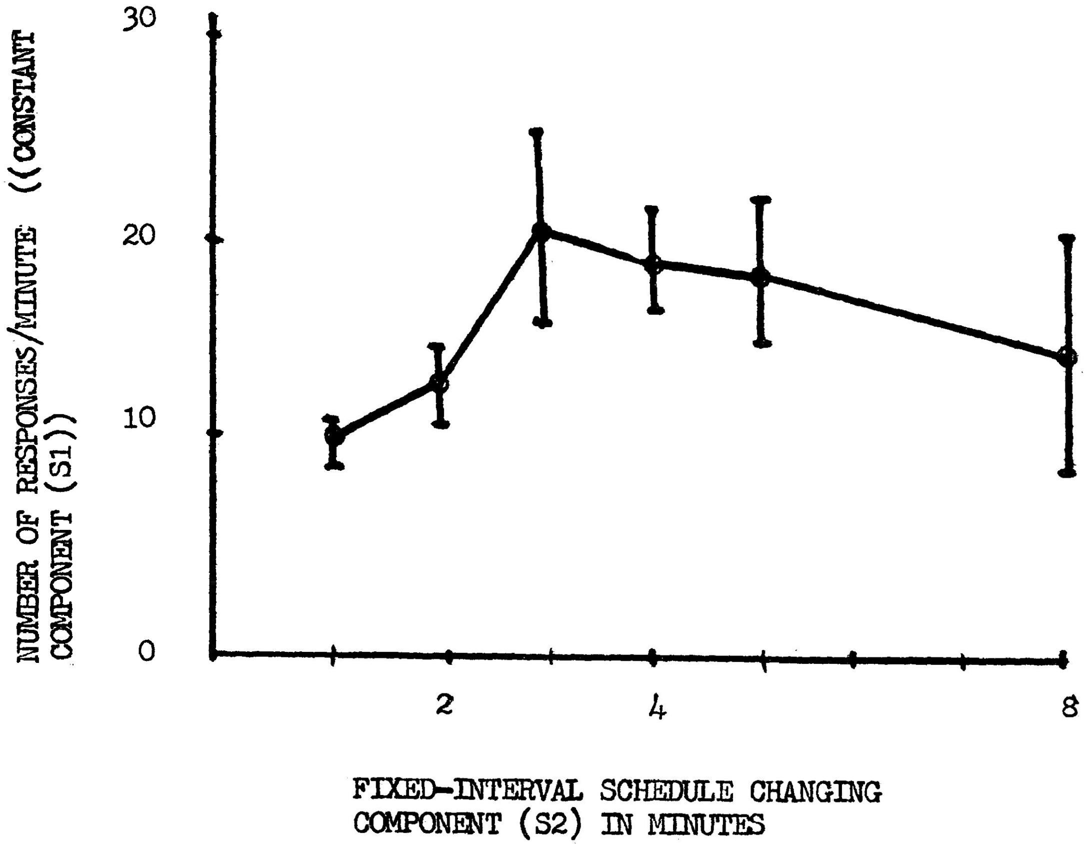


Fig. 14 All subjects mean response rate for 5 consecutive days at the beginning of each phase. The baseline rate at FI-1 was obtained by collapsing the last 5 consecutive days of phase 1. Standard deviation for each subject was included.

Discussion

A number of studies (Reynolds, 1961a; Terrace, 1968) indicated that when the schedule of reinforcement in the variable component (S2) of multiple schedules was changed to extinction, the rate of response associated with the unchanged component (S1) increased. Others (Dews, 1958; Findley, 1958; Reynolds, 1961c) suggested that the change of the frequency of reinforcement in the S2 component could result in a change in the response rate associated with the S1 component.

Reynolds (1961a) maintained that the relative frequency of reinforcement was the necessary and sufficient condition for producing contrast effects. His position was supported by several studies (Catania, 1961; Reynolds, 1961c, 1963; Nevin, 1968) where the magnitude of contrast effects was demonstrated to be inversely related to the frequency of reinforcement in the changing component (S2). However, Terrace (1963a, 1963b) showed that contrast effects did not occur under the errorless learning condition, and that the extended discrimination training resulted in a gradual disappearance of contrast effects (Terrace, 1966). These findings led him to a different view of contrast which emphasized the suppression of responding rather than reinforcement as a sufficient condition for the occurrence of contrast effects. Attempts to separate the effect of reinforcement frequency and response suppression have not successfully resolved this issue (Reynolds, 1961a; Catania,1961; Bloomfield, 1967; Terrace, 1968; Weisman, 1970; Halliday and Boakes, 1971; Weisman and Ramsden. 1973; Thomas and Cameron, 1974).

The results from the current study are consistent with Reynolds' position that relative frequency of reinforcement is the necessary and sufficient condition for the occurrence of contrast effects. Positive behavioral contrast, as he put it, "is usually defined as an increase in response rate in the unchanged component of a multiple schedule <u>under conditions of a decrease in the frequency of reinforcement</u>

in an alternate component", a view that has been reiterated by Beninger and Kendall (1975), Hamilton and Silberberg (1978) as well as McSweeney and Norman (1979). The present study showing a significant increase (Appendix 3) of the response rate in the constant component (S1) due to a reduction of reinforcement frequency in the variable component (S2) is consistent with this definition.

Skinner (1938) and Terrace (1966) suggested that the direction of responding in two-component multiple schedules be used to define the type of interaction. An increase in the rate of responding in both components of multiple schedules was referred to as positive induction whereas a reduction in the rate of responding in both components was referred to as negative induction. An increase in the rate of response in the constant component accompanied by a reduction of response rate in the changing component was referred to as positive contrast. Such a definition of interaction is entirely based upon the relative response rate in each component of multiple schedules without specifically referring to the frequency of reinforcement in each component.

According to such a definition, the present study has demonstrated a positive induction effect. On the other hand, if Reynolds' Relative Reinforcement Frequency position is taken, contrast effects are apparent in this study. To avoid the confusion due to different definitions, the present study has mainly confined itself to contrast effects produced by the changes in the rate of reinforcement in the variable component.

The demonstration of interaction effects between the two components in multiple schedules in the present study confirms the finding that the response rate in one component (S1) can be influenced by the change of the reinforcement schedule associated with the other component (S2) (Findley, 1958; Reynolds, 1961b; Terrace, 1963b; Hamilton and Silberberg, 1978). In addition, the results have demonstrated a reliable relation between the response rate in S1 and the schedule values in S2 as well as between the rate of responses in S1 and the relative frequency of reinforcement in S2 ($F(5, 15)=7.2$, $p=0.001$) (Appendix 5). In other words, the effect exerted from one onto the other is not a random one; it can be described as a bitonic function (Figs. 14 & 15).

Employing a concurrent schedule and two rats as subjects, Falk (1966a) has demonstrated a bitonic function in schedule-induced polydipsia. In the present study, two-component multiple schedules and four rat subjects were used. The results have also indicated a bitonic function of interaction effects. When individual curves were compared, subject 105 in this study and subject I-10 in Falk's displayed a remarkably similar bitonic function whereas subject 103 in the present study and subject I-11 in Falk's showed an inconclusive bitonic function (Fig. 16).

Therefore, since the obtained bitonic function relating to the response rate in S1 and reinforcement frequency in S2 coincided with Reynolds' view of contrast and is also consistent with Falk's data, it seems to point to the possibility of a common causal mechanism between contrast and adjunctive effects.

It is apparent that the primary objective of this study has been achieved. The results indicate that the constant component (S1) rates follow an inverted U curve which is also evident in polydipsia and other adjunctive behaviors. However, when the individual curves are examined (Fig. 17), in the early phases from FI-1 to FI-3, all subjects demonstrated higher S2 rates than S1 rates whereas in later phases three out of four subjects showed higher S1 rates. The outcome observed

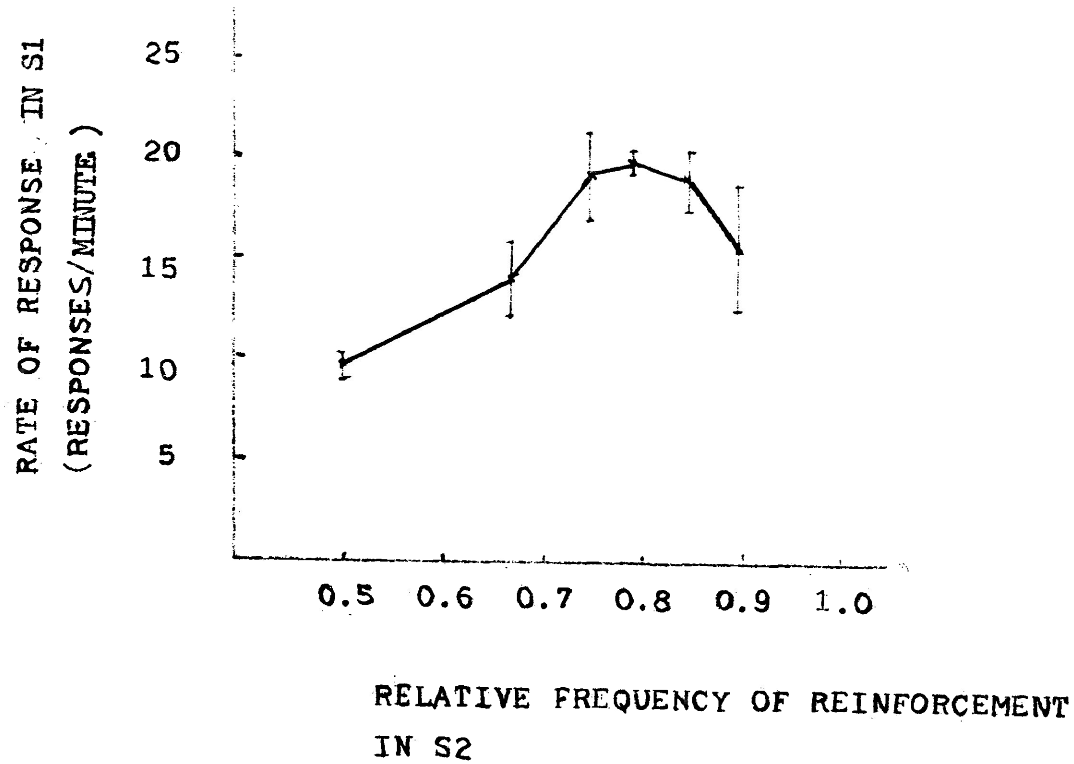


Fig. 15 Rate of response in S1 is expressed as a function of relative frequency of reinforcement in S2 across six phases.

