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**The experimental analysis of variation in a human operant**

**Korber, Edward John, Ph.D.**

**City University of New York, 1989**

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**THE EXPERIMENTAL ANALYSIS OF VARIATION IN A HUMAN OPERANT**

by

**EDWARD J. KORBER**

A dissertation submitted to the Graduate Faculty in  
Psychology in partial fulfillment of the requirements  
for the degree of Doctor of Philosophy, The City  
University of New York.

1989

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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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**Abstract****THE EXPERIMENTAL ANALYSIS OF VARIATION IN A HUMAN  
OPERANT**

by

**Edward J. Korber****Adviser: Professor Robert N. Lanson**

Several studies, in the schedule control of humans and non-humans, have reported demonstrating systematic effects of reinforcement on response indices other than rate of responding. None relate these effects to the covariation of the interdependent behavioral indices. Such information would enhance our understanding of how reinforcement contingencies control aspects of behavior beyond that required for reinforcement and of how adequate a single index of movement predicts the value and direction of trend in other measures. Knowledge of these relations would also contribute to an empirical resolution of discrepant results in the literature.

This investigation was undertaken to explore these relations and the manner in which they expand understanding of intermittent reinforcement and schedule control of behavior.

A within-subject multiple schedule design assessed concurrent changes in schedule effects on central tendency and variance measures of distance traveled across the surface of a graphics tablet in making a response, the average speed per response and the total time of the response, in four human subjects. Each subject was exposed to manipulation of the minimal interreinforcement interval given a response (Sessions 1 to 10: T = 15 secs., 30 secs., 60 secs., 120 secs., 240 secs.) and the probability of reinforcement delivery for each response (sessions 11 to 20: P = 1, .5, .25, .125, .065). The T and P values selected replicate, with fixed interval, and extend, with random interval, the range of schedule values and types explored with human and non-human subjects.

The results of the study indicated that (1) response subclass indices were adventitiously sensitive to and covaried with the manipulation of minimal interreinforcer interval and probability of reinforcer, even when rate of responding did not (2) the effect of reinforcement is such that its production of adventitious control, in a unique fashion from subject to subject over various dimensional properties of subjects' actions, allowed for covariation of these measures in a manner which accounted for apparent instances of insensitivity of the rate index and (3) the variance measures showed systematic proportional increase with increasing reinforcer intermittency.

To my wife Michele

and our children

Melanie

Leanne

Jonathan

You have all demonstrated

infinite love

and

patience

which is of greater importance than all of man's limited knowledge

## Acknowledgments

The present work was made possible through the direct assistance and investigative works of Drs. Robert N. Lanson, Brett K. Cole, Bruce Brown and William N. Schoenfeld. I sincerely thank you all for your efforts and the knowledge you have bestowed upon me during these last 13 years. In modeling all I have learned from you, both good and bad, I have used the best of what I have acquired to the benefit of those who are not as fortunate as the most unfortunate of us. I will continue to do so.

Special thanks to John Leong of the Queens College Computer Center, Malcolm McCullough, Elizabeth Ramirez, Lupita Coll, Gene Fisch and all of my peers in the "Conditioning" Program. May your fondest dreams come true.

My deepest thanks to my wife, Michele Blanc, her parents, John and Fannie Blanc, my parents, John and Mildred Korber, and the anonymous authors of the S.E.E.K. and College Discovery and Development Programs of C.U.N.Y.. All of you had blind faith in a disadvantaged twelve year old boy and allowed him to achieve what he and the majority of others felt would not be possible.

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## INTRODUCTION

An operational definition of response units, defined by changes effected in the physical environment, entails classifying an organism's action by the categorical appearance and nonappearance of some environmental event (Schoenfeld, 1968; Skinner, 1935). Such classes are typically defined by intension, i.e., by a property common to all its members and peculiar to them (Russell, 1971). These indicators of the organism's actions are traditionally described as achievement descriptions (Drummond, 1981; Zuriff, 1985), "the rat depressed the lever", and treated as invariant for the purpose of deriving a quantitative index of performance (i.e., rate of response). Although any class member with its defining characteristics is interchangeable with any other member of the same class, it is not an exhaustive description of behavior, and there always remain other characteristics by which one may define additional classes (Rapoport, 1953). While it has proven convenient to regard the response as an invariant, observations typically reveal an indefinite range of subgenera within the general response class (Dodge, 1931; Catania, 1979; Hull, 1943; Skinner, 1935). Given the numerous factors which interact at any one moment to generate a given performance it is not surprising to find such fluctuation in behavior (Dodge, 1931; Sidman, 1960). However, some theorists (Skinner, 1938; Schoenfeld, 1968; Hillner, 1979) have suggested that the regularity in patterns of conventional indicators, e.g. response frequency, also suggests regularity in the covariation and variability of other dimensions of

movement, e.g. velocity, duration and extension in space. This study was undertaken in order to empirically assess the nature of variability and changes in such additional effect-defined measures given varying schedules of intermittent, response-dependent reinforcement.

It has been argued that variation in behavioral indicators stems from discernable, controllable sources, both internal and external to the subject. Some learning theorists have focused on identification of the external sources controlling performance variability. Their works (Fiske and Rice, 1955; Mowrer and Jones, 1945; Skinner, 1948; Staddon and Simmelhag, 1971) suggest that variation in response class properties changes lawfully as the passage of time and space place the organism in a position remote from the maintaining environmental events. Others (Amsel, 1967; Capaldi, 1967; Denny, 1946; Guthrie, 1935; Hull, 1952; Schoenfeld, 1968; Sheffield, 1949) have proposed theoretical accounts of fundamental phenomena, such as the partial reinforcement effect and resistance to extinction, which hinge upon the study and understanding of response class dispersion. These accounts propose solutions to what many believe are paradoxical findings of greater response strength following exposure to intermittent reinforcement (Jenkins and Stanley, 1950; Mackintosh, 1974). These accounts also appeal to other correlated indices of movement which, although present, are typically left unspecified in the reinforcement contingencies and, therefore, remain unmeasured.

Skinner (1938), Skinner and Morse (1957), Keller and Schoenfeld (1952) have indicated and stressed the necessity of an analysis of response variation for an adequate understanding of acquisition and response differentiation

processes. Schoenfeld (1968) argued that the paradoxical nature of findings of greater response strength following intermittent reinforcement was the outcome of a failure to examine the specific effects of stimulus intermittency on response subclasses. Both theorists have argued that one effect of intermittent schedules is to strengthen a greater range of both essential and adventitious response properties than during exposure to continuous reinforcement contingencies. The strengthening of both required and coincidental response properties increases the likelihood that subsequent responses will not be exact replicas. Each of the resulting variants thus formed could be strengthened or weakened in accordance with the traditionally proposed negatively accelerated function which relates response strength to the number of reinforcers (Hull, 1943). According to Skinner, such occurrences would occasion increased deviation from the desired behavioral property sought. Both also argued that such effects would be self-limiting due to the greater frequency effect of reinforcement on the contingent properties and the concurrent effects of negative reinforcement associated with motor fatigue and delay of reinforcement.

Early infrahuman studies addressing these issues focused upon the effects of the two proposed extremes of a reinforcement probability continuum: continuous reinforcement and extinction. These studies, unlike much of the operant literature which uses response rate as the primary index of performance, also explored other measures, e.g. transitional probabilities, force, duration, and locus. These investigations demonstrated that other indices of movement were also susceptible to control when subject to the reinforcement contingencies.

Frick and Miller (1951) and Miller and Frick (1949) examined orders of serial dependency in the bar press and the tray approach behaviors of rats. Compared to operant level performance, the effect of continuous reinforcement contingencies was to produce a gradual restriction in the range of sequential patterning of behaviors. The introduction of an extinction contingency then produced a broad disruption of the behavioral regularities attained during continuous reinforcement. Vogel and Annau (1973) also explored serial dependency in key peck patterns of pigeons. Using a discrimination task, which allowed for variability in reinforced response pattern, these authors found a wide sampling of alternative response sequences during baseline which decreased radically under continuous reinforcement contingencies. Similar findings emerged in studies of response locus.

Antonitis (1951) investigated the effects of continuous reinforcement/extinction procedures on response locus measure with rats and noted wide sampling of the response loci range during operant level. Following the introduction of continuous reinforcement, performance was characterized by more frequent sampling of a narrower range of response elements. The effect of reestablishing extinction contingencies, as in operant level, was to produce a broader sampling of all possible response locations. However, unlike many other authors, Antonitis reinstated continuous reinforcement contingencies and found the development of even greater stereotypy in performance. These outcomes supported the proposition that continuous reinforcement contingencies establish a tendency for organisms to distribute the major portion of their responding within a narrow range

along a response measure continuum.

Millenson and Hurwitz (1961) also describe similar changes in response durations with rats during exposure to continuous reinforcement and extinction. During extinction the response distributions increased in variability with a shift in the distributions to longer durations not attained under continuous reinforcement. Margulies (1961) extended this work with rats by examining the effects of the number of reinforcements on response duration. As in the Millenson and Hurwitz study, extinction contingencies increased the percentage of longer duration events. An increase in the number of reinforcements delivered during continuous reinforcement produced shorter durations and greater restriction of range. An increase in the total number of responses emitted was also noted. These findings are paralleled in studies of response force.

In Skinner's (1938) early studies of response differentiation, with rats as subjects, the measures of response force and duration were examined. For both measures, limited variation about the minimal defining response criteria was reported during continuous reinforcement and greater sampling of other low frequency values was noted during extinction. These observations influenced Schoenfeld's position, as well as those of Goldberg (1959), Notterman and Block (1960) and Notterman and Mintz (1965), concerning the effects of continuous reinforcement and extinction contingencies on response force. In these studies, continuous reinforcement increased stereotypy in response force. With the introduction of extinction there was a broadening and shift in range of the frequency distributions of the force measure. This outcome has been commonly encountered within and

across the spectrum of measures examined. However, generalizations based on these studies are restricted by the limiting experimental contingencies. As Skinner(1938) and Keller and Schoenfeld (1950) have indicated, the regular reinforcement of behavior is not the world's rule; very few reinforcements are unailing, and periods of extinction are interrupted by occasional reinforcements. The effects of such periodic and aperiodic nonreciprocal contingencies on the variation of operants have been explored by others interested in contingencies involving the systematic repetition of conditioning and extinction cycles which allow for variation in the ratio of contingent responding to the instrumental requirement (Allison, 1983).

Millenson et al. (1961), using rats as subjects, obtained inconclusive results in a parametric investigation of fixed interval and random ratio schedules. In comparison to continuous reinforcement, fixed interval schedules showed greater variability in response duration measures. No systematic trend related the value of the fixed interval schedule to the dispersion measures. Subjects exposed to the random ratio schedules produced non-monotonic inverted U-shaped functions relating response duration and its dispersion to the mean ratio value. Tremont (1981) studied the effects of random interval and random ratio schedules on the interresponse time, response duration and response force-time integrals measures of rats. There was no trend relating the random interval values to the dispersion measures. No systematic relation between changes in the reinforcement contingencies and response duration or response force-time integrals were found, though interresponse time means were sensitive to the changes in interval values and response probability. Tremont was also unable to replicate the

non-monotonic function relating random ratio value to response duration reported by Millenson.

In design and outcome, similar reports also exist in the literature addressing intermittent schedules and response locus measures. Boren, Moerschbaecher and Whyte (1978) studied fixed interval and ratio contingency effects on lever choice with monkeys. Using an array of six centered and horizontally aligned levers he observed increasing variation in response locus with increasing interval value. No trend was noted across the ratio contingencies. Ferraro and Branch (1968), investigating variable interval and continuous reinforcement contingencies, reported greater dispersion associated with the intermittent schedules. In a parametric investigation of random interval schedules Eckerman and Lanson (1969), using pigeons as subjects, found increased variability in response locus to be associated with increasing random interval value. In addition, they replicated earlier findings on continuous reinforcement and extinction effects for response locus measures. Increasing variability as the interreinforcement interval is lengthened has also been reported for variable ratio (Eckerman and Vreeland, 1973) and fixed ratio contingency studies (Korber, 1982) using humans as subjects. Pear (1985) has reported greater regularity in spatio-temporal patterns as the interreinforcement interval decreases in variable interval schedules. Yet the reports of other investigators (Gates and Fixen, 1968; Herrnstein, 1961), using both nonhuman and human subjects, suggest less dispersion in response locus measures for variable interval schedules when contrasted with continuous reinforcement performance. Taken together the findings reviewed indicate the possibility of great

variation of results across studies and measures. Some authors (Boren, Moerschbaeher and Whyte, 1978) have suggested that the results of these studies fail to confirm any simple relationship between response variability and intermittent reinforcement. Of the various schedule types reviewed, fixed interval schedules have produced the most consistent outcomes with reference to those noted for continuous reinforcement and extinction. Yet even with this most thoroughly studied schedule type, opposing conclusions regarding the influence of intermittency on the various dependent measures have been reported, suggesting a need for further study.