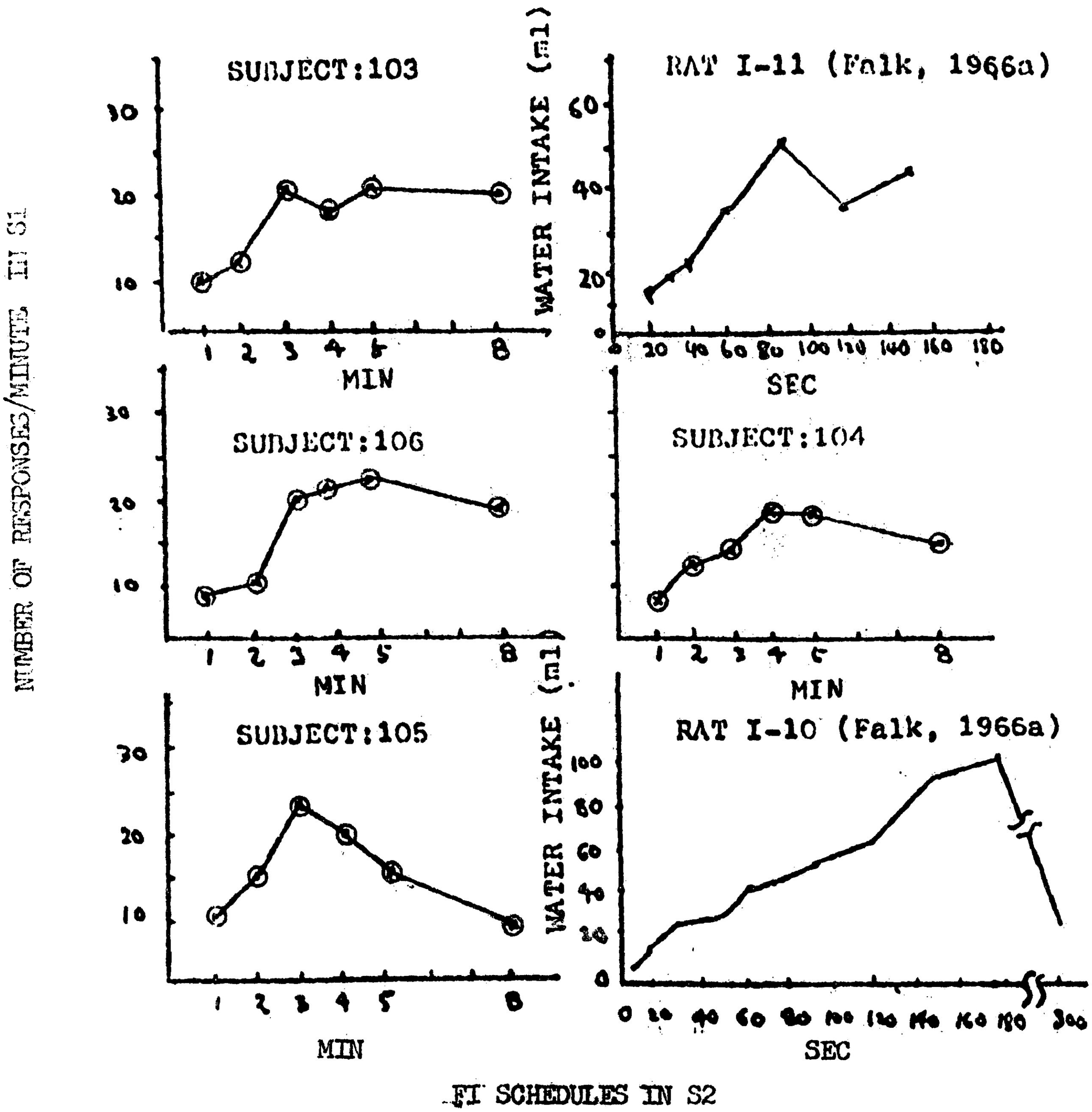


Fig. 16 A comparison of results of the present study to Falk's (1966a)

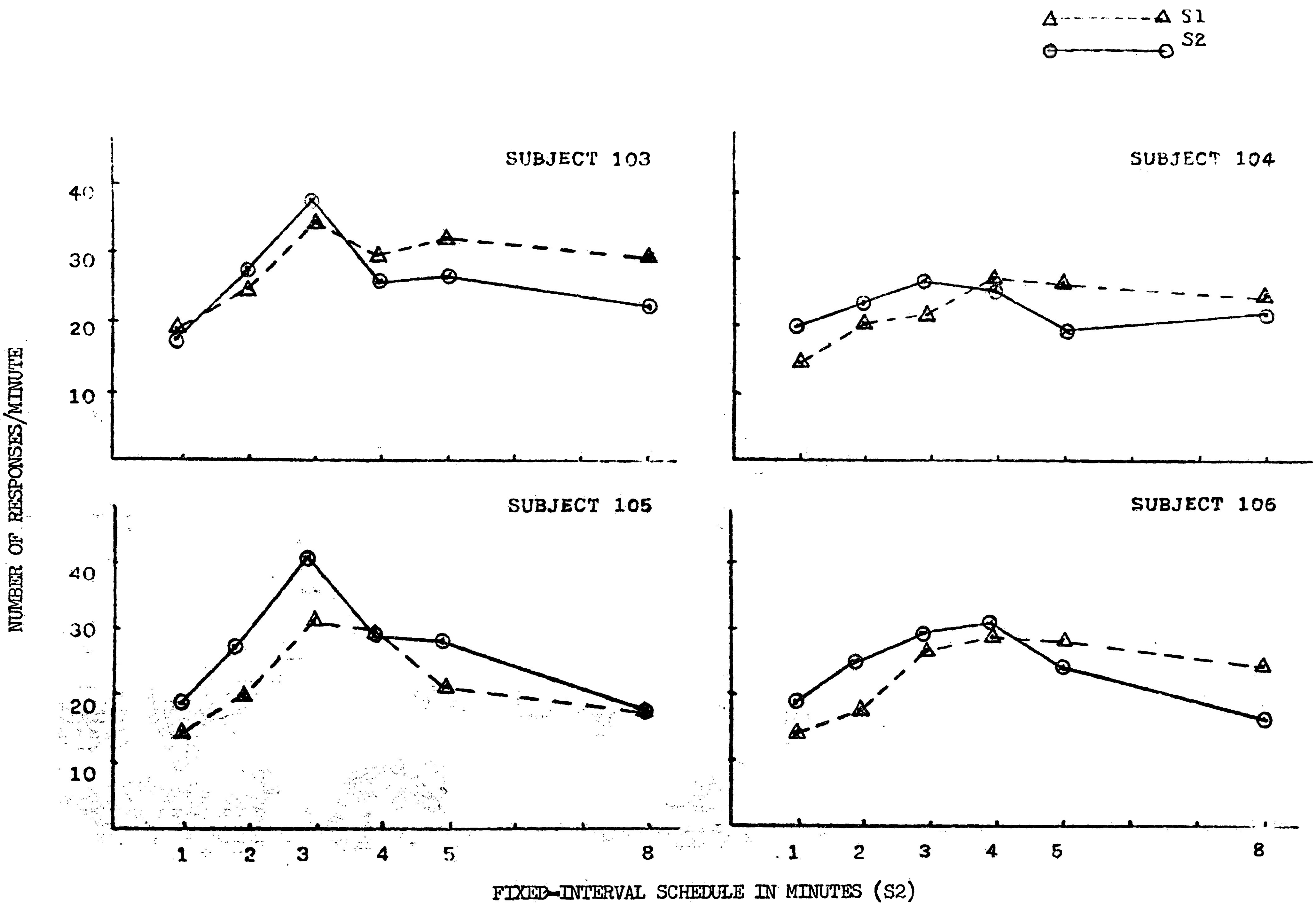


Fig. 17 Compensated mean responses for 5 consecutive days at the beginning of each phase. The baseline rate at FI-1 min. was obtained from the last 5 consecutive days of phase 1.

in the early phases has raised a number of questions. First, the outcome may have been attributable to the absence of control by the multiple schedules; that is, the mere alternation of schedules of reinforcement with which there are corresponding exteroceptive stimulus changes is a necessary but not sufficient basis for claiming that the behavior observed reflects multiple schedule control. Second, it may have been due to the lack of stimulus control along with insufficient evidence to confirm the presence of stimulus control; that is, the rationale for the "probe test" is faulty since reversing the order of presentations of the discriminative stimuli and their associated schedules of reinforcement merely makes it possible to show that serial order of components was not controlling the responding. Third, the apparent difference in the rate of responding between the components may have resulted from the disruptive effects of reinforcer delivery rather than stimulus control.

To deal with the absence of multiple schedules, it is imperative to distinguish between the procedure that defines multiple schedules, and the outcome of that procedure. In Freeman's study (1971(a)), it was stated that, "A multiple schedule is one in which two or more schedules of reinforcement are alternated with a different exteroceptive stimulus associated with each other." The procedure used in this study was in accordance with such a definition. It is the result of this procedure that interaction effects were demonstrated. Interaction effects were replicated in all the four subjects. Thus the probability of the effects being manifested by chance alone was deemed as very low. Furthermore, according to the interschedule definition (Hamilton and Silberberg, 1978, Beninger and Kendall, 1975; McSweeney and Norman, 1979), positive contrast effects were evident in the present study. Thus, the existence of multiple schedules in this study was supported by the procedural difinition (Freeman, 1971(a)) as well as the behavioral definition (Beninger and Kendall, 1975; Hamilton and Silberberg, 1978; McSweeney and Norman, 1979).

As to the issue of lack of stimulus control in this experiment, only the order of presentations of discriminative stimuli and not the reinforcement schedules had been reversed during the probe period. Had both the stimuli and schedules order of presentations been reversed simultaneously during the probe period, it would have been impossible to determine the presence or absence of stimulus control. As a result of only reversing the discriminative stimuli, the probe test showed that the order of components had not controlled the rate of responding. It might be argued, however, that the probe test can only allow a determination of the order effect and can not offer any further proof of stimulus control. Although the probe test does not meet the criterion of an absolute test, it offers adequate measures to determine whether there is any stimulus control. Should the rate of responding be under stimulus control, the rate of responding in each component would reverse its direction immediately after a reversal of stimuli. This reversal effect of response rates was clearly shown in three out of four subjects, i.e. subjects 106, 105 and 104 (Fig. 8). In addition, such a reversal effect corresponding to the switch of stimulus was also evident in the second single probe test session.

The question covering the apparent difference in the rate of responding between the components resulting from the disruptive effects of reinforcer delivery rather than stimulus control can be dealt with in two ways. First, the mean post-reinforcement pause reflects the mean length of time the subjects lost in one session (30 minutes) due to the frequent interrutpion of reinforcement presentations. Thus from the mean response rate in a particular schedule, a mean loss of response rates due to frequent interruption can be calculated (Appendix 15). This new measure of responses can be used as the basis for plotting the discrimination curves. Had the differential response rates been caused by the frequent pausing induced by frequent reinforcement interruption, the rate of responding in S1 and S2 across different phases should have overlapped each other. The new compensated discrimination curves as shown in Fig. 16 did not show any overlapping however. Furthermore, the original differences in the rate of responding between S1 and S2 in the pre-compensated data was preserved and exaggerated in the compensated curves (Fig. 17).

Second, the analysis of response rates in the same component (S1) across the six phases indicated that there were significant schedule effects ($F(5, 15)=9.0$, $p<0.001$) (Appendix 4) exerted from the other component (S2) (Fig. 18). Moreover, had the response rates been soley influenced by the frequent interruption in one schedule, the rates of responding across different phases would have been more or less uniform since the frequency of interruption was consistent in the constant component (S1) FI-1 min. The results of this compensated new rate of responses clearly indicated that not only the rates of responding in S1 and S2 did not overlap each other but there was also a reliable relation between the compensated response rate of the constant component (S1) and the schedule values of the variable component (S2) (Fig. 18).

The choice of rats as experimental subjects may also be questioned on the following grounds: first, studies of contrast phenomena typically employ pigeons rather than rats as subject. Secondly, it seems that when rats are used as experimental subjects, clear-cut contrast effects are not always obtained (Bernheim and Williams, 1967; Freeman, 1971b; Pear and Wilkie, 1971; de Villers, 1977). Furthermore, Freeman (1971b) suggested that, with bar-pressing rats, induction rather than contrast occurred.

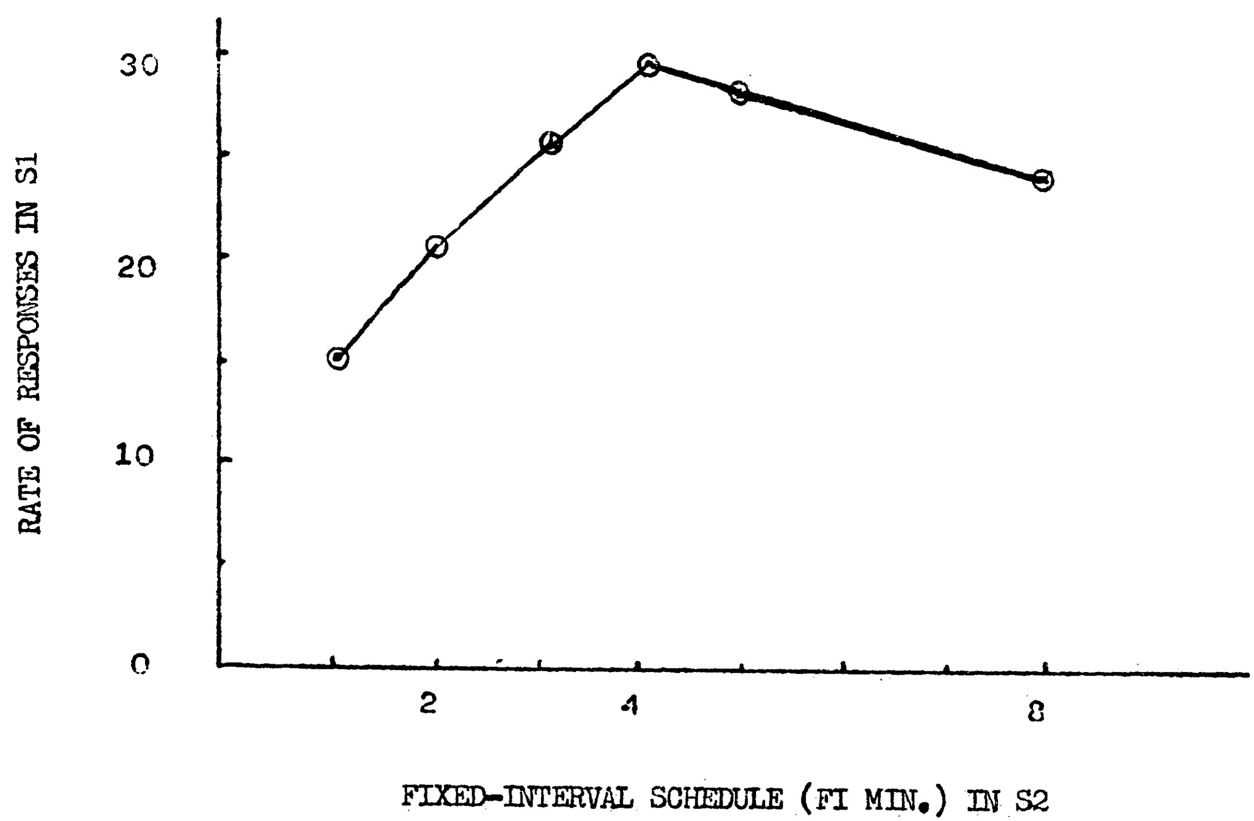


Fig. 18 Compensated mean response rate for 5 consecutive days at the beginning of each phase. The baseline rate at FI-1 was obtained by collapsing the last 5 consecutive days of phase 1.

Despite the unpopularity of rats in studying contrast effects, the present study used rats as subjects mainly because rats have been frequently used in studies of adjunctive behavior and bitonic relations. Since the present study also dealt with contrast effects, various rat studies in connection with both contrast and adjunctive behavior have been consulted. Among them were Amsel's 1952 classical study; Allen and Porter, 1975; Eisenberger, Frank and Park, 1975; Porter and Allen, 1977. In addition, special attention has been placed on Falk's study (1966a) in which he employed two rats as the subjects. It was hoped that the choice of the subjects in the present study would allow the results of the two studies to be compared.

It is very unlikely that the absence of multiple schedules or the lack of stimulus control, or the disruptive effect of reinforcer delivery is responsible for the observed outcome, that is, higher S2 rates than S1. In an attempt to resolve this phenomenon, a possible explanation is proposed. Three phenomena, namely, the post reinforcement pause, constant rate of response within the interval, and a positive function between the response rate and fixed interval schedules suggest that the subjects may have responded to FI schedules as if they were FR schedules. A further discussion on these phenomena is in order.

The post reinforcement pause has been obtained from both fixed-ratio (FR) schedules (Ferster and Skinner, 1957; Gott and Weiss, 1972) and fixed-interval schedules (Cumming and Schoenfeld, 1958; Schneider, 1969; Shull, 1971). Also, the positive relation between the length of the pause and the requirement of schedules as obtained in this study (Fig. 19) has been replicated in FR schedules studies (Premack, Schaeffer, and Hundt, 1964; Elsmore, 1971; Nevin, 1973). It appears then that the post reinforcement pause can be generated by either FR or FI schedules.