A number of authors (Buskist and Miller, 1982; Baron and Perone, 1982; Buskist, Morgan and Barry, 1983) have also noted the dearth of published reports relating the experimental analysis of these basic issues to human behavior. Much of the existing literature addressing the topic of stimulus intermittency and control of human performance has focused either on the instructional control of human operant behavior (Baron and Galizio, 1983; Lowe, 1979; Shimoff, Cattania and Matthews, 1981) or attempts to confirm the hyperbolic relationship between response and reinforcement rates during exposure to variable interval schedules of monetary reinforcement (Bradshaw, Ruddle and Szabadi, 1981; McDowell, 1981; McDowell and Wood, 1984). All these studies leave unsettled the question of how reinforcement contingencies control aspects of behavior beyond that which is required for the reinforcer's delivery. Failures to obtain systematic effects in the schedule control of human and non-human subjects' behavior may actually reflect an inadequate account of the schedules' control. How the several interdependent indices covary with one another, and the extent to which these relations may

account for the discrepant results have not been addressed. The present study was undertaken in part to investigate the possible existence of such relations and the extent to which they might contribute to our understanding of schedule control in human performance during exposure to intermittent schedules of reinforcement.

In the present study, production of reinforcement intermittency was arranged through the manipulation of two parameters, T - programmed minimal interreinforcer interval given a response, and P - probability of reinforcer delivery given a response (Schoenfeld and Cole, 1972). The T and P values were selected so as to replicate with fixed interval schedules and extend with random interval schedules the range of both schedule values and types previously explored with human and non-human subjects. These values extend the range of past investigations of nonreciprocal schedules (Allison, 1983) in relation to the covariation of several behavioral indices, in this case, distance traveled per response and speed of response, as they influence rate of responding. The empirical assessment of these measures may aid in clarifying the role reinforcement plays in the mechanism of behavioral control by intermittent schedules. The exploration of these measures will also provide information regarding the adequacy of using a single index of movement to predict the value and direction of trend in other measures.

Unlike the studies reviewed earlier, this experiment employed a within-subject multiple schedule design. This design allows for an assessment of changes in schedule effects across subjects and sessions (Hearst, 1961). Given demonstrations of significant change in both the central tendency and

variance of response rate associated with extended exposure to intermittent reinforcement schedules (Korber, Cole, and Ramirez, 1981), the use of this design procedure is of particular interest in that the disparate results of earlier studies may simply reflect time of sampling and/or ordering effects associated with the use of sequential exposure designs .

## METHOD

### Subjects

Four humans, two male and two female, agreed to participate in this study. These subjects, 16 to 30 years in age, had no prior history of training in psychology and were experimentally naive at the start of training. All subjects were right-handed.

### Apparatus

A Tektronics graphics tablet (Model #4954), 87.63 cm wide by 107.95 cm long, served as the experimental surface upon which the subjects' movement of a stylus could be recorded. A Tektronics graphics terminal (Model #4015-1) with a green phosphorescent screen 25.4 cm by 38.1 cm was placed adjacent to the graphics tablet 45.7 cm from the lower left-hand corner of the tablet surface. The screen was positioned such that turning one's head 90 degrees to the left brought the terminal screen into full view when the subject was seated in front of the tablet surface. The terminal screen was used to display alphanumeric characters, .5 cm high by .5 cm wide per character, to the subject. The graphics terminal was used to initiate the execution of the Sigma 6/7 Fortran IV programs. These programs controlled the experimental contingencies and allowed for the determination of time and location of the electronic stylus on the tablet surface. For the purpose of this study, a response consisted of having the subject move the stylus from the left hand side of the graphics tablet's surface across an unmarked vertical line bisecting the tablet's width and back again to the left-hand side of the surface.

### Procedure

The experiment consisted of two ten-session phases in which subjects were consecutively exposed to fixed and random interval stimulus schedules. A within-subject, multiple schedule design was employed. The order of exposure to schedule components, within sessions, was the same for all subjects with the specific order of exposure for each session randomly determined.

At the start of each session, the subject was asked to remove all jewelry (i.e., watches and rings) from their hands and wrists and was informed that such objects would interfere with the operation of the apparatus. The subject was then seated in front of the graphics tablet and the height of the seat adjusted so that the subject's elbows would rest at the edge of the tablet. In session 1 the following instructions were delivered to the subject after he or she was seated:

" In this experiment you can earn points which will be exchanged for money at the end of the study. Each point is worth three cents. You can earn points by keeping this stylus on the tablet surface. Each time you have earned a point, you will hear a brief tone and see a new display of the total number of points you have earned on this screen. There are several conditions. Each condition has its own number and you will work on five conditions each night. You will know which condition is in effect by looking at the lower left-hand corner of the board here

(investigator points to the numbered condition card). You will receive a message on the screen telling you when each condition has ended. When a condition is over, you can take a five-minute break while I prepare the machine for the next condition. Any question?"

In sessions 2 through 20 the experimenter would ask the subject to indicate when he or she was ready. At the subject's prompting, the experimenter then initiated the graphics terminal commands controlling the operation of the experimental contingencies.

Each session was composed of five eight-minute components within which the probability that a reinforcer or the size of the repeating temporal cycle could be varied. A cued five minute timeout period occurred between each component. The order of exposure to each of the five components was randomized within each session. During phase one (sessions 1 to 10), the probability of a stimulus display for the first response within any one time cycle was held constant at  $P = 1.0$  for all session components. Immediately after the emission of the first response the stimulus display indicating the cumulative points earned in the prevailing component was presented accompanied by a brief one-second tone. Each component within a session was associated with one of five discriminative cues (numbered condition cards) and its related time cycle value which was not disclosed to the subject (card # - T cycle value: #1 - 15 secs., #2 - 30 secs., #3 - 60 secs., #4 - 120 secs., #5 - 240 secs.).

In phase two, sessions 11 through 20, the repetitive time cycle value

was fixed at 15 seconds for all schedule components. Each of the five eight-minute components within a session was associated with a different discriminative cue (numbered condition card). The related probability of stimulus display for the first response emitted by the subject within the repeating time cycle was, as in the first phase, not disclosed to the subject (card # - P value: #6 - 1.0, #7 - 0.5, #8 - 0.25, #9 - 0.125, #10 - 0.0625). The result of this manipulation was the production of mean interstimulus intervals comparable to those programmed in phase one.

## RESULTS

Central tendency and variance indicators for interresponse time (the total time of a response cycle), distance traveled per response (the sum distance traveled across the tablet surface during the response cycle) and speed per response (the average speed per response cycle), as a function of the fixed and random interval value, are presented in figures 1 through 12 . Each figure depicts the arithmetic mean or standard deviation functions of the four subjects plotted on exponential coordinates. All plotted points represent the averaged outcome of the last five sessions in each condition. The values of these points, along with the geometric, harmonic means, and the coefficient of variation are presented in tables 1 through 20.

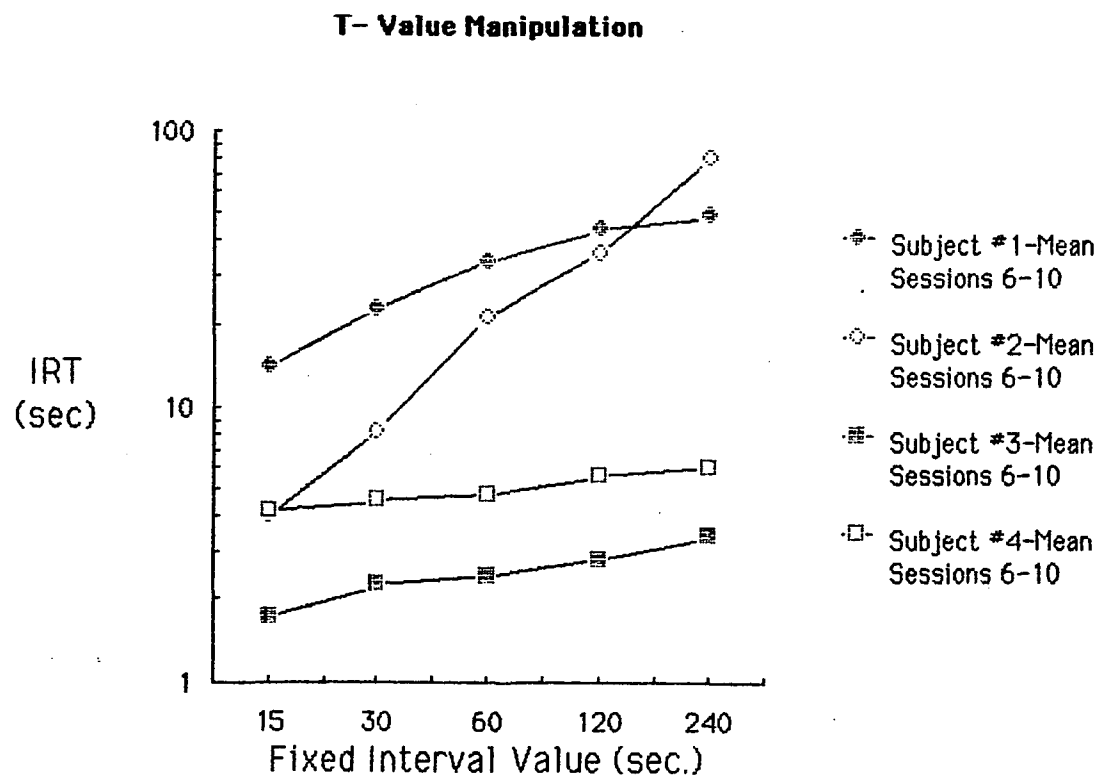
### FIXED INTERVAL - T MANIPULATION

Figures 1 and 2 show that the means and standard deviations of the subjects' interresponse times increased as the fixed interval value was increased. The functions suggest a wide range of response styles across subjects. Subjects 3 and 4 generated short interresponse times across the interval dimension. Subjects 1 and 2 produced longer interresponse times and wider range of values sampled as the interval value increased.