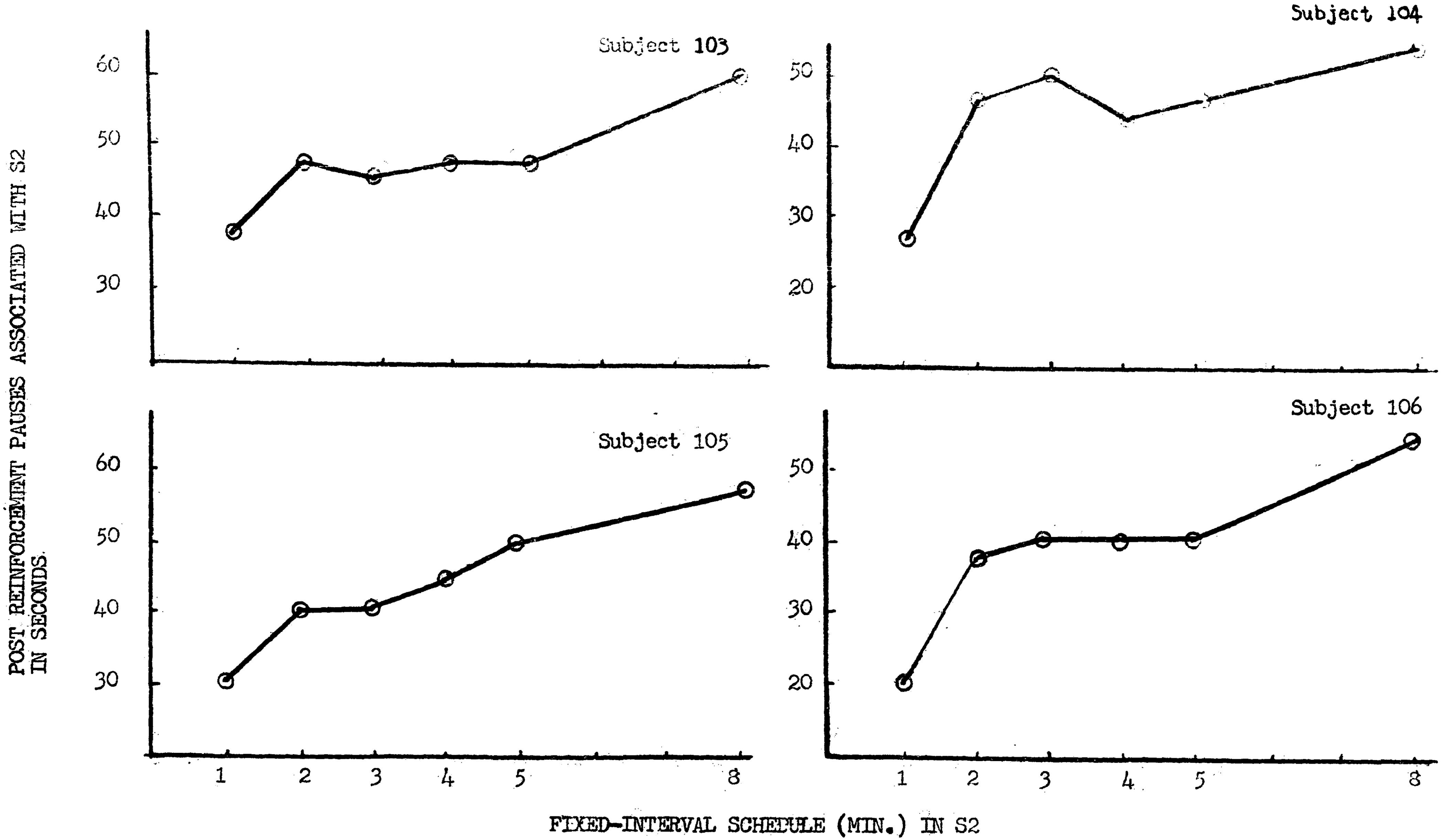


Fig. 19 Post reinforcement pause is expressed as a function of fixed-interval schedules associated with the variable component (S2).

The constant response rate can be generated by a low value of FI schedules (Hearst, 1958). Under this condition, subjects develop a "break-and-run performance", i.e. post-reinforcement pause and constant terminal rate. These properties also closely resemble FR response curves as observed by Ferster and Skinner (1957) and Boren (1961). It seems that the break-and-run pattern can be obtained from both FR and low-valued FI schedules.

The properties of the response rate in relation to fixed-ratio schedules are uncertain. Some studies have demonstrated a positive relation (Boren, 1961; Premack, Schaeffer, and Hundt, 1964), while others have found a negative function (Ferster and Skinner, 1957). In this experiment, when the value of FI schedules increased up to 3 or 4 minutes, the relation between the response rate and the FI schedules was positive. As the FI schedules further increased, the relation became a negative one (Fig. 20). Although the results seem to be contradictory to most findings, nevertheless, other things being equal, if the fixed-interval schedules were viewed as fixed-ratio schedules, the results would have been in compliance with many studies (Kaplan, 1956; Boren, 1961).

Many studies have demonstrated that FR schedules can induce such adjunctive behavior as aggression and polydipsia (Gentry, 1968; Hutchinson, Azrin, and Hunt, 1968; Keehn and Colotra, 1971; Richards and Rilling, 1972; Cohen and Looney, 1973). Most of these studies have also observed adjunctive behavior occurring during the post reinforcement pause. It seems very likely, then, that FR schedules can exert influences upon the behavioral outcome of subjects in a multiple schedules situation. If indeed the FI schedules in the early phases

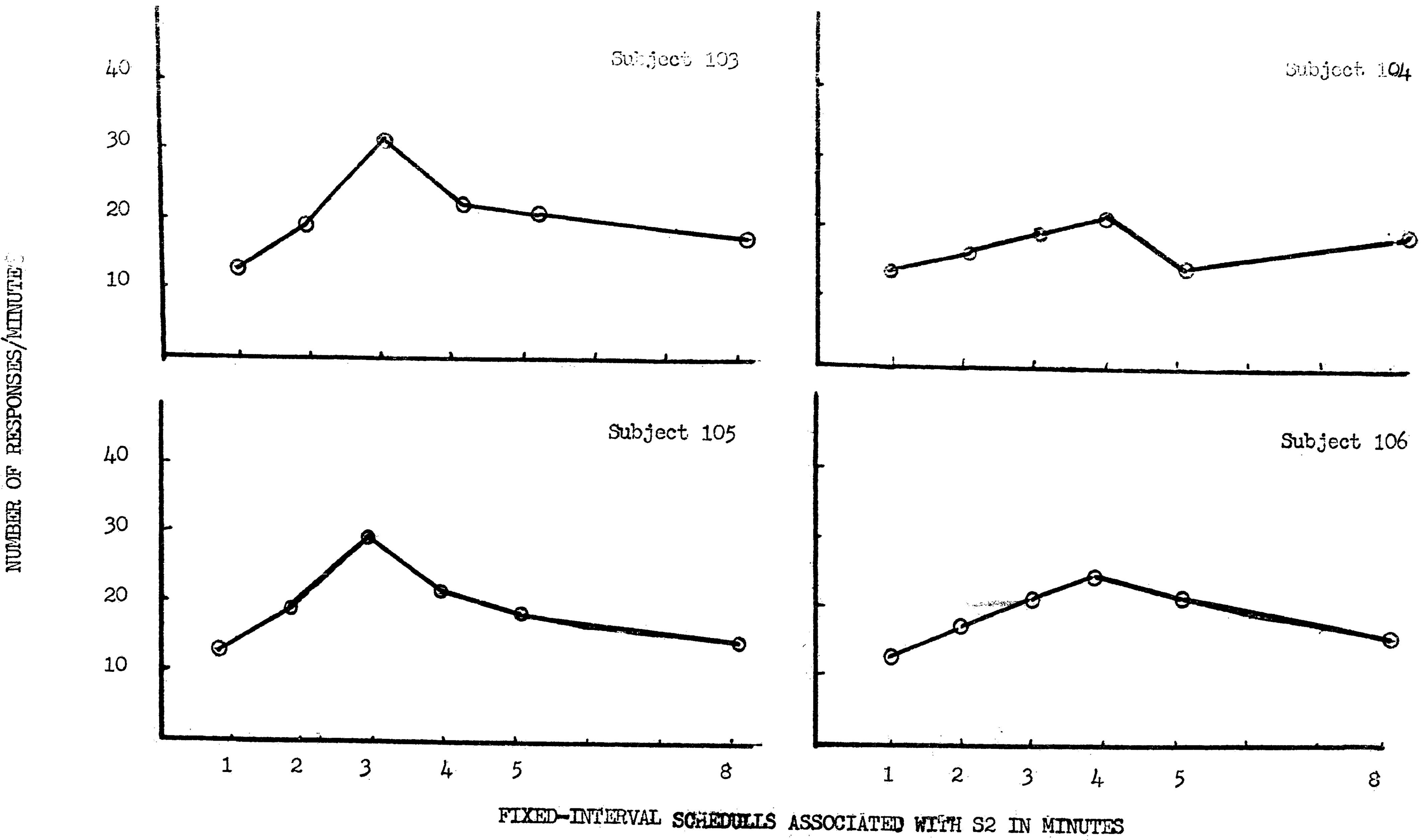


Fig. 20 Rate of responding in variable component is expressed as a function of fixed-interval schedules associated with the variable component.

of this experiment have been treated as FR schedules, the observed interaction effects should support the hypothesis that FR schedules may indeed produce an interaction effect in a multiple schedules situation.

Since ratio schedules of reinforcement produce higher rates of response than interval schedules (Catania, 1966; Reynolds, 1968; Zuriff, 1970), if the FI schedules associated with S2 were indeed responded to as FR schedules, S2 would result in a higher rate than S1. Furthermore, if the schedules associated with both S1 and S2 were responded to as FR schedules, the result would still show a higher S2 rate (Ferster and Skinner, 1957).

In short, it has been demonstrated that high-valued fixed-ratio schedules share many similar properties with various fixed-interval schedules. The similarities are summed up as follows: 1) the post-reinforcement pause; 2) the positive function between schedule requirement and pause length; 3) multiple pauses in both schedules; 4) the terminal rate being reached immediately after the pause and maintained until the schedule was complete, and 5) ratio schedules generating higher rates of response than interval schedules. It is highly probable, then, that the FI schedules may have been responded to as FR schedules.

Since adjunctive behavior is usually studied and observed in the concurrent schedule situation, and behavioral contrast in the multiple schedules situation, a close look at these two experimental situations is imperative. Studies have indicated that adjunctive behavior can occur under multiple schedules (Jacquet, 1972; Allen and Porter, 1975; Porter and Allen, 1977), and contrast behavior in concurrent schedules (Catania, 1961; Eisenberger, Frank, and Park, 1975; Williams, 1977). These findings confirm the notion that adjunctive behavior and behavioral contrast can be generated from the same experimental situation, i.e. concurrent, or multiple schedules.

Using a concurrent schedule, Falk has demonstrated a bitonic function in schedule-induced polydipsia. Based upon multiple schedules, the present experiment has also demonstrated a bitonic function in interaction effects. These findings suggest that, first, there is a unitary mechanism underlying adjunctive behavior and interaction effects, and second that, a bitonic function can occur in the contrast situation under multiple schedules. The concept of common underlying mechanism is further strengthened by Porter and Allen's (1977) study in which they showed that under multiple schedules, contrast effects can be obtained with schedule-induced polydipsia.

The values of schedules in the variable component associated with the peak performance in the constant component have been found very similar to those of Reynolds (1963), Falk (1966a), Flory (1969), and Wayner and Greenberg (1973), that is, they range from FI-3 min. to FI-8 min. The slope of curves obtained from these studies has been very similar as well. The rate of responding associated with the variable component increases gradually to a point, approximately between FI-3 and FI-4 min. (with the exception of Reynold's 1963 study in which the peak was found at FI-8 min.), and gradually falls off at lower reinforcement values. The bitonic function observed in the present study indicates that the strength of influences exerting upon the constant component reaches its maximum at 3 to 4 minutes on the changing component. Such results have been found in a variety of situations ranging from polydipsia, induced aggression, to bar-pressing responses.

The research presented in this thesis suggests a relationship between contrast effects and adjunctive behavior. The nature of this relationship may be further investigating in subsequent work which allows both phenomena to simultaneously operate in a given subject.

Summary

Bitonic function in contrast effects was studied using two-component multiple schedules. Food-deprived rats were placed under multiple FI FI schedules.

The results indicated that interaction effects occurred when the constant component was associated with a FI-1 min. schedule, while the variable component was associated with six individual FI values in different phases.

A bitonic relation was found between the change of response rates in the constant component (S1) and the length of fixed-interval schedules associated with the variable component (S2).

The results of this experiment supported the Relative Reinforcement Frequency Theory. It was evident that the existing classification was inadequate to define different kinds of interaction effects.

The direction of response rates in S2 being explained by several phenomena, it was concluded that the subjects may have responded to FI schedules as if they were FR schedules.

Given that both the present research and Falk's adjunctive study yielded a bitonic function using respectively multiple schedules and concurrent schedules, it was concluded that contrast effects and adjunctive behavior may share some common underlying mechanisms.

References

Alferink, L.A., Bartness, T.J., and Harder, S.R. Control of the temporal location of polydipsic licking in the rat. Journal of the Experimental Analysis of Behavior, 1980, 33, 119-129.

Allen, J.D., and Porter, J.H. Demonstration of behavioral contrast with adjunctive drinking. Physiology and Behavior, 1975, 15, 511-515.

Amsel, A., and Roussel, J. Motivational properties of frustration: I. Effect on a running response of the addition of frustration to the motivational complex. Journal of Experimental Psychology, 1952, 43, 363-368.

Amsel, A. The role of frustrative nonreward in noncontinuous reward situation. Psychological Bulletin, 1958, 55, 102-119.

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

Bernheim, J.W., and Williams, D.R. Time-dependent contrast effect in a multiple schedule of food reinforcement. Journal of the Experimental Analysis of Behavior, 1967, 10, 243-249.

Blackman, D. Operant conditioning: An experimental analysis of behavior, Methuen & Co. Ltd, 1974.

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

Boren, J.J. Resistance to extinction as a function of the fixed ratio. Journal of Experimental Psychology, 1961, 61, 304-308.

Brethower, D.H., and Reynolds, G.S. A facilitative effect of punishment on unpunished behavior. Journal of the Experimental Analysis of Behavior, 1962, 5, 191-199.

Brown, P.L., and Jenkins, H.M. Auto-shaping of the pigeons key-peck. Journal of the Experimental Analysis of Behavior, 1968, 11, 1-8.

Brownstein, A.J., and Pliskoff, S.S. Some effects of relative reinforcement rate and changeover delay in response-independent concurrent schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 683-688.

Burks, C.C. Schedule-induced polydipsia: Are response-dependent schedules a limiting condition? Journal of the Experimental Analysis of Behavior, 1970, 13, 351-358.

Carlisle, H.J. Fixed-ratio polydipsia: Thermal effects of drinking, pausing, and responding. Journal of Comparative and Physiological Psychology, 1971, 75, 10-22.

Catania, A.C. Concurrent operants. In W.K. Honig (Ed.), Operant behavior: areas of research and application. New York: Appleton-Century-Crofts, 1966, 213-270.

Catania, A.C. Behavioral contrast in a multiple and concurrent schedule of reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 335-342.

Catania, A.C. Concurrent performances: synthesizing rate constancies by manipulating contingencies for a single response. Journal of the Experimental Analysis of Behavior, 1972, 17, 139-145.

Clark, F.C. Some observations on the adventitious reinforcement of drinking under food reinforcement. Journal of the Experimental Analysis of Behavior, 1962, 5, 61-63.

Cohen, P.S., and Looney, T.A. Schedule-induced mirror responding in the pigeon. Journal of the Experimental Analysis of Behavior, 1973, 19, 395-408.

Crespi, L.P. Quantitative variation in incentive and performance in the white rat. American Journal of Psychology, 1942, 55, 467-517.

Cumming, W.W., and Schoenfeld, W.N. Behavior under extended exposure to a high-value fixed interval reinforcement schedule. Journal of the Experimental Analysis of Behavior, 1958, 1, 245-263.

de Villiers, P.A. Choice in concurrent schedules and a quanitative formulation of the law of effect: in W.K. Honig and J.E.R. Staddon (eds), Handbook of operant behavior, Englewood Cliffs, New Jersey: Prentice-Hall, 1977, 233-287.

Dews, P.B. Studies on behavior. II. The effects of pentobarbital, methatphetamine, and scopolamine on performances in pigeons involving discriminations. Journal of Pharmacology and Experimental Therapeutics, 1955, 115, 380-389.

Dews, P.B. Effects of chlorpromazine and promazine on performance on a mixed schedule of reinforcement. Journal of the Experimental Analysis of Behavior, 1958, 1, 73-82.

Eisenberger, R., Frank, M., and Park, D. Incentive contrast of choice behavior. Journal of Experimental Psychology: Animal Behavior Processes, 1975, 1, 346-354.

Elsmore, T.F. Independence of postreinforcement pause length and running rate on fixed-interval pacing reinforcement schedules. Psychonomic Science, 1971, 23, 371-372.

Falk, J.L. Production of polydipsia in normal rats by an intermittent food schedule. Science, 1961, 133, 195-196.

Falk, J.L. The motivational properties of schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1966, 9, 19-25. (a)

Falk, J.L. Schedule-induced polydipsia as a function of fixed interval length. Journal of the Experimental Analysis of Behavior, 1966, 9, 37-39. (b)

Falk, J.L. Control of schedule-induced polydipsia type, size, and spacing of meals. Journal of the Experimental Analysis of Behavior, 1967, 10, 199-206.

Falk, J.L. Conditions producing psychogenic polydipsia. New York Academy of Science, 1969, 157, 569-589.

Falk, J.L. The nature and determinants of adjunctive behavior. Physiology and Behavior, 1971, 6, 577-588.

Ferster, C.B., and Skinner, B.F. Schedules of reinforcement. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1957.

Findley, J.D. Preference and switching under concurrent scheduling. Journal of the Experimental Analysis of Behavior, 1958, 1, 123-145.

Flory, R.K. Attack behavior as a function of minimum inter-food interval. Journal of the Experimental Analysis of Behavior, 1969, 12, 825-826.

Freeman, B.J. Behavioral contrast: reinforcement frequency or response suppression? Psychological Bulletin, 1971, 75, 347-356. (a)

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

Gentry, W.D. Fixed-ratio schedule-induced aggression. Journal of the Experimental Analysis of Behavior, 1968, 11, 813-817.

Goetz, E. M., and Baer, D.M. Descriptive social reinforcement of "creative" block building by young children. Journal of Applied Behavior Analysis, 1973, 6, 209-218.

Goldstein, S.R. Distal Shift: a spatial contrast phenomena. Unpublished study, 1971.

Gott, C.T., and Weiss, B. The development of fixed-ratio performance under the influence of Ribonucleic Acid. Journal of the Experimental Analysis of Behavior, 1972, 18, 481-497.

Gutman, A., Sutterer, J.R., and Brush, F.R. Positive and negative behavioral contrast in the rat. Journal of the Experimental Analysis of Behavior, 1975, 23, 377-383.

Hanson, H.M. Effects of discrimination training on stimulus generalization. Journal of Experimental Psychology, 1959, 58, 321-334.

Halliday, M.S., and Boakes, R.A. Behavioral contrast and response in dependent reinforcement. Journal of the Experimental Analysis of Behavior, 1971, 16, 429-434.

Hall, R.V., Lund, D., and Jackson, D. Effects of teacher attention on study behavior. Journal of Applied Behavior Analysis, 1968, 1, 1-12.

Hamilton, B.E., and Silberberg, A. Contrast and auto-shaping in multiple schedules varying reinforcer rate and duration. Journal of the Experimental Analysis of Behavior, 1978, 30, 107-122.

Hearst, E. The behavioral effects of some temporally defined schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1958, 1, 45-55.

Hutchinson, R.R., Azrin, N.H., and Hunt, G.M. Attack produced by intermittent reinforcement of a concurrent operant response. Journal of the Experimental Analysis of Behavior, 1968, 11, 489-495.

Hymowitz, N., Freed, E., and Lester, D. The independence of barpressing and schedule-induced drinking. Psychonomic Science, 1970, 20, 45-46.

Innis, N.K. Contrast effects in multiple fixed-interval reinforcement schedules. Journal of the Experimental Analysis of Behavior, 1978, 29, 233-242.

Jacquet, Y.F. Schedule-induced licking during multiple schedules. Journal of the Experimental Analysis of Behavior, 1972, 17, 413-423.