Figures 3 and 4 depict the associated mean and standard deviation distance per response functions. For subjects 1, 2 and 3, the means and standard deviations of the distance measure increased as the interval value increased. This trend is not apparent in the data of subject 4. The values of

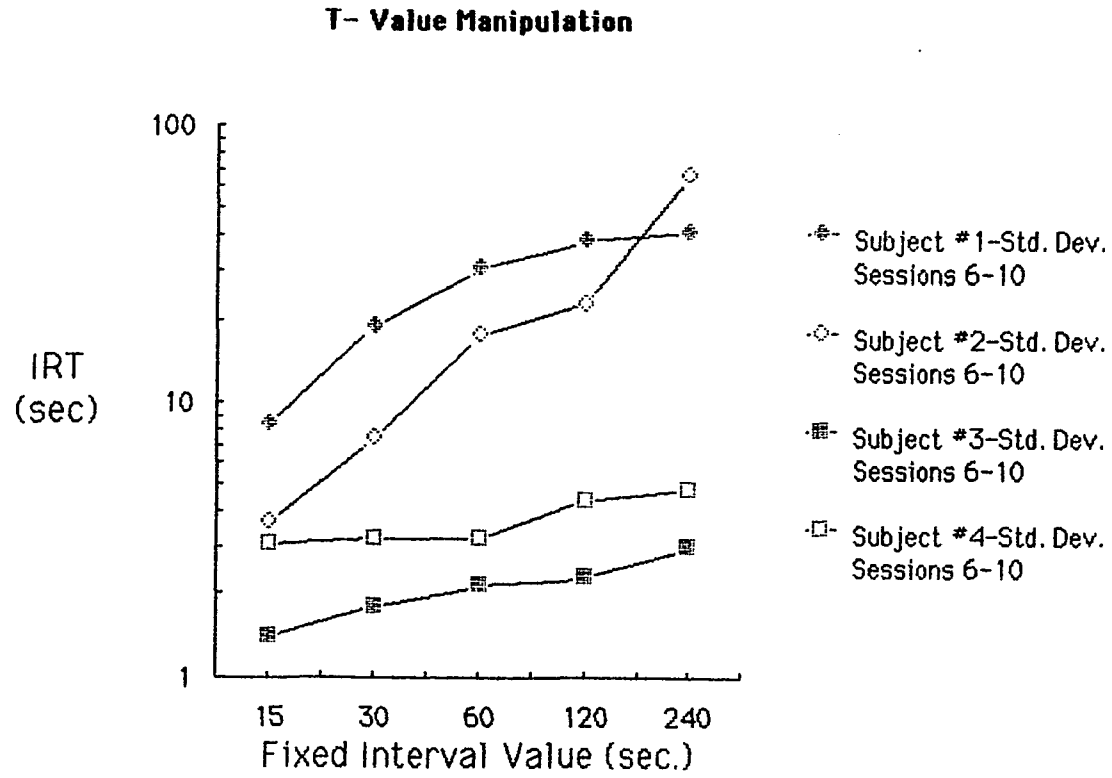
**Figure 1. The arithmetic means of interresponse times as a function of T value. Each subjects' function in this figure represents the data averaged across the last five sessions of the T manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for T - 15 sec. (FI 15 sec.). Moving to the right the other points represent values determined for T - 30 sec.(FI 30 sec.), 60 sec. (Fi 60 sec.), 120 sec. (FI 120 sec.), and 240 sec. (FI 240 sec.) respectively.**

Figure #1



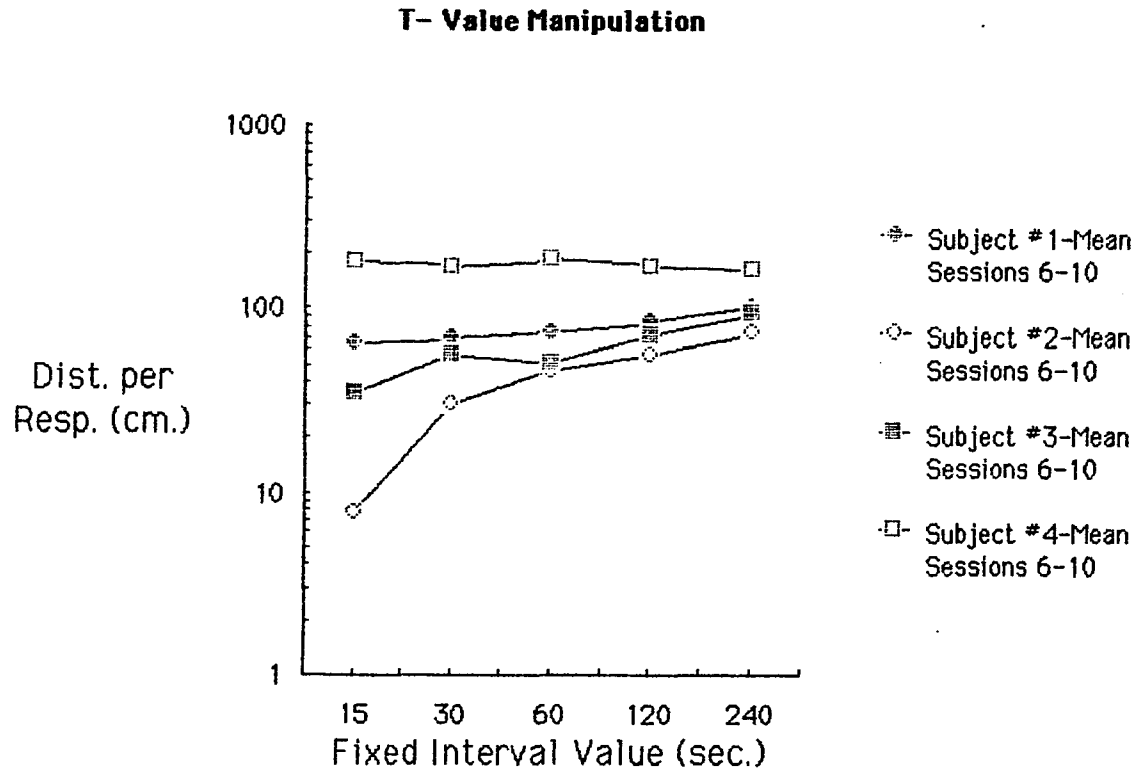
**Figure 2. The standard deviations of interresponse times as a function of T value. Each subjects' function in this figure represents the data averaged across the last five sessions of the T-manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for T - 15 sec. (FI 15 sec.). Moving to the right the other points represent values determined for T - 30 sec.(FI 30 sec.), 60 sec. (FI 60 sec.), 120 sec. (FI 120 sec.), and 240 sec. (FI 240 sec.) respectively.**

Figure #2



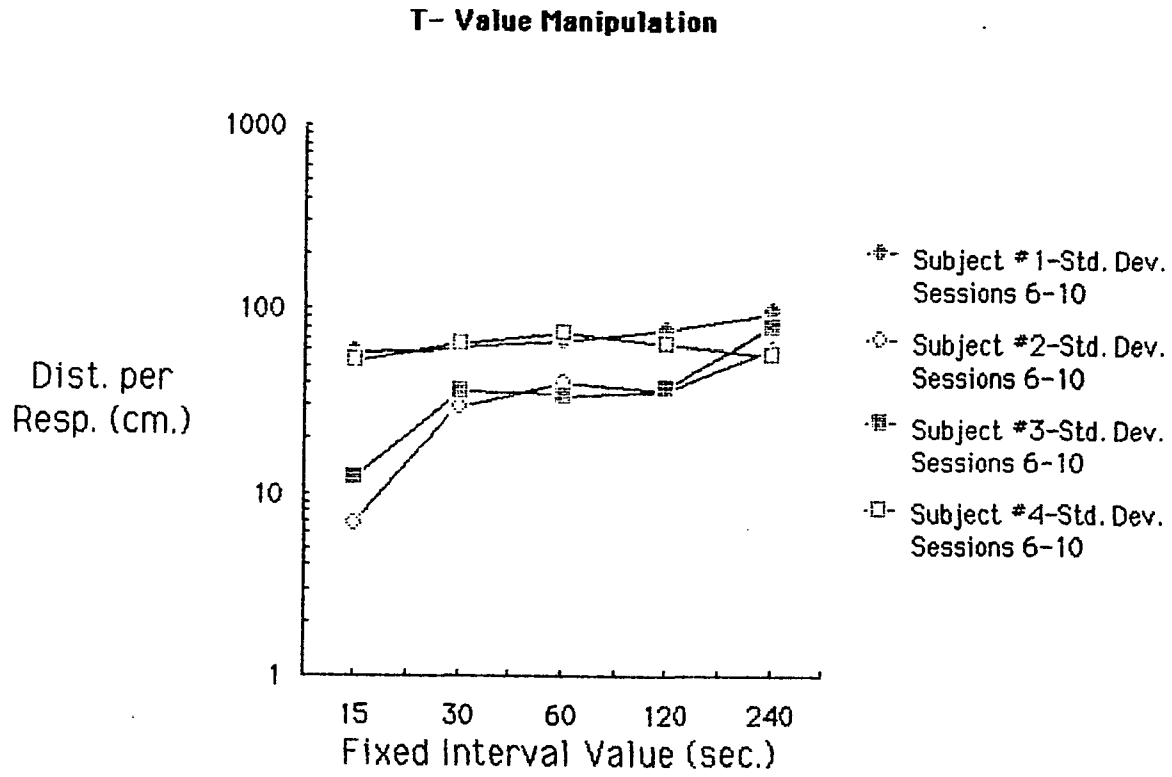
**Figure 3. The arithmetic means of distance per response as a function of T value. Each subjects' function in this figure represents the data averaged across the last five sessions of the T manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for T - 15 sec. (FI 15 sec.). Moving to the right the other points represent values determined for T - 30 sec.(FI 30 sec.), 60 sec. (Fi 60 sec.), 120 sec. (FI 120 sec.), and 240 sec. (FI 240 sec.) respectively.**

Figure #3



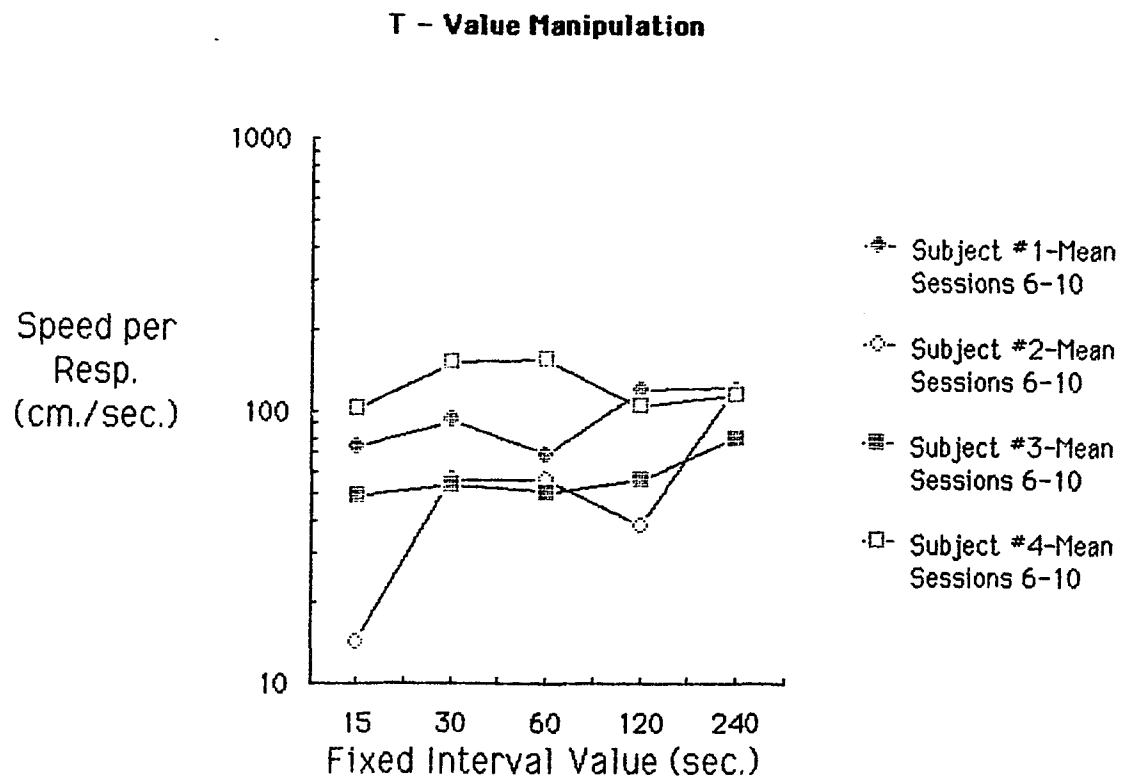
**Figure 4. The standard deviations of distance per response as a function of T value. Each subjects' function in this figure represents the data averaged across the last five sessions of the T manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for T = 15 sec. (FI 15 sec.). Moving to the right the other points represent values determined for T = 30 sec.(FI 30 sec.), 60 sec. (Fi 60 sec.), 120 sec. (FI 120 sec.), and 240 sec. (FI 240 sec.) respectively.**

Figure #4



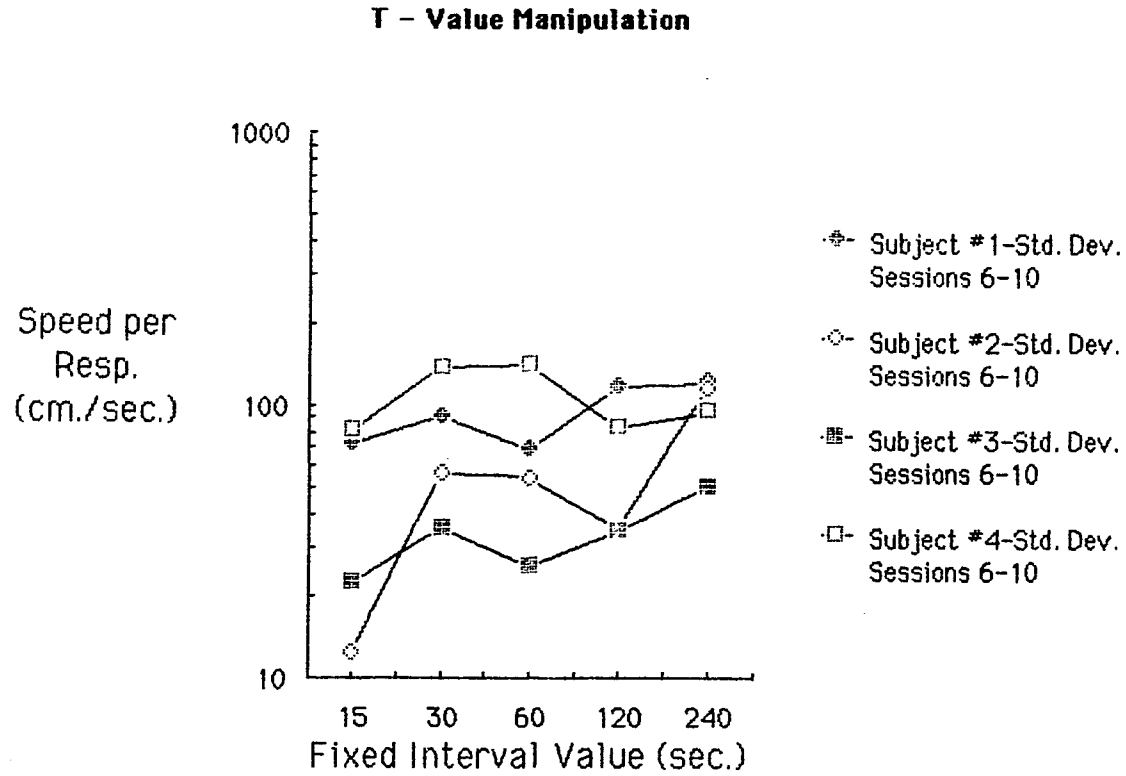
**Figure 5. The arithmetic means of speed per response as a function of T value. Each subjects' function in this figure represents the data averaged across the last five sessions of the T manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for T - 15 sec. (FI 15 sec.). Moving to the right the other points represent values determined for T - 30 sec.(FI 30 sec.), 60 sec. (Fi 60 sec.), 120 sec. (FI 120 sec.), and 240 sec. (FI 240 sec.) respectively.**

Figure #5



**Figure 6. The standard deviations of speed per response as a function of T value. Each subjects' function in this figure represents the data averaged across the last five sessions of the T-manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for T - 15 sec. (FI 15 sec.). Moving to the right the other points represent values determined for T - 30 sec.(FI 30 sec.), 60 sec. (FI 60 sec.), 120 sec. (FI 120 sec.), and 240 sec. (FI 240 sec.) respectively.**

Figure #6



the arithmetic means suggest a shallow inverse trend and an inverted u-trend for the standard deviations of this subject.

Figures 5 and 6 depict the mean and standard deviation functions for speed per response. Despite some reversals, the means and standard deviations of the speed measure for subjects 1, 2 and 3 increased as the duration of the interval value is increased. The data of subject 4 suggest an inverted u-shaped trend for the standard deviation and arithmetic mean functions.

Expressing each standard deviation as a percentage of its respective arithmetic mean produces a coefficient of variation representing the relative variability of the measures in the distribution. This measure, though unique for each subject, appears constant within each subject across the interval continuum for interresponse time, distance and speed (Tables 1, 2, 3).

Friedman two-way analyses of variance (subjects by schedule) were used to determine the likelihood that the correlated values plotted in these figures were from different populations (Siegel, 1956; Lehner, 1979). Table 7 presents summary statistics suggesting that for the arithmetic means, IRT ( $p=.003$ ) produced a differential effect across the schedule values. The speed ( $p=.06$ ) and distance ( $p=.19$ ) arithmetic means did not reach the conventional .05 level of significance. For all measures, presented in Table 8, the resulting Chi-square values for the standard deviations indicated significant differences (.05 level or better) across the fixed interval values. For each of the measures the coefficient of variation showed no significant effects across the interval continuum

Tables 9 and 10 present Kendall Correlation Coefficients and  $p$ -values, obtained between conditions for each subject, which reaffirm the general

**Table 1. The interresponse time central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3 are shown here. Values reflect the the combined outcomes of the last 5 sessions of the t-manipulation. The left most column of figures represents values obtained for each subject when  $p = 1.0$  and  $t = 15$  sec. (FI 15). Moving left to right the other columns are for  $p = 1.0$  and  $t = 30$  sec. (FI 30), 60 sec. (FI 60), 120 sec. (FI 120), and 240 sec. (FI 240) respectively.**

**Table #1**  
**Interresponse Time (sec.)**  
**Central Tendency and Variance Indicators**  
**Sessions 6 through 10**

Interval Value (sec.)	FI 15	FI 30	FI 60	FI 120	FI 240
<b>Subject #1</b>					
Arithmetic Mean	14.04	22.71	33.76	44.34	48.95
Standard Deviation	8.42	19.10	30.30	37.97	41.09
Coefficient of Variation	59.98	84.09	89.76	85.63	83.94
Geometric Mean	11.23	12.29	14.88	22.90	26.60
Harmonic Mean	8.98	6.65	6.56	11.83	14.46
<b>Subject #2</b>					
Arithmetic Mean	3.99	8.14	21.01	36.14	80.34
Standard Deviation	3.69	7.45	17.65	22.81	66.66
Coefficient of Variation	92.55	91.52	84.00	63.11	82.97
Geometric Mean	1.51	3.28	11.40	28.03	44.84
Harmonic Mean	0.57	1.32	6.19	21.74	25.03
<b>Subject #3</b>					
Arithmetic Mean	1.72	2.24	2.45	2.81	3.42
Standard Deviation	1.39	1.81	2.15	2.30	2.95
Coefficient of Variation	80.89	80.79	87.83	81.75	86.26
Geometric Mean	1.01	1.32	1.17	1.62	1.73
Harmonic Mean	0.59	0.78	0.56	0.93	0.88
<b>Subject #4</b>					
Arithmetic Mean	4.20	4.57	4.82	5.61	6.04
Standard Deviation	3.06	3.20	3.16	4.38	4.86
Coefficient of Variation	72.93	70.05	65.55	78.03	80.51
Geometric Mean	2.87	3.26	3.64	3.51	3.58
Harmonic Mean	1.96	2.33	2.75	2.19	2.12

**Table 2. The distance per response central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3 are shown here. Values reflect the the combined outcomes of the last 5 sessions of the t-manipulation. The left most column of figures represents values obtained for each subject when p 1.0 and t - 15 sec. (FI 15). Moving left to right the other columns are for p - 1 and t - 30 sec. (FI 30), 60 sec. (FI 60), 120 sec. (FI 120), and 240 sec. (FI 240) respectively.**

**Table #2**  
**Distance per Response (cm.)**  
**Central Tendency and Variance Indicators**  
**Sessions 6 through 10**

Interval Value (sec.)	FI 15	FI 30	FI 60	FI 120	FI 240
<b>Subject #1</b>					
Arithmetic Mean	64.29	68.43	73.65	83.84	100.67
Standard Deviation	57.99	61.74	66.33	76.30	96.63
Coefficient of Variation	90.20	90.22	90.06	91.00	95.98
Geometric Mean	27.75	29.50	32.00	34.75	28.25
Harmonic Mean	11.98	12.72	13.90	14.40	7.93
<b>Subject #2</b>					
Arithmetic Mean	7.68	30.13	45.97	56.67	73.26
Standard Deviation	6.72	29.30	40.00	35.96	61.50
Coefficient of Variation	87.54	97.24	87.01	63.45	83.94
Geometric Mean	3.71	7.02	22.65	43.80	39.81
Harmonic Mean	1.79	1.64	11.16	33.85	21.63
<b>Subject #3</b>					
Arithmetic Mean	34.76	56.43	50.45	72.01	94.42
Standard Deviation	12.24	36.40	34.13	36.90	79.88
Coefficient of Variation	35.21	64.50	67.65	51.24	84.60
Geometric Mean	32.53	43.12	37.15	61.84	50.34
Harmonic Mean	30.45	32.95	27.36	53.10	26.84
<b>Subject #4</b>					
Arithmetic Mean	180.16	169.47	185.67	170.26	163.18
Standard Deviation	52.00	64.77	74.30	64.42	56.20
Coefficient of Variation	28.86	38.22	40.01	37.83	34.43
Geometric Mean	172.49	156.60	170.15	157.60	153.20
Harmonic Mean	165.15	144.71	155.93	145.88	143.83

**Table 3. The speed per response central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the last 5 sessions of the t-manipulation. The left most column of figures represents values obtained for each subject when p - 1.0 and t - 15 sec. (FI 15). Moving left to right the other columns are for p -1 and t - 30 sec. (FI 30), 60 sec. (FI 60), 120 sec. (FI 120), and 240 sec. (FI 240) respectively.**

**Table #3**  
**Speed per Response (cm. per sec.)**  
**Central Tendency and Variance Indicators**  
**Sessions 6 through 10**

Interval Value (sec.)	FI 15	FI 30	FI 60	FI 120	FI 240
<b>Subject #1</b>					
Arithmetic Mean	73.70	92.51	69.40	118.88	123.31
Standard Deviation	73.00	92.00	69.00	118.19	123.00
Coefficient of Variation	99.05	99.44	99.42	99.41	99.74
Geometric Mean	10.10	9.70	7.40	12.80	8.80
Harmonic Mean	1.38	1.02	0.79	1.38	0.63
<b>Subject #2</b>					
Arithmetic Mean	14.10	55.95	55.50	38.15	120.83
Standard Deviation	12.24	55.40	53.79	35.43	114.36
Coefficient of Variation	86.83	99.00	96.92	92.86	94.64
Geometric Mean	6.99	7.86	13.66	14.15	39.00
Harmonic Mean	3.47	1.10	3.36	5.25	12.59
<b>Subject #3</b>					
Arithmetic Mean	48.65	53.74	50.34	56.48	79.89
Standard Deviation	22.20	35.50	25.29	34.27	50.39
Coefficient of Variation	45.63	66.06	50.23	60.65	63.07
Geometric Mean	43.29	40.34	43.53	44.89	62.00
Harmonic Mean	16.32	-5.22	12.35	1.41	-2.28
<b>Subject #4</b>					
Arithmetic Mean	102.43	150.49	156.28	103.40	114.14
Standard Deviation	80.76	138.01	142.12	83.49	95.83
Coefficient of Variation	78.84	91.70	90.93	80.74	83.96
Geometric Mean	63.00	60.00	65.00	61.00	62.00
Harmonic Mean	38.75	23.92	27.03	35.99	33.68

**Table \* 4 Friedman Analysis of Variance outcomes (subjects by schedule value) of arithmetic means for sessions 6 thru 10 of t-manupliation (fixed interval schedules). Table shows summary values for interresponse time (sec.), distance per response (cm.), and speed per response (cm./sec.) indicating that only mean interresponse time achived a significance level greater than .05.**

Table #4

## Friedman Analysis of Variance

Interresponse Times (sec.)  
Arithmetic Means - Sessions 6 through 10

Schedule	Mean	Std. Est.	Minimum	Maximum
FI 15	5.98	5.48	1.72	14.04
FI 30	9.41	9.18	2.24	22.71
FI 60	15.5	14.69	2.45	33.75
FI 120	22.22	21.1	2.81	44.33
FI 240	34.68	36.9	3.42	80.33

Friedman Statistic 15.99  
Significance level 0.003  
Kendall coefficient 1

Distance per Response (cm.)  
Arithmetic Means - Sessions 6 through 10

Schedule	Mean	Std. Est.	Minimum	Maximum
FI 15	71.72	75.89	7.68	180.16
FI 30	81.11	61.03	30.13	169.47
FI 60	88.93	65.62	45.97	185.66
FI 120	95.69	50.93	56.66	170.25
FI 240	107.88	38.68	73.25	163.17