Jenkins, H.M., and Boakes, R.A. Observing stimulus sources that signal food or no food. Journal of the Experimental Analysis of Behavior, 1973, 20, 197-207.

Kaplan, M. The maintenance of escape behavior under fixed-ratio reinforcement. Journal of Comparative and Physiological Psychology, 1956, 49, 153-157.

Keehn, J.D., and Colotla, V.A. Stimulus and subject control of schedule-induced drinking. Journal of the Experimental Analysis of Behavior, 1971, 16, 257-262.

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

King, G.D. Wheel running in the rat induced by a fixed-time presentation of water. Animal Learning and Behavior, 1974, 2, 325-328.

Knutson, J.F. Aggression during the fixed-ratio and extinction components of a multiple schedule of reinforcement. Journal of the Experimental Analysis of Behavior, 1970, 13, 221-231.

Madson, C.H., Hoffman, M., Thomas, D.R., Koropsak, E., and Madsen, C.K. Comparisons of toilet training techniques. In D.M. Gelfand, Social learning in childhood. Belmont, California: Brooks and Cole, 1969, 124-132.

McSweeney, F.K., and Norman, W.D. Defining behavioral contrast for multiple schedules. Journal of the Experimental Analysis of Behavior, 1979, 32, 457-461.

Mendelson, J., and Chillag, D. Schedule-induced air licking in rats. Physiology and Behavior, 1970, 5, 535-537.

Morse, W.H., and Kelleher, R.T. Schedules as fundamental determinants of behavior. In W.N. Schoenfeld (ed.), The theory of reinforcement schedule, Englewood, Cliffs, N.J.: Prentice-Hall, Inc., 1970.

Nevin, J.A., and Shettleworth, S.J. An analysis of contrast effects in multiple schedules. Journal of the Experimental Analysis of Behavior, 1966, 9, 305-315.

Nevin, J.A. Differential reinforcement and stimulus control of not responding. Journal of the Experimental Analysis of Behavior, 1968, 11, 715-726.

Nevin, J.A. The maintenance of behavior in the study of behavior. Edited by John A. Nevin: The study of behavior: learning, motivation, emotion, and instinct. Scott, Foresman and Company, Glenview, Illinois, Bringhton, England, 1973.

Ney, P.G., Palvesky, A.E., and Markely, J. Relative effectiveness of operant conditioning and play therapy in childhood schizophrenia. Journal of Autism and Childhood Schizophrenia, 1971, 1, 337-349.

O'Leary, K.D., and Drabman, R.S. Token reinforcement programs in the classroom: a review. Psychological Bulletin, 1971, 75, 379-398.

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

Poling, A., Krafft, K., Chapman, L., and Lyon, D. Polydipsia induced by intermittent delivery of salted liquid foods. Journal of the Experimental Analysis of Behavior, 1980, 33, 337-344.

Porter, J.H., and Allen, J.D. Schedule-induced polydipsia contrast in the rat. Animal Learning & Behavior, 1977, 5, 184-192.

Premack, D., Schaeffer, R.W., and Hundt, A. Reinforcement for drinking by running: effect of fixed ratio and reinforcement time. Journal of the Experimental Analysis of Behavior, 1964, 7, 91-96.

Redford, M.E., and Perkins, Jr., C.C. The role of autopecking in behavioral contrast. Journal of the Experimental Analysis of Behavior, 1974, 21, 145-150.

Reynolds, G.S., and Catania, A.C. Behavioral contrast with fixed-interval and low-rate reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 387-391.

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

Reynolds, G.S. An analysis of interaction in a multiple schedule. Journal of the Experimental Analysis of Behavior, 1961, 4, 107-117. (b)

Reynolds, G.S. Relativity of response rate and reinforcement frequency in a multiple schedule. Journal of the Experimental Analysis of Behavior, 1961, 4, 179-184. (c)

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

Reynolds, G.S. A primer of operant conditioning, Scott, Foresman and Company, 1968.

Richards, R.W., and Rilling, M. Aversive aspects of a fixed-interval schedule of food reinforcement. Journal of the Experimental Analysis of Behavior, 1972, 17, 405-411.

Rilling. M., Askew, H.R., Ahlskog, J.E., and Kramer, T.J. Aversive properties of the negative stimulus in a suggestive discrimination. Journal of the Experimental Analysis of Behavior, 1969, 12, 917-932.

Schaeffer, R.W., Diehl, J.C., and Salzberg, C.L. An application of Premack's theory to behaviors associated with a FFI food schedule, Psychonomic Science, 1966, 6, 405-506.

Schneider, B.A. A two-state analysis of fixed-interval responding in the pigeon. Journal of the Experimental Analysis of Behavior, 1969, 12, 677-687.

Shull, R.L., and Pliskoff, S.S. Changeover delay and concurrent schedules: some effects on relative performance measures. Journal of the Experimental Analysis of Behavior, 1967, 10, 517-527.

Shull, R.L. Sequential patterns in post-reinforcement pauses on fixed-interval schedules of food. Journal of the Experimental Analysis of Behavior, 1971, 15, 221-231.

Skinner, B.F. The behavior of organisms. New York: Appleton-Century-Crofts, 1938.

Smith, C.B. Effects of d-amphetamine upon operant behavior of pigeons: Enhancement by reserpihe. Journal of Pharmacology and Experimental Therapeutics, 1964, 146, 167-174.

Stricker, E.M., and Adair, E.R. Body fluid balance, taste, and postprandial factors in schedule-induced polydipsia. Journal of Comparative and Physiological Psychology, 1966, 62, 449-454.

Stubbs, D.A., Pliskoff, S.S., and Reid, H.M. Concurrent schedules: A quantitative relation between changeover behavior and its consequences. Journal of the Experimental Analysis of Behavior, 1977, 27, 85-96.

Terrace, H.S. Behavioral contrast and the peak shift: Effect of extended discrimination training. Journal of the Experimental Analysis of Behavior, 1968, 9, 613-617.

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

Terrace, H.S. Discrimination learning with and without "errors." Journal of the Experimental Analysis of Behavior, 1963, 6, 1-27. (a)

Terrace, H.S. Errorless transfer of a discrimination across two continua. Journal of the Experimental Analysis of Behavior, 1963, 6, 223-232. (b)

Thomas, G.V., and Cameron, G.N. Response rate, reinforcement frequency, and behavioral contrast. Journal of the Experimental Analysis of Behavior, 1974, 22, 427-432.

Thomka, M.L., and Rosellim, R.A. Frustration and the production of schedule-induced polydipsia. Animal Learning and Behavior, 1975, 3, 380-384.

Villarreal, J. Schedule-induced pica. Paper read at Eastern Psychological Association, Boston, April, 1967.

Wayner, M.J., and Greenberg, I. Schedule dependent of schedule-induced polydipsia and lever pressing. Physiology and Behavior, 1973, 10, 965-966.

Weisman, R.G. Some determinants of inhibitory stimulus control. Journal of the Experimental Analysis of Behavior, 1969, 12, 443-450.

Weisman, R.G. Factors influencing inhibitory stimulus control: differential reinforcement of other behavior during discrimination training. Journal of the Experimental Analysis of Behavior, 1970, 14, 87-91.

Weisman, R.G., and Ramsden, M. Discrimination of a response-independent component in a multiple schedule. Journal of the Experimental Analysis of Behavior, 1973, 19, 55-64.

Westbrook, R.F. Failure to obtain positive contrast when pigeons press a bar. Journal of the Experimental Analysis of Behavior, 1973, 20, 499-510.

Whipple, W.R., and Fantino, E. Key-peck durations under behavioral contrast and differential reinforcement. Journal of the Experimental Analysis of Behavior, 1980, 34, 167-176.

White, J.M. Changeover ratio effects on concurrent variable-interval performance. Journal of the Experimental Analysis of Behavior, 1979, 31, 239-252.

Williams, B.A. Contrast effects in simultaneous discrimination learning. Animal Learning and Behavior, 1977, 5, 47-50.

Williams, C.D. The elimination of tantrum behavior by extinction procedures. Journal of Abnormal and Social Psychology, 1959, 4, 269.

Wilkie, D.M. Variable-time reinforcement in multiple and concurrent schedule. Journal of the Experimental Analysis of Behavior, 1972, 17, 59-66.

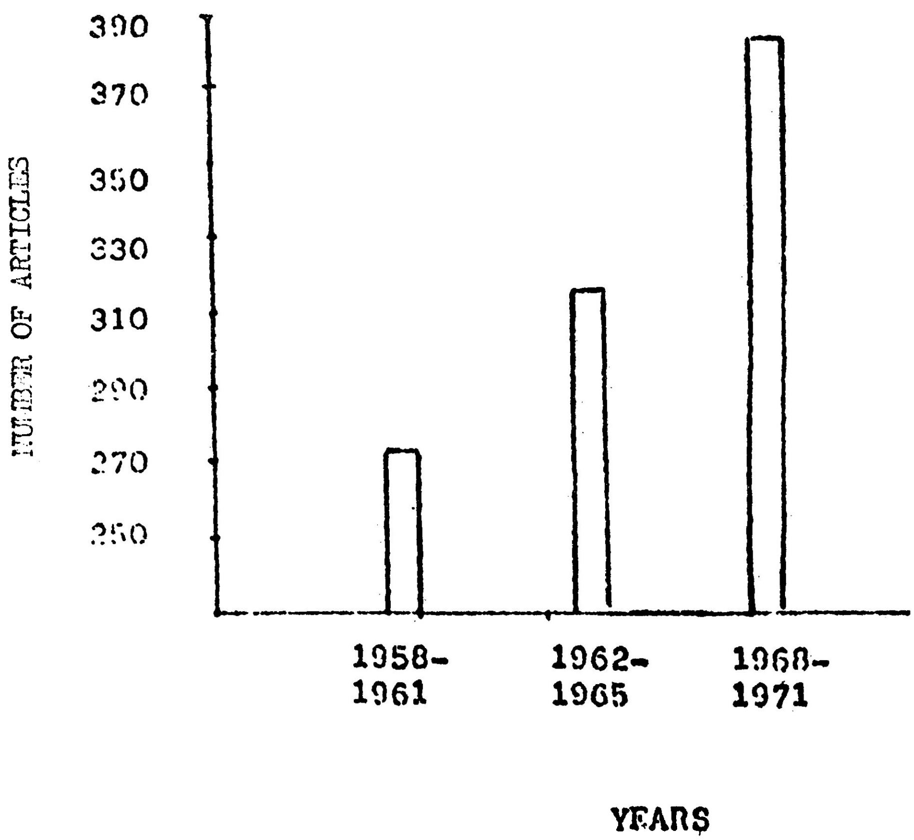
Yoburn, B.C., and Cohen, P.S. Assessment of attack and drinking in white king pigeons on response-independent food schedules. Journal of the Experimental Analysis of Behavior, 1979, 31, 91-101.

Zuriff, G.E. A comparison of variable-ratio and variable-interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1970, 13, 369-374.

APPENDICES

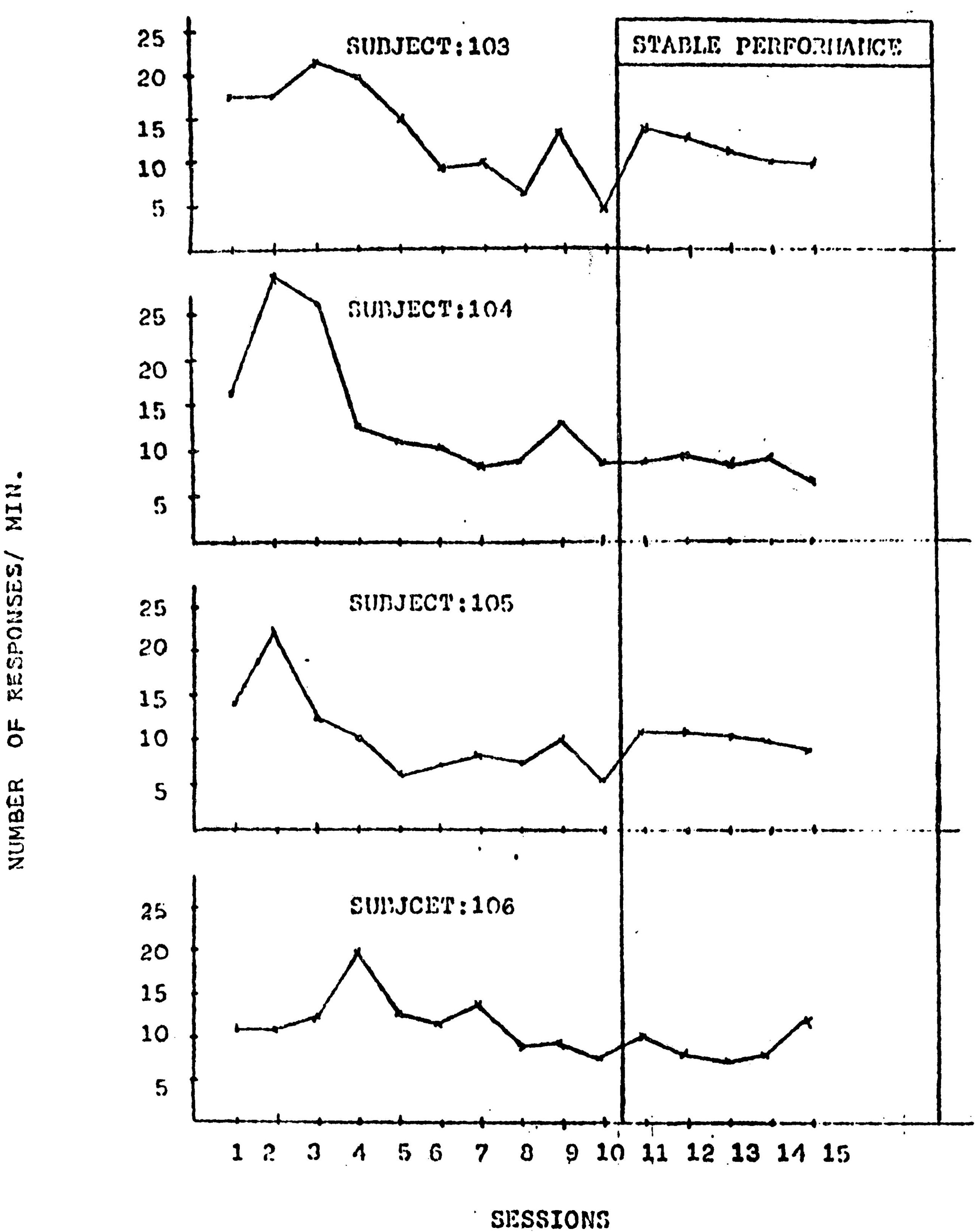
Appendix 1

NUMBER OF ARTICLES PUBLISHED IN THE JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR.



Appendix 2

Multiple FI-1 FI-1 minute schedule baseline training.



Appendix 5

ANALYSIS OF VARIANCE (FOUR SUBJECTS, FIRST FIVE CONSECUTIVE DAYS OF EACH TREATMENT PHASE , AND SIX REPEATED TREATMENT MEASUREMENTS)

SOURCE	DF	SS	MS	F	P
SUBJECTS	3	256.88			
TREATMENTS	5	1735.76	347.15	12.964	.00005
EW1B	15	401.65	26.78		
DAYS	4	54.90	13.72	1.141	.38364
EW2B	12	144.35	12.03		

Appendix 4

ANALYSIS OF VARIANCE (FOUR SUBJECTS, FIRST FIVE CONSECUTIVE DAYS OF EACH TREATMENT PHASE, AND SIX COMPENSATED REPEATED TREATMENT MEASURES). See Fig. 17

Source	DF	SS	MS	F	P
SUBJECTS	3	56.93			
TREATMENTS	5	502.07	100.41	9.0405	.00040

Appendix 5

ANALYSIS OF VARIANCE (FOUR SUBJECTS, FIRST FIVE CONSECUTIVE DAYS OF EACH TREATMENT PHASE, AND SIX COMPENSATED REPEATED TREATMENT MEASURES). See Fig. 14

SOURCE	DF	SS	MS	F	P
SUBJECTS	3	27.33			
TREATMENTS	5	269.50	53.90	7.2729	.00122

Appendix 6

Trend analysis: polymonial

Schedule(s)	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5	Schedule 8
Counts		4	4	4	4	
Mean	10.03	12.36	20.76	18.87	18.67	15.88

SOURCE	D.F.	SUM OF SQUARES	MS	F	P
Between groups	5	347.15	69.43		
Linear term		122.23	122.23	3.04	.1015
Quad. term		171.26	171.26	4.26	.0567
Cubicle term	1	1.20	1.20	0.03	.8651

When n=3 (Subjects 104, 105 and 106)

Schedules	1	2	3	4	5	8
Counts	3	3	3	3	3	3
Mean	9.6	12.1	19.4	18.9	17.8	14.6

	D.F.	SUM OF SQUARES	F RATIO	F PROB.
Linear term	1	74.167	12.31	< 0.01
Quad. term	1	137.73	22.87	< 0.001

Appendix 7

Multiple FI-1 FI-1 minute schedule baseline training.

SUBJECTS		103	104	105	106
Sessions	1	18.2	16.5	14.8	11.3
	2	18.0	29.0	22.7	10.8
	3	20.9	25.1	13.3	12.6
	4	19.6	13.4	9.8	10.4
	5	14.4	10.6	6.7	12.3
	6	7.8	9.7	7.4	11.6
	7	8.1	7.8	8.3	14.3
	8	6.0	8.3	7.9	6.2
	9	14.5	14.4	10.5	8.6
	10	4.5	3.7	5.7	7.7
	11	14.8	8.1	13.4	11.7
	12	13.7	9.3	13.3	7.6
	13	10.7	8.6	12.9	6.4
	14	8.9	9.9	8.9	7.0
	15	8.9	6.1	6.9	13.3

NO. OF RESPONSES /MIN.

Appendix 8

Individual discrimination index during the last 8 sessions in six phases.

SUBJECT:105

S2	DAY 1	2	3	4	5	6	7	8
FI1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
FI2	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4
FI3	0.4	0.5	0.4	0.4	0.4	0.4	0.5	0.5
FI4	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.5
FI5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
FI8	0.5	0.4	0.4	0.5	0.3	0.4	0.4	0.4

SUBJECT:106

FI1	0.3	0.4	0.4	0.5	0.4	0.4	0.3	0.5
FI2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
FI3	0.5	0.5	0.4	0.4	0.4	0.4	0.5	0.5
FI4	0.4	0.5	0.5	0.4	0.4	0.3	0.4	0.5
FI5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5
FI8	0.5	0.5	0.6	0.5	0.5	0.5	0.6	0.5

Appendix 9

Individual discrimination index during the last 8 sessions in six phases.