Friedman Statistic 5.99  
Significance level 0.19  
Kendall coefficient 0.37

Speed per Response (cm./sec.)  
Arithmetic Means - Sessions 6 through 10

Schedule	Mean	Std. Est.	Minimum	Maximum
FI 15	59.72	37.52	14.10	102.42
FI 30	88.17	45.15	53.74	150.49
FI 60	82.87	49.59	50.33	156.27
FI 120	79.22	38.12	38.14	118.88
FI 240	109.54	20.14	79.88	123.30

Friedman Statistic 8.99  
Significance level 0.06  
Kendall coefficient 0.56

**Table \* 5 Friedman Analysis of Variance outcomes (subjects by schedule value) of standard deviations for sessions 6 thru 10 of t-manupliation (fixed interval schedules). Table shows summary values for interresponse time (sec.), distance per response (cm.), and speed per response (cm./sec.) indicating that all measures achived a significance level greater than .05.**

Table #5

## Friedman Analysis of Variance

Interresponse Times (sec.)  
Standard Deviations - Sessions 6 through 10

Schedule	Mean	Std. Est.	Minimum	Maximum
FI 15	4.14	3.01	1.39	8.42
FI 30	7.89	7.84	1.81	19.10
FI 60	13.31	13.35	2.15	30.30
FI 120	16.86	16.82	2.30	37.97
FI 240	28.88	30.69	2.95	66.66

Friedman Statistic 15.39  
Significance level 0.003  
Kendall coefficient 0.96

Distance per Response (cm.)  
Standard Deviations - Sessions 6 through 10

Schedule	Mean	Std. Est.	Minimum	Maximum
FI 15	31.73	26.00	6.72	57.99
FI 30	48.05	17.83	29.30	64.77
FI 60	53.68	19.61	34.13	74.30
FI 120	53.39	20.18	35.96	76.30
FI 240	73.55	18.42	56.19	96.63

Friedman Statistic 9.79  
Significance level 0.04  
Kendall coefficient 0.61

Speed per Response (cm./sec.)  
Arithmetic Means - Sessions 6 through 10

Schedule	Mean	Std. Est.	Minimum	Maximum
FI 15	47.05	34.82	12.24	80.75
FI 30	80.22	45.07	35.5	138
FI 60	72.54	49.79	25.28	142.11
FI 120	67.84	40.65	34.27	118.19
FI 240	95.89	32.38	50.38	123

Friedman Statistic 9.59  
Significance level 0.04  
Kendall coefficient 0.6

**Table \* 6 Kendall Correlation Coefficients and signifiante levels of subjects 1 and 2 for sessions 6 thru 10 of t-manupliation (fixed interval schedules). The matrix values indicates that for subject 1 and 2 the values of interresponse time (sec.) and distance per response (cm.) measures were siginifently interrelated with speed per response (cm./sec.) notnot always achiving a significance level greater than .05.**



**Table \* 7 Kendall Correlation Coefficients and signifiante levels of subjects 3 and 4 for sessions 6 thru 10 of t-manupliation (fixed interval schedules). The matrix values indicates that for subject 3 the values of interresponse time (sec.), distance per response (cm.) and speed per response measures were signifently interrelated achiving a significance levels greater than .05 . However subject \* 4 does not show the high level of measure interlationship observed in the other subjects.**

Table #7- Kendall Correlation Coefficients

T-Manupliation (Fixed Interval Schedules)

Subject #3 Measures		IRT Std. Dev.	Distance Mean	Distance Std. Dev.	Speed Mean	Speed Std. Dev.
IRT Mean	Tau p. value	1 *0.007	0.8 *0.025	0.8 *0.025	0.8 *0.025	0.6 0.07
IRT Std. Dev			0.8 *0.025	0.8 *0.025	0.8 *0.025	0.6 0.07
Distance Mean				1 *0.007	1 *0.007	0.8 *0.025
Distance Std. Dev					1 *0.007	0.8 *0.025
Speed Mean						0.8 *0.025
Subject #4 Measures		IRT Std. Dev.	Distance Mean	Distance Std. Dev.	Speed Mean	Speed Std. Dev.
IRT Mean	Tau p. value	0.8 *0.025	-0.4 0.16	0 0.5	0.2 0.31	0.2 0.31
IRT Std. Dev			-0.6 *0.07	-0.2 0.31	0 0.5	0 0.5
Distance Mean				0.2 0.31	0 0.5	0 0.5
Distance Std. Dev					0.8 *0.025	0.8 *0.025
Speed Mean						1 *0.007

graphical trends suggesting measure interrelation. The data of subjects 1, 2 and 3 yield positive correlations between all dependent measures across schedules. For these subjects all indicators of IRT and distance were significantly interrelated ( $p \leq .05$ ). In the case of subject 3 additional significant interrelations between IRT, distance and the speed indicators occur. Subject 4 produced several significant positive correlations between the standard deviations and means of the different measures, but no significant correlations between the measures of central tendency occur in the data. None of the negative correlations between distance and IRT measures reached the traditional level of significance ( $p \leq .05$ ).

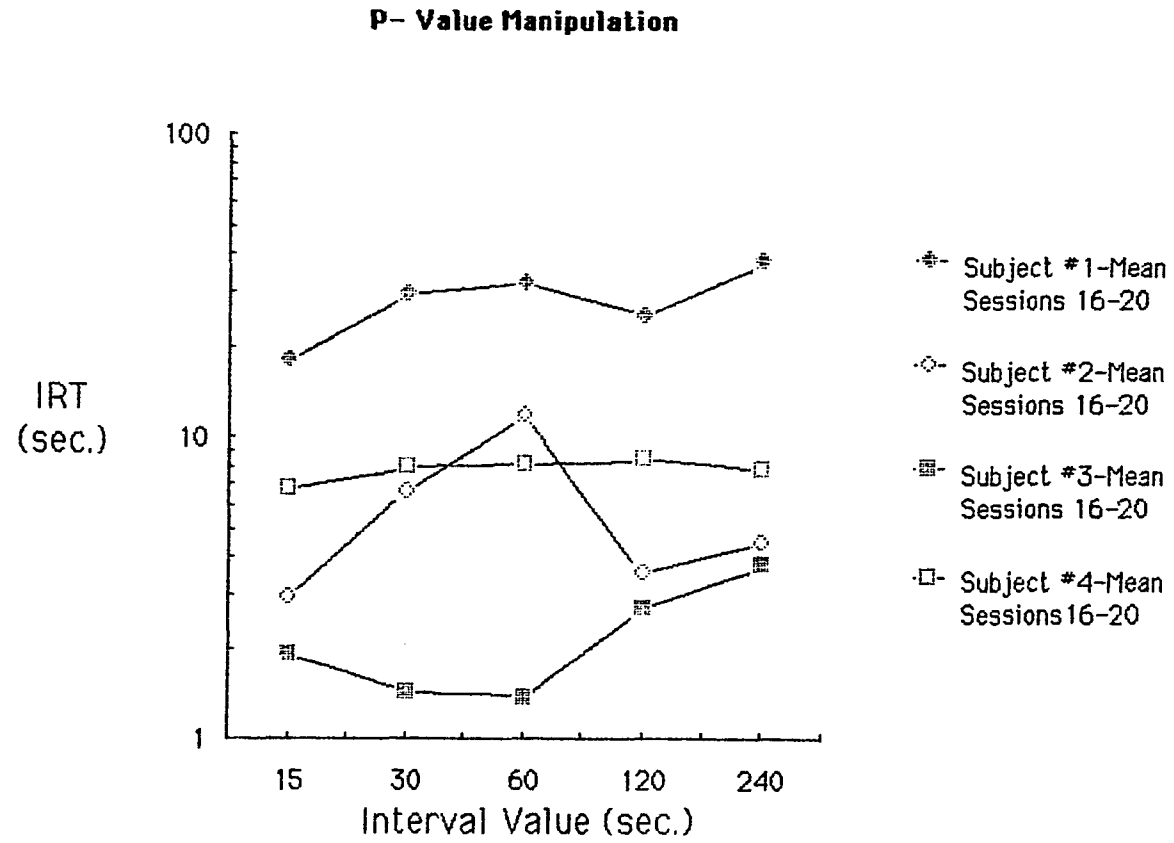
#### RANDOM INTERVAL - P-MANIPULATION

Figures 7 and 8 depict the trends of the interresponse time means and standard deviations following exposure to the random interval contingencies. When contrasted with the fixed interval outcomes, a general reduction in the range of IRT values sampled by the subjects is apparent. Subjects 1, 2 and 3 made, more often than not, shorter interresponse times for the equivalent mean interreinforcement intervals produced by the reinforcement probability manipulation. Subject 4 once again proved the exception with little differentiation across the continuum and higher interresponse time values when contrasted with those attained under the fixed interval contingencies.

Figures 9 and 10 show the change in distance indicators as a function of

**Figure 7. The arithmetic means of interresponse times as a function of P value when T-cycle length is held constant at 15 seconds. Each subjects' function in this figure represents the data averaged across the last five sessions of the P-manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for P - 1.0 (FI 15 sec.). Moving to the right the other points represent values determined for P - .5 (RI 30 sec.), .25 (RI 60sec.), .125 (RI 120 sec.), and .065 (RI 240 sec.) respectively.**

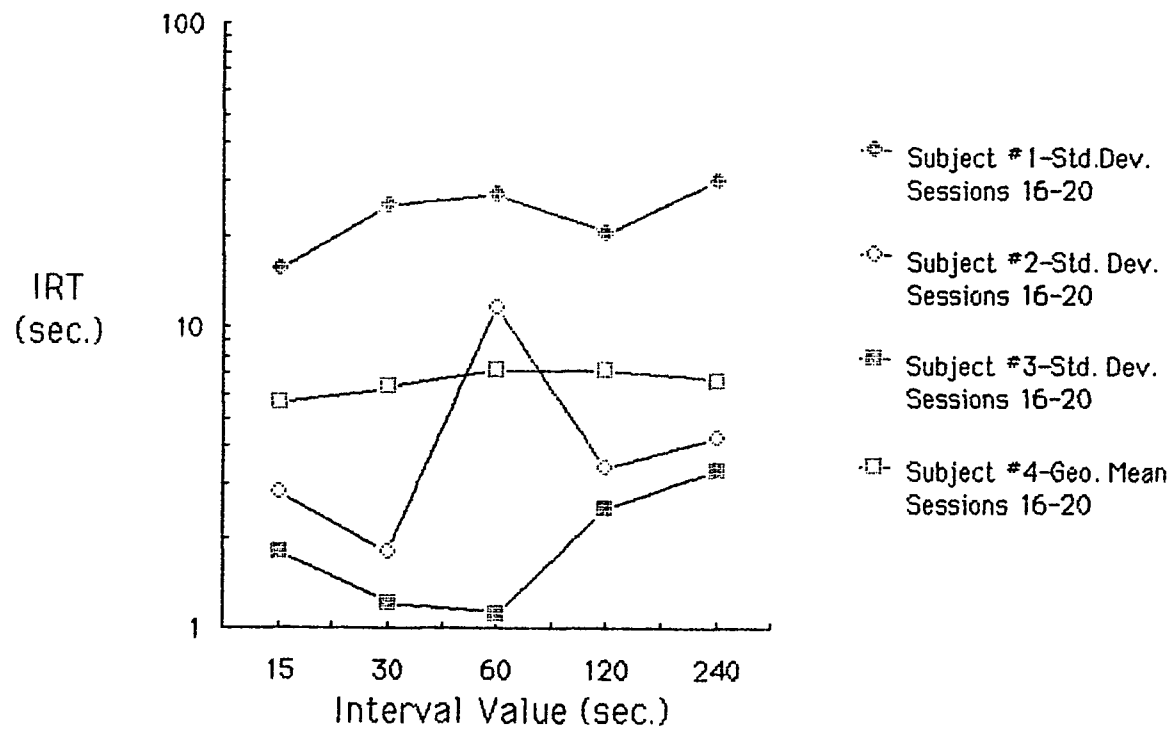
Figure #7



**Figure 8. The standard deviations of interresponse times as a function of P value when T-cycle length is held constant at 15 seconds. Each subjects' function in this figure represents the data averaged across the last five sessions of the P-manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for P - 1.0 (FI 15 sec.). Moving to the right the other points represent values determined for P - .5 (RI 30 sec.), .25 (RI 60sec.), .125 (RI 120 sec.), and .065 (RI 240 sec.) respectively.**

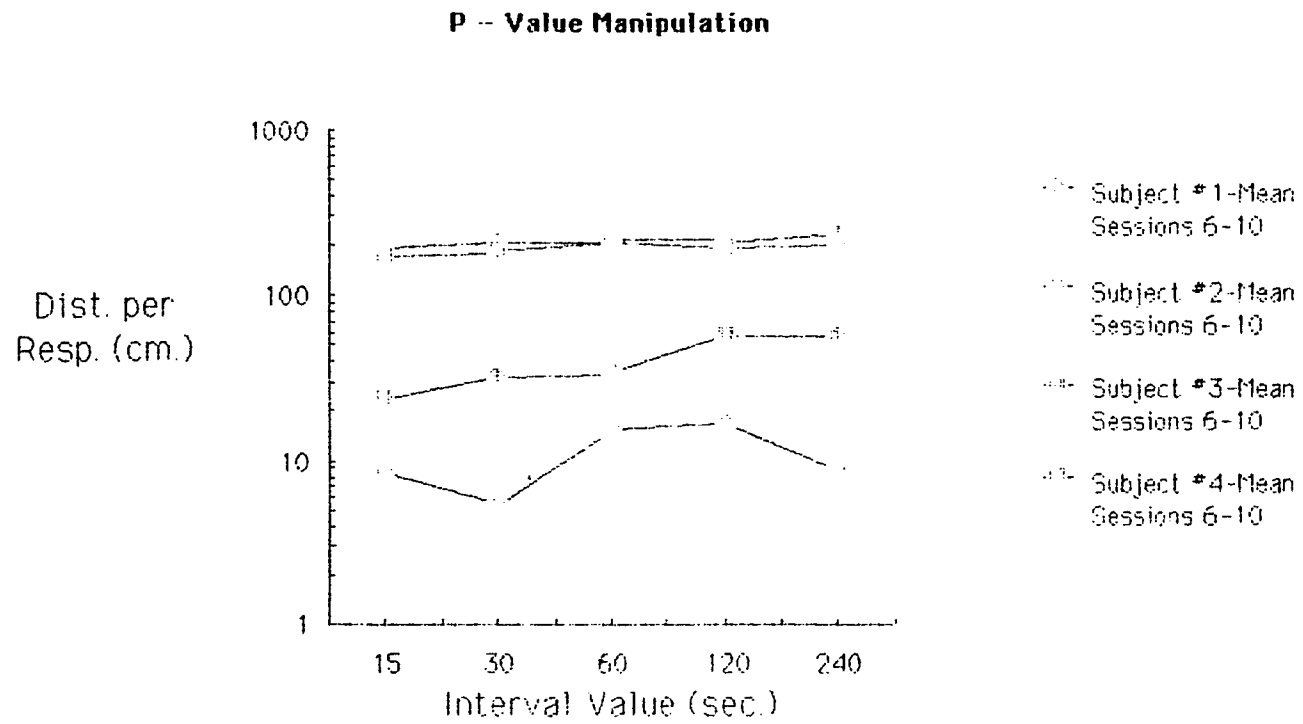
Figure #8

**P- Value Manipulation**



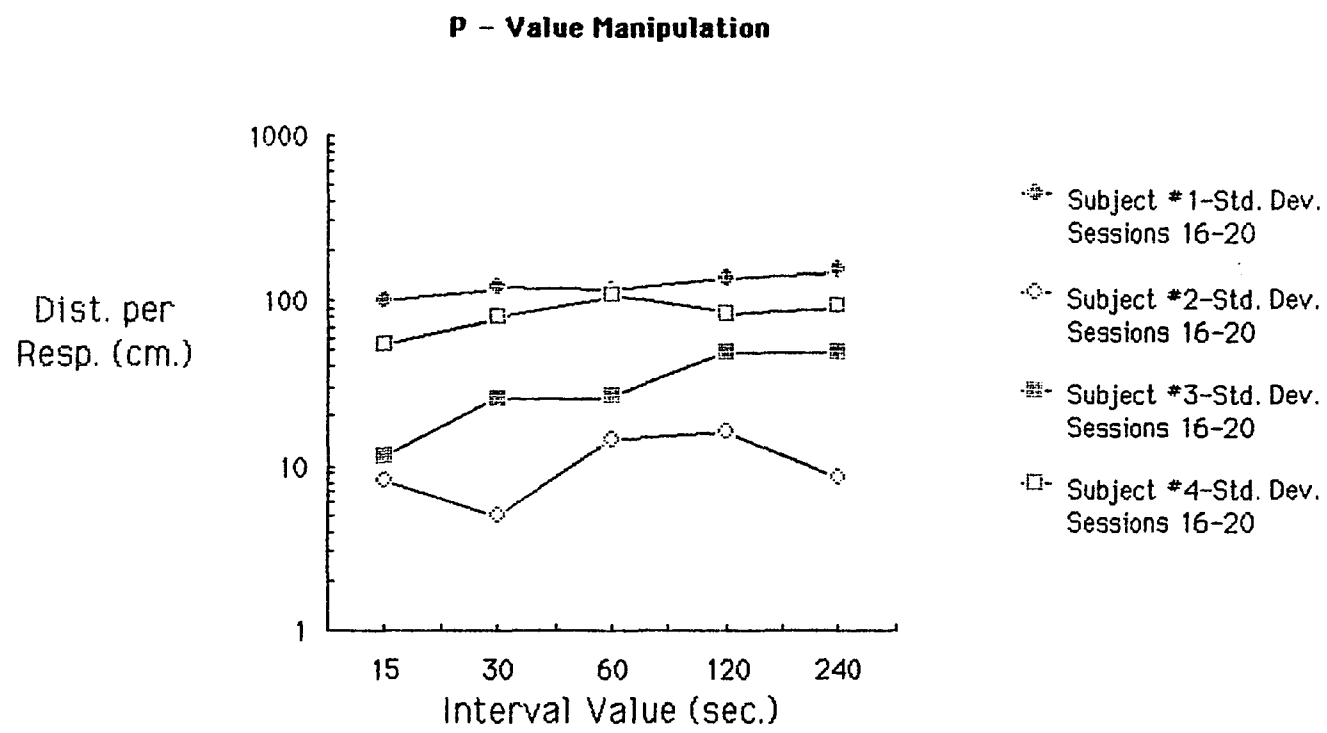
**Figure 9. The arithmetic means of distance per response as a function of P value when T-cycle length is held constant at 15 seconds. Each subjects' function in this figure represents the data averaged across the last five sessions of the P-manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for P = 1.0 (FI 15 sec.). Moving to the right the other points represent values determined for P = .5 (RI 30 sec.), .25 (RI 60sec.), .125 (RI 120 sec.), and .065 (RI 240 sec.) respectively.**

Figure #9



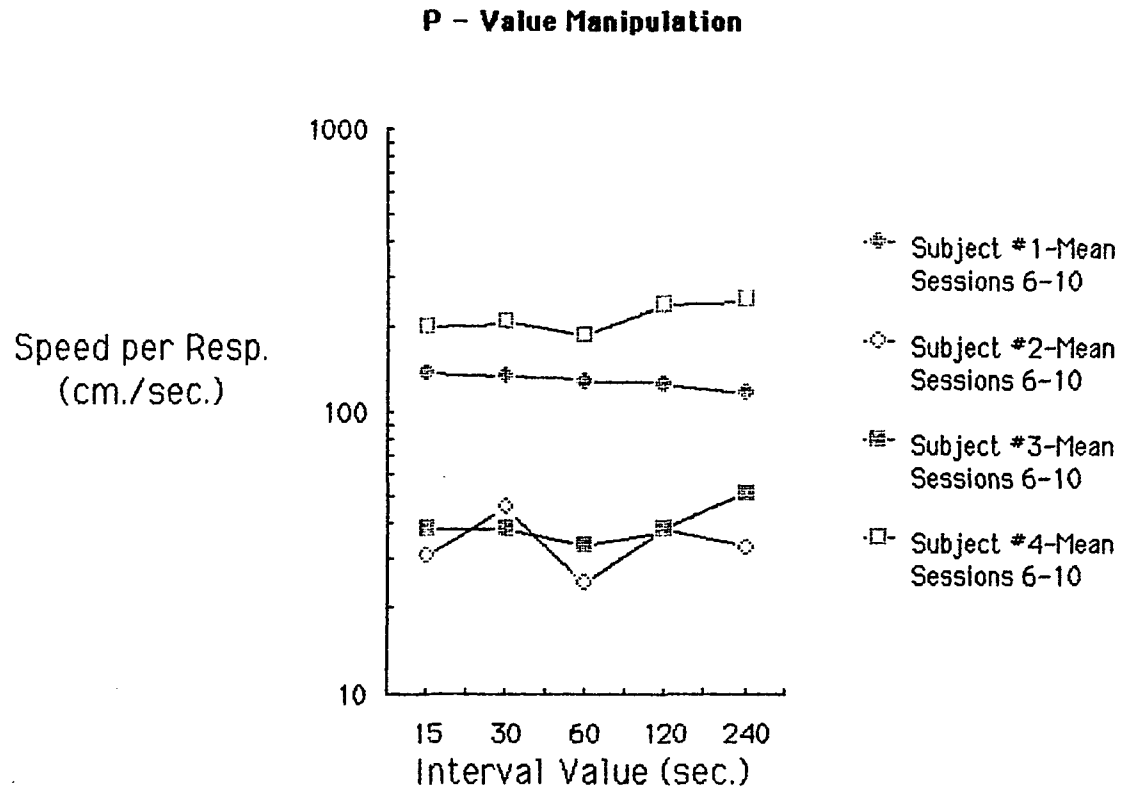
**Figure 10. The standard deviations of distance per response as a function of P value when T-cycle length is held constant at 15 seconds. Each subjects' function in this figure represents the data averaged across the last five sessions of the P-manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for P - 1.0 (FI 15 sec.). Moving to the right the other points represent values determined for P - .5 (RI 30 sec.), .25 (RI 60sec.), .125 (RI 120 sec.), and .065 (RI 240 sec.) respectively.**

Figure #10



**Figure 11. The arithmetic means of speed per response as a function of P value when T-cycle length is held constant at 15 seconds. Each subjects' function in this figure represents the data averaged across the last five sessions of the P-manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for P - 1.0 (FI 15 sec.). Moving to the right the other points represent values determined for P - .5 (RI 30 sec.), .25 (RI 60sec.), .125 (RI 120 sec.), and .065 (RI 240 sec.) respectively.**

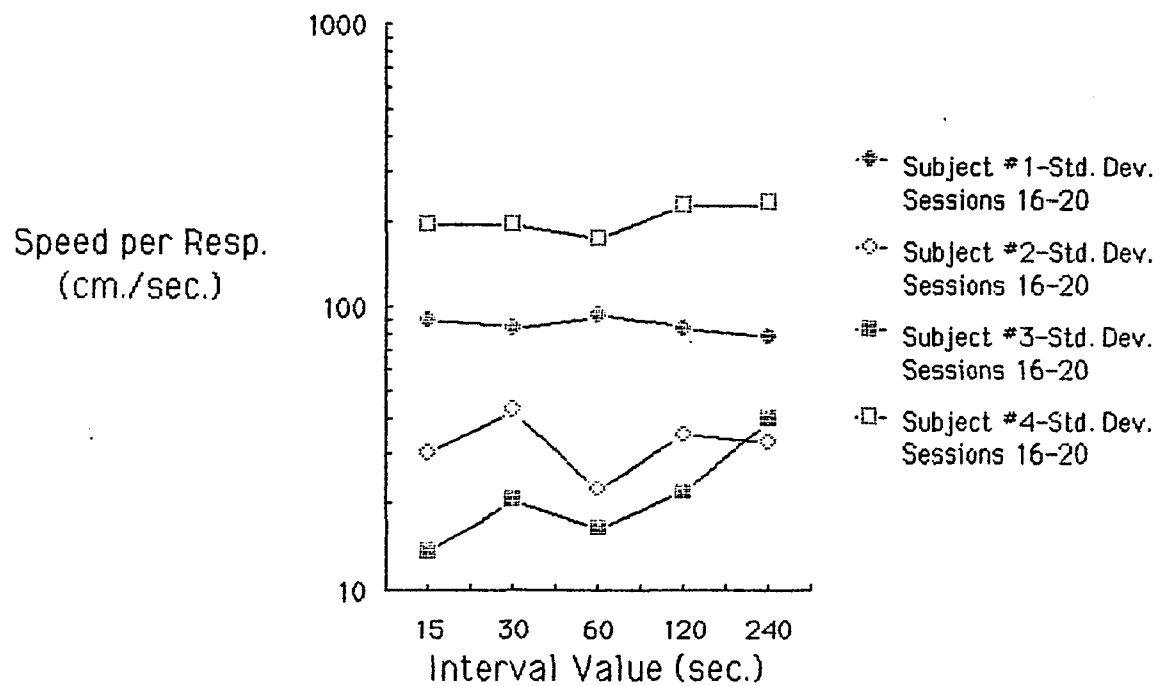
Figure #11



**Figure 12. The standard deviations of speed per response as a function of P value when T-cycle length is held constant at 15 seconds. Each subjects' function in this figure represents the data averaged across the last five sessions of the P-manipulation condition. Note the use of a logarithmic scale on the ordinate. The left most point on each function is for P = 1.0 (FI 15 sec.). Moving to the right the other points represent values determined for P = .5 (RI 30 sec.), .25 (RI 60 sec.), .125 (RI 120 sec.), and .065 (RI 240 sec.) respectively.**

Figure #12

**P - Value Manipulation**



**Table 8. The interresponse time central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the last 5 sessions of the p-manipulation. The left most column of figures represents values obtained for each subject when t - 15 sec. and p = 1.0 (FI 15). Moving left to right the other columns are for t - 15 sec. and p = .5 (RI 30), .25 (RI 60), .125 (RI 120), and .0625 (RI 240) respectively.**

**Table #8**  
**Interresponse Time (sec.)**  
**Central Tendency and Variance Indicators**  
**Sessions 16 through 20**

<b>Interval Value (sec.)</b>	<b>FI 15</b>	<b>RI 30</b>	<b>RI 60</b>	<b>RI 120</b>	<b>RI 240</b>
<b>Subject #1</b>					
<b>Arithmetic Mean</b>	18.02	29.35	31.97	25.19	37.74
<b>Standard Deviation</b>	15.42	25.00	27.14	20.54	30.45
<b>Coefficient of Variation</b>	85.55	85.17	84.88	81.52	80.67
<b>Geometric Mean</b>	9.33	15.38	16.90	14.59	22.30
<b>Harmonic Mean</b>	4.83	8.06	8.93	8.45	13.18
<b>Subject #2</b>					
<b>Arithmetic Mean</b>	2.94	6.63	11.79	3.54	4.45
<b>Standard Deviation</b>	2.85	1.80	11.74	3.41	4.28
<b>Coefficient of Variation</b>	96.95	27.15	99.58	96.40	96.22
<b>Geometric Mean</b>	0.72	6.38	1.07	0.94	1.21
<b>Harmonic Mean</b>	0.18	6.14	0.10	0.25	0.33
<b>Subject #3</b>					
<b>Arithmetic Mean</b>	1.91	1.43	1.38	2.71	3.77
<b>Standard Deviation</b>	1.78	1.21	1.12	2.53	3.38
<b>Coefficient of Variation</b>	93.23	84.68	81.37	93.49	89.75
<b>Geometric Mean</b>	0.69	0.76	0.80	0.96	1.66
<b>Harmonic Mean</b>	0.25	0.40	0.46	0.34	0.73
<b>Subject #4</b>					
<b>Arithmetic Mean</b>	6.77	7.96	8.24	8.53	7.76
<b>Standard Deviation</b>	3.75	4.83	4.00	4.61	4.00
<b>Coefficient of Variation</b>	55.36	60.66	48.56	54.02	51.54
<b>Geometric Mean</b>	5.64	6.33	7.20	7.18	6.65
<b>Harmonic Mean</b>	4.70	5.03	6.29	6.04	5.70

**Table 9. The distance per response central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the last 5 sessions of the p-manipulation. The left most column of figures represents values obtained for each subject when t - 15 sec. and p - 1.0 (FI 15). Moving left to right the other columns are for t - 15 sec. and p - .5 (RI 30), .25 (RI 60), .125 (RI 120), and .0625 (RI 240) respectively.**

**Table #9**  
**Distance per Response(cm.)**  
**Central Tendency and Variance Indicators**  
**Sessions 16 through 20**

<b>Interval Value (sec.)</b>	<b>FI 15</b>	<b>RI 30</b>	<b>RI 60</b>	<b>RI 120</b>	<b>RI 240</b>
<b>Subject #1</b>					
<b>Arithmetic Mean</b>	192.89	209.25	212.94	206.74	236.88
<b>Standard Deviation</b>	102.67	122.00	116.87	137.93	153.04
<b>Coefficient of Variation</b>	53.22	58.30	54.88	66.71	64.60
<b>Geometric Mean</b>	163.30	170.00	178.00	154.00	180.80
<b>Harmonic Mean</b>	138.25	138.11	148.79	114.72	138.00
<b>Subject #2</b>					
<b>Arithmetic Mean</b>	8.44	5.44	15.38	16.94	8.84
<b>Standard Deviation</b>	8.27	4.89	14.66	16.47	8.48
<b>Coefficient of Variation</b>	97.97	89.84	95.31	97.24	95.94
<b>Geometric Mean</b>	1.69	2.39	4.65	3.95	2.49
<b>Harmonic Mean</b>	0.34	1.05	1.41	0.92	0.70
<b>Subject #3</b>					
<b>Arithmetic Mean</b>	23.97	32.62	34.20	56.78	57.81
<b>Standard Deviation</b>	11.54	26.05	26.88	49.72	48.42
<b>Coefficient of Variation</b>	48.14	79.86	78.60	87.5651	83.75
<b>Geometric Mean</b>	21.01	19.63	21.14	27.42	31.58
<b>Harmonic Mean</b>	18.42	11.81	13.07	13.24	17.25
<b>Subject #4</b>					
<b>Arithmetic Mean</b>	172.01	183.32	208.39	192.61	202.25
<b>Standard Deviation</b>	55.82	81.32	108.37	83.43	92.62
<b>Coefficient of Variation</b>	32.45	44.35	52.00	43.31	45.79
<b>Geometric Mean</b>	162.70	164.30	178.00	173.60	179.80
<b>Harmonic Mean</b>	153.89	147.25	152.04	156.47	159.84

**Table 10. The interresponse time central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the last 5 sessions of the p-manipulation. The left most column of figures represents values obtained for each subject when t - 15 sec. and p - 1.0 (FI 15). Moving left to right the other columns are for t - 15 sec. and p - .5 (RI 30), .25 (RI 60), .125 (RI 120), and .0625 (RI 240) respectively.**

**Table #10**  
**Speed per Response (cm. per sec.)**  
**Central Tendency and Variance Indicators**  
**Sessions 16 through 20**

Interval Value (sec.)	FI 15	RI 30	RI 60	RI 120	RI 240
<b>Subject #1</b>					
Arithmetic Mean	137.49	134.33	128.90	126.44	117.83
Standard Deviation	89.70	84.90	92.90	84.90	79.20
Coefficient of Variation	65.24	63.20	72.07	67.14	67.21
Geometric Mean	104.20	104.10	89.36	93.70	87.24
Harmonic Mean	78.97	80.67	61.95	69.44	64.59
<b>Subject #2</b>					
Arithmetic Mean	30.53	45.62	24.47	38.55	33.14
Standard Deviation	29.95	43.45	22.71	35.64	32.68
Coefficient of Variation	98.11	95.24	92.82	92.442	98.61
Geometric Mean	5.90	13.90	9.10	14.70	5.50
Harmonic Mean	1.14	4.24	3.38	5.61	0.91
<b>Subject #3</b>					
Arithmetic Mean	38.23	38.86	33.92	38.49	52.03
Standard Deviation	13.41	20.52	16.39	21.98	40.06
Coefficient of Variation	35.07	52.80	48.31	57.10	76.99
Geometric Mean	35.80	33.00	29.70	31.60	33.20
Harmonic Mean	33.53	28.02	26.00	25.94	21.19
<b>Subject #4</b>					
Arithmetic Mean	201.39	207.57	185.73	241.22	248.35
Standard Deviation	196.30	197.00	175.00	230.00	234.00
Coefficient of Variation	97.47	94.90	94.22	95.35	94.22
Geometric Mean	45.00	65.40	62.20	72.70	83.20
Harmonic Mean	10.06	20.61	20.83	21.91	27.87

the mean interval value. The tabled values suggest increasing trends for both the means and standard deviations as the interval value increases. Little or no change in the speed indicators, figures 11 and 12, is apparent with the increase in mean interval value. The coefficient of variation representing the relative variability of the measures in a distribution once again appears unique for each subject and constant across the interval continuum for the distance, speed and interresponse time measures.

Friedman two-way analyses of variance were again applied to determine the likelihood that the correlated values plotted in these figures were from different populations. The resulting Chi-square values, tables 11 and 12, suggest no significant effects ( $p \geq .05$ ) for the interresponse time and speed measures. However, the central tendency and variance indicators for distance per response did produce significant outcomes indicating a differential effect across the random interval values. As in the fixed interval case, no significant effect was found across the interval continuum for the coefficients of variation (Tables 4, 5, and 6).

Under the random interval conditions, the Kendall Correlation Coefficients, tables 13 and 14, indicate a marked reduction in the number of significant correlations among the measures. The tables also suggest an increase in the occurrence of negative correlations among the dependent measures. The data of subjects 1 and 2 produced a number of null or weak negative correlations between interresponse time, speed and distance measures. Subject 3 once again produced the greatest number of significant positive correlations between the dependent measures with no negative correlations. In the case of Subject 4 only, the means of distance, speed and their respective variance were significantly correlated.

**Table \* 11 Friedman Analysis of Variance outcomes (subjects by schedule value) of arithmetic means for sessions 16 thru 20 of the p-manupliation (random interval schedules). Table shows summary values for interresponse time (sec.), distance per response (cm.), and speed per response (cm./sec.) indicating that only mean distance per response achived a significance level greater than .05.**

Table #11

## Friedman Analysis of Variance

Interresponse Times (sec.)  
Arithmetic Means - Sessions 16 through 20

Schedule	Mean	St. Dev.	Minimum	Maximum
FI 15	7.41	7.37	1.91	18.02
RI 30	11.34	12.33	1.43	29.35
RI 60	13.34	13.14	1.38	31.97
RI 120	9.99	10.45	2.71	25.19
RI 240	13.43	16.3	3.77	37.74

Friedman Statistic 4.99  
Significance level 0.28  
Kendall coefficient 0.31

Distance per Response (cm.)  
Arithmetic Means - Sessions 16 through 20

Schedule	Mean	St. Dev.	Minimum	Maximum
FI 15	99.32	96.56	8.44	192.88
RI 30	107.65	103.48	5.44	209.25
RI 60	117.72	107.6	15.38	212.94
RI 120	118.26	95.57	16.94	206.74
RI 240	126.44	110.27	8.84	236.88

Friedman Statistic 10.99  
Significance level 0.02  
Kendall coefficient 0.68

Speed per Response (cm./sec.)  
Arithmetic Means - Sessions 16 through 20

Schedule	Mean	St. Dev.	Minimum	Maximum
FI 15	176.91	122.45	38.22	330.53
RI 30	106.59	80.14	38.86	207.57
RI 60	93.25	77.61	24.47	185.72
RI 120	111.17	96.09	38.49	241.22
RI 240	112.83	97.36	33.13	248.35

Friedman Statistic 4.99  
Significance level 0.28  
Kendall coefficient 0.31

**Table #12 Friedman Analysis of Variance outcomes (subjects by schedule value) of standard deviations for sessions 16 thru 20 of p-manupliation (random interval schedules). Table shows summary values for interresponse time (sec.), distance per response (cm.), and speed per response (cm./sec.) indicating that only the distance per response measures achived a significance level greater than .05.**

Table #12

## Friedman Analysis of Variance

Interresponse Times (sec.)  
Standard Deviations - Sessions 16 through 20

Schedule	Mean	St. Dev.	Minimum	Maximum
FI 15	5.95	6.36	1.78	15.42
RI 30	8.21	11.3	1.21	25.00
RI 60	10.99	11.65	1.12	27.13
RI 120	7.77	8.55	2.53	20.53
RI 240	10.52	13.28	3.38	30.44

Friedman Statistic 4.74  
Significance level 0.31  
Kendall coefficient 0.29

Distance per Response (cm.)  
Standard Deviations - Sessions 16 through 20

Schedule	Mean	St. Dev.	Minimum	Maximum
FI 15	44.57	44.38	8.27	102.66
RI 30	58.56	53.16	4.89	122.00
RI 60	66.69	53.37	14.66	116.86
RI 120	71.88	51.82	16.47	137.92
RI 240	75.63	61.99	8.48	153.03

Friedman Statistic 10.99  
Significance level 0.02  
Kendall coefficient 0.68

Speed per Response (cm./sec.)  
Standard Deviations - Sessions 16 through 20

Schedule	Mean	St. Dev.	Minimum	Maximum
FI 15	82.33	82.73	13.41	196.30
RI 30	86.46	78.35	20.52	197.00
RI 60	76.75	74.11	16.38	175.00
RI 120	93.12	95.16	21.97	230.00
RI 240	96.48	93.92	32.67	234.00

Friedman Statistic 3.04  
Significance level 0.54  
Kendall coefficient 0.19

**Table \* 13 Kendall Correlation Coefficients and signifiante levels of subjects 1 and 2 for sessions 16 thru 20 of p-manupliation (random interval schedules). The matrix values indicate that in the majority of instances the interresponse time (sec.), distance per response (cm.) and speed per response measures were not highly interrelated (achiving a signifiante levels greater than .05). However both subjects do show negative correlations which reach signifiante levels greater than .05.**

Table #13 - Kendall Correlation Coefficients

## P- Manipulation (Random Interval Schedules)

Subject #1 Measures		IRT Std. Dev.	Distance Mean	Distance Std. Dev.	Speed Mean	Speed Std. Dev.
IRT Mean	Tau p. value	1 0.007	-0.6 0.07	-0.32 0.22	1 *0.007	0.4 0.16
IRT Std. Dev			-0.6 0.07	-0.32 0.22	1 *0.007	0.4 0.16
Distance Mean				0.52 0.1	-0.6 0.07	-0.8 *0.02
Distance Std. Dev					-0.32 0.22	-0.73 *0.03
Speed Mean						0.4 0.16
Subject #2 Measures		IRT Std. Dev.	Distance Mean	Distance Std. Dev.	Speed Mean	Speed Std. Dev.
IRT Mean	Tau p. value	0.4 0.16	-0.6 0.07	0 0.5	0 0.5	0 0.5
IRT Std. Dev			-0.8 *0.025	-0.6 0.07	0.6 0.07	0.6 0.07
Distance Mean				0.4 0.16	-0.4 0.16	-0.4 0.16
Distance Std. Dev					-0.2 0.31	-0.2 0.31
Speed Mean						1 *0.007

**Table \* 14 Kendall Correlation Coefficients and signifiante levels of subjects 3 and 4 for sessions 16 thru 20 of p-manupliation (random interval schedules). The matrix values indicate that in the majority of instances the interresponse time (sec.), distance per response (cm.) and speed per response measures were not highly interrelated (achiving a signifiante levels greater than .05).**

**Table #14 - Kendall Correlation Coefficients**  
**P-Manupliation (Random Interval Schedules)**

**Subject #3**

Measures		IRT Std. Dev.	Distance Mean	Distance Std. Dev.	Speed Mean	Speed Std. Dev.
IRT Mean	Tau p. value	1 *0.007	0.6 0.07	0.6 0.07	0.4 0.16	0.2 0.31
IRT Std. Dev			0.6 0.07	0.6 0.07	0.4 0.16	0.2 0.312
Distance Mean				0.6 0.07	0.4 0.164	0.2 0.31
Distance Std. Dev					0.8 *0.02	0.6 0.07
Speed Mean						0.8 *0.02

**Subject #4**

Measures		IRT Std. Dev.	Distance Mean	Distance Std. Dev.	Speed Mean	Speed Std.
IRT Mean		0.52 0.1	0 0.5	0 0.5	0.4 0.16	0.4 0.16
IRT Std. Dev			0.1 0.4	0.1 0.4	-0.1 0.4	-0.1 0.4
Distance Mean				1 *0.007	0.2 0.312	0.2 0.312
Distance Std. Dev					0.2 0.31	0.2 0.31
Speed						1

**Table 15. The interresponse time central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the first 5 sessions of the t-manipulation. The left most column of figures represents values obtained for each subject when p -1.0 and t - 15 sec. (FI 15). Moving left to right the other columns are for p - 1.0 and t - 30 sec. (FI 30), .60 sec. (FI 60), 120 sec. (FI 120), and 240 sec. (FI 240) respectively.**

**Table #15**  
**Interresponse Times (sec.)**  
**Central Tendency and Variance Indicators**  
**Sessions 1 through 5**

<b>Fixed Interval Value (sec.)</b>	<b>FI 15</b>	<b>FI 30</b>	<b>FI 60</b>	<b>FI 120</b>	<b>FI 240</b>
<b>Subject #1</b>					
<b>Arithmetic Mean</b>	9.9	13.7	13.91	17.74	16.49
<b>Standard Deviation</b>	7.51	10.02	11.85	11.93	13.2
<b>Coefficient of Variation</b>	75.85	73.13	85.19	67.24	80.04
<b>Geometric Mean</b>	6.46	9.35	7.29	13.13	9.89
<b>Harmonic Mean</b>	4.21	6.37	3.81	9.71	5.93
<b>Subject #2</b>					
<b>Arithmetic Mean</b>	2.29	2.85	3.49	4.20	4.12
<b>Standard Deviation</b>	1.57	2.08	2.68	3.24	3.43
<b>Coefficient of Variation</b>	68.55	72.98	76.79	77.14	83.25
<b>Geometric Mean</b>	1.68	1.95	2.25	2.68	2.29
<b>Harmonic Mean</b>	1.22	1.33	1.44	1.70	1.27
<b>Subject #3</b>					
<b>Arithmetic Mean</b>	3.11	6.96	3.28	7.99	5.98
<b>Standard Deviation</b>	2.86	6.79	3.04	7.76	5.61
<b>Coefficient of Variation</b>	91.96	97.55	92.68	97.12	93.7
<b>Geometric Mean</b>	1.23	1.55	1.25	1.92	2.09
<b>Harmonic Mean</b>	0.48	0.34	0.47	0.46	0.72
<b>Subject #4</b>					
<b>Arithmetic Mean</b>	9.61	6.24	8.53	7.34	5.81
<b>Standard Deviation</b>	7.77	4.59	6.83	6.34	4.32
<b>Coefficient of Variation</b>	80.85	73.55	80.07	86.37	74.35
<b>Geometric Mean</b>	5.67	4.24	5.12	3.71	3.89
<b>Harmonic Mean</b>	3.34	2.87	3.07	1.87	2.60

**Table 16. The distance per response central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the first 5 sessions of the t-manipulation. The left most column of figures represents values obtained for each subject when p -1.0 and t - 15 sec. (FI 15). Moving left to right the other columns are for p - 1.0 and t - 30 sec. (FI 30), .60 sec. (FI 60), 120 sec. (FI 120), and 240 sec. (FI 240) respectively.**

**Table #16**  
**Distance per Response (cm.)**  
**Central Tendency and Variance Indicators**  
**Sessions 1 through 5**

<b>Fixed Interval Value (sec.)</b>	<b>FI 15</b>	<b>FI 30</b>	<b>FI 60</b>	<b>FI 120</b>	<b>FI 240</b>
<b>Subject #1</b>					
<b>Arithmetic Mean</b>	136.92	132.86	128.43	154.26	170.02
<b>Standard Deviation</b>	96.21	80.64	86.59	89.43	103.6
<b>Coefficient of Variation</b>	70.26	60.69	67.42	57.97	60.93
<b>Geometric Mean</b>	97.43	105.6	94.85	125.7	134.82
<b>Harmonic Mean</b>	69.32	83.92	70.04	102.42	106.9
<b>Subject #2</b>					
<b>Arithmetic Mean</b>	50.64	75.18	56	78.48	58.76
<b>Standard Deviation</b>	50.31	74.91	55.72	78.24	58.45
<b>Coefficient of Variation</b>	99.34	99.64	99.5	99.69	99.47
<b>Geometric Mean</b>	5.78	6.47	5.66	6.16	6.08
<b>Harmonic Mean</b>	0.65	0.55	0.57	0.48	0.62
<b>Subject #3</b>					
<b>Arithmetic Mean</b>	39.04	42.26	57.66	45.45	49.1
<b>Standard Deviation</b>	20.51	16.93	37.31	25.63	26.55
<b>Coefficient of Variation</b>	52.53	40.06	64.7	56.39	54.07
<b>Geometric Mean</b>	33.23	38.73	43.97	37.54	41.31
<b>Harmonic Mean</b>	28.27	35.48	33.52	31	34.75
<b>Subject #4</b>					
<b>Arithmetic Mean</b>	74.76	179.62	170.34	185.95	164.41
<b>Standard Deviation</b>	73.61	88.9	82.84	94.92	72.24
<b>Coefficient of Variation</b>	98.46	49.49	48.63	51.04	43.93
<b>Geometric Mean</b>	13.08	156.08	148.84	159.9	147.7
<b>Harmonic Mean</b>	2.28	135.62	130.05	137.49	132.68

**Table 17. The speed per response central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the first 5 sessions of the t-manipulation. The left most column of figures represents values obtained for each subject when p -1.0 and t - 15 sec. (FI 15). Moving left to right the other columns are for p - 1.0 and t - 30 sec. (FI 30), .60 sec. (FI 60), 120 sec. (FI 120), and 240 sec. (FI 240) respectively.**

**Table #17**  
**Speed per Response (cm. per sec.)**  
**Central Tendency and Variance Indicators**  
**Sessions 1 through 5**

<b>Fixed Interval Value (sec.)</b>	<b>FI 15</b>	<b>FI 30</b>	<b>FI 60</b>	<b>FI 120</b>	<b>FI 240</b>
<b>Subject #1</b>					
<b>Arithmetic Mean</b>	176.96	176.33	179.62	190.98	147.76
<b>Standard Deviation</b>	168	167.6	169.4	181.04	142.92
<b>Coefficient of Variation</b>	94.93	95.04	94.31	94.79	96.72
<b>Geometric Mean</b>	55.62	54.81	59.75	60.82	37.52
<b>Harmonic Mean</b>	17.48	17.03	19.87	19.36	9.52
<b>Subject #2</b>					
<b>Arithmetic Mean</b>	107.6	138.58	79.08	106	130.19
<b>Standard Deviation</b>	107.3	138.07	78.45	105.39	129.61
<b>Coefficient of Variation</b>	99.72	99.63	99.2	99.42	99.55
<b>Geometric Mean</b>	8.05	11.97	10.04	11.4	12.37
<b>Harmonic Mean</b>	3.46	1.03	1.27	1.22	1.15
<b>Subject #3</b>					
<b>Arithmetic Mean</b>	70.12	78.93	63.67	61.04	54.44
<b>Standard Deviation</b>	55.7	59.16	37.54	39.26	31.53
<b>Coefficient of Variation</b>	79.43	74.95	58.96	64.31	57.91
<b>Geometric Mean</b>	42.6	52.25	51.43	46.74	44.38
<b>Harmonic Mean</b>	25.87	34.58	41.54	35.78	36.17
<b>Subject #4</b>					
<b>Arithmetic Mean</b>	151.78	224.18	342.65	291.11	230.31
<b>Standard Deviation</b>	137.11	205.11	327	276	205
<b>Coefficient of Variation</b>	90.33	91.49	95.43	94.8	89.01
<b>Geometric Mean</b>	65.11	90.48	102.4	92.57	104.97
<b>Harmonic Mean</b>	27.92	36.51	30.6	29.43	47.84

**Table 18. The interresponse time central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the first 5 sessions of the p-manipulation. The left most column of figures represents values obtained for each subject when t - 15 sec. and p = 1.0 (FI 15). Moving left to right the other columns are for t - 15 sec. and p = .5 (RI 30), .25 (RI 60), .125 (RI