SUBJECT:103

S2	DAY 1	2	3	4		6	7	8
FI1	0.5	0.5	0.3	0.5	0.5	0.5	0.5	0.5
FI2	0.4	0.4	0.5	0.5	0.4	0.5	0.4	0.4
FI3	0.4	0.6	0.4	0.4	0.5	0.5	0.5	0.4
FI4	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.5
FI5	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.5
FI8	0.5	0.5	0.6	0.5	0.5	0.6	0.7	0.5

SUBJECT:104

FI1	0.4	0.5	0.4	0.3	0.4	0.4	0.5	0.3
FI2	0.4	0.5	0.3	0.3	0.3	0.4	0.4	0.4
FI3	0.3	0.6	0.3	0.4	0.5	0.4	0.4	0.5
FI4	0.4	0.5	0.5	0.4	0.5	0.4	0.4	0.4
FI5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5
FI8	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Appendix 10

RESPONSE RATES IN S1 AND S2 BEFORE, DURING, AND AFTER THE PROBE PERIODS

SESSIONS

SUBJECTS		1	2	3	4	5	6	7	8	9	10	11	12
103	S2	33.6	25.7	22.9	28.7	20.8	15.5	25.7	24.0	18.0	20.9	1[illegible].2	20.7
	S1	26.1	23.1	21.5	28.5	19.6	24.7	18.2	16.5	18.5	19.7	18.4	15.8
104	S2	16.5	22.1	19.3	19.3	22.2	11.8	21.8	18.9	20.0	16.2	21.0	23.2
	S1	13.8	15.4	16.5	17.8	10.8	15.8	10.9	11.6	16.8	12.0	16.8	22.3
105	S2	26.5	24.9	25.6	33.9	30.7	34.6	29.0	23.1	28.8	25.2	18.6	24.6
	S1	19.8	16.6	23.7	27.1	22.8	31.5	19.3	14.9	15.9	17.5	16.0	22.5
106	S2	21.7	20.6	22.0	22.3	25.6	19.7	19.0	24.8	18.8	21.5	17.8	20.0
	S1	12.0	16.3	28.5	24.1	22.2	22.5	14.2	16.9	13.8	14.4	15.7	18.2
				PROBE	PROBE		PROBE						

Post reinforcement pause is expressed as a function of fixed-interval schedules associated with the variable component.

FIXED-INTERVAL SCHEDULE IN S2

MEAN RESPONSE RATE (SEC/SESSION)

SUBJECTS	COMPONENTS	FI1 MIN	FI2 MIN	FI3 MIN	FI4 MIN	FI5 MIN	FI8 MIN
103	S1	40	33	30	37	33	30
	S2	37	47	43	47	47	30
104	S1	40	36	27	27	27	30
	S2	27	47	50	43	47	53
105	S1	17	23	27	33	40	40
	S2	30	40	40	43	50	57
106	S1	33	30	23	27	23	27
	S2	20	37	40	40	40	53

Appendix 12

All subjects mean response rate for 5 consecutive days at the beginning of each phase. The baseline rate at FI-1 min. was obtained by collapsing the last 5 consecutive days of phase 1. Standard deviation for each subject was included.

FIXED - INTERVAL SCHEDULE S^D

	1	2	3	4	5	8	
X	10.0	12.4	20.8	13.9	13.7	15.9	
SD	1.4	1.6	3.9	2.1	3.1	3.2	

Response rate associated with S1 and S2 during the last 8 sessions in six phases

FIXED-INTERVAL			SESSIONS 1	2	3	4	5	6	7	8
FI-1	S1	105	7.9	10.5	5.7	13.4	13.0	12.9	8.9	6.9
FI-1	S2		8.6	13.2	5.8	11.2	13.1	12.7	11.2	10.9
FI-1	S1		13.2	19.6	15.2	13.6	22.9	21.6	27.5	27.6
FI-2	S2		17.9	26.7	21.1	20.9	27.2	26.7	35.9	36.9
FI-1	S1		22.8	31.5	19.2	14.8	19.9	17.5	16.0	22.5
FI-3	S2		30.7	34.6	28.0	23.1	28.8	25.2	18.6	24.6
FI-1	S1		20.1	18.2	18.4	21.6	23.4	17.2	21.0	21.9
FI-4	S2		23.0	26.7	22.4	26.9	27.1	23.5	27.6	23.2
FI-1	S1		15.4	15.3	14.6	15.2	15.7	11.7	10.6	9.8
FI-5	S2		18.7	15.4	13.0	17.6	19.9	16.8	15.4	13.4
FI-1	S1		13.0	8.5	10.5	12.7	10.2	11.1	10.4	9.8
FI-8	S2		14.6	10.6	13.6	15.2	19.9	14.6	13.9	15.3
FI-1	S1	106	8.2	9.6	7.7	11.7	7.6	6.4	7.0	13.6
FI-1	S2		10.1	15.2	11.5	11.0	13.0	10.8	15.3	15.9
FI-1	S1		12.5	15.3	13.1	17.9	12.8	10.6	15.2	16.7
FI-2	S2		18.8	22.3	24.8	28.2	24.2	17.9	26.8	25.1
FI-1	S1		22.2	22.5	14.2	16.9	13.8	14.4	16.7	18.2
FI-3	S2		25.6	19.7	19.0	24.8	18.8	21.5	17.8	20.0
FI-1	S1		24.3	25.1	24.4	17.4	20.2	18.3	21.1	20.3
FI-4	S2		30.3	28.6	25.6	26.6	37.1	37.3	31.9	34.0
FI-1	S1		17.7	20.5	19.5	16.8	28.8	19.8	19.1	14.9
FI-5	S2		20.6	24.0	15.7	18.7	26.4	27.0	19.9	16.3
FI-1	S1		14.0	13.0	18.0	19.4	14.4	13.1	18.4	20.0
FI-8	S2		14.5	12.3	11.9	16.4	14.2	11.9	14.8	17.3

Response rate associated with S1 and S2 during the last 8 sessions in six phases.

FIXED-INTERVAL		SESSIONS 1	2	3	4	5	6	7	8
FI-1	S1 103	6.0	14.8	4.5	14.8	13.7	10.7	8.9	8.9
FI-1	S2	5.6	15.5	9.0	15.0	11.3	10.9	9.9	7.7
FI-1	S1	17.6	12.5	17.2	21.2	19.3	20.4	19.5	20.7
FI-2	S2	23.7	17.5	20.7	23.3	27.5	22.8	28.7	27.0
FI-1	S1	19.6	24.7	18.2	16.5	16.5	19.7	18.4	15.8
FI-3	S2	29.8	15.5	25.7	24.0	18.6	20.9	18.2	20.7
FI-1	S1	19.1	18.9	19.1	13.7	13.3	16.3	22.7	20.1
FI-4	S2	25.6	21.3	22.5	18.4	17.8	20.9	25.4	23.0
FI-1	S1	18.4	19.4	27.5	24.4	20.3	15.5	19.5	22.1
FI-5	S2	15.5	19.5	26.3	25.8	25.6	15.6	21.6	26.9
FI-1	S1	22.4	16.1	21.9	22.0	13.2	22.4	22.9	20.3
FI-8	S2	19.3	17.1	16.4	19.6	16.0	16.4	12.3	19.5
FI-1	S1 104	8.3	14.4	8.7	8.1	9.3	8.6	8.9	6.1
FI-1	S2	13.6	14.7	12.4	15.3	13.3	12.8	11.3	12.5
FI-1	S1	12.3	19.2	11.3	6.6	7.9	10.5	8.8	12.1
FI-2	S2	20.9	22.3	21.2	15.6	16.2	17.6	15.8	19.9
FI-1	S1	10.8	15.3	10.9	11.6	16.8	12.0	16.8	22.3
FI-3	S2	22.2	11.8	21.8	16.9	20.0	16.2	21.0	23.2
FI-1	S1	14.4	23.8	13.6	16.3	31.1	21.0	17.4	16.9
FI-4	S2	21.2	24.4	16.7	22.4	27.3	29.1	23.6	22.9
FI-1	S1	9.3	8.9	20.2	19.1	16.3	18.8	21.3	19.6
FI-5	S2	10.1	8.9	19.2	16.5	18.9	15.2	20.2	17.6
FI-1	S1	14.8	12.8	14.5	20.1	17.3	16.8	19.3	18.2
FI-8	S2	24.9	15.1	17.7	24.0	15.8	14.1	14.1	18.4

Appendix 15

Compensated mean response rate is expressed as a function of fixed-interval schedule associated with the variable component.

Subjects		FI1 MIN	FI2 MIN	FI3 MIN	FI4 MIN	FI5 MIN	FI8 MIN
103	S1	18.8	23.8	33.7	28.7	31.6	30.3
	S2	17.6	25.2	36.0	25.2	25.7	21.6
104	S1	13.8	20.0	21.0	27.1	26.5	25.2
	S2	19.0	22.2	25.5	24.9	18.5	22.3
105	S1	14.0	19.9	31.2	29.9	22.0	18.0
	S2	18.2	26.6	40.3	29.8	27.0	18.0
106	S1	14.2	18.0	26.7	29.2	29.1	24.3
	S2	17.8	24.7	28.2	30.8	23.9	15.9

Rate of response in S1 is expressed as a function of relative frequency of reinforcement in S2 across six phases

	RELATIVE REINFORCEMENT IN S2	RATE OF RESPONDING IN S1				RESPONSES PER MIN.	
		SUBJECTS					
FI	RFS1/RFS1+S2	103	104	105	106	MEAN	VARIANCE
1	0.5	11	8	11	9	9.8	1.5
2	0.67	15	13	15	12	13.8	3.0
3	0.75	20	14	22	19	18.8	3.9
4	0.80	18	19	19	21	19.3	1.3
5	0.85	21	18	13	21	18.3	2.8
8	0.90	20	17	11	17	16.3	4.8

Appendix 17

Compensated mean response rate in S1 is expressed as a function of the fixed-interval schedules in S2

	SUBJECTS				MEAN
	103	104	105	106	
FI1 MIN	18.8	13.8	14.0	14.2	15.2
FI2 MIN	23.8	20.0	19.9	18.0	20.4
FI3 MIN	23.7	21.0	31.2	26.7	25.7
FI4 MIN	28.7	27.1	29.9	29.2	28.7
FI5 MIN	31.6	26.5	22.0	29.1	27.3
FI8 MIN	30.3	25.2	18.0	24.3	24.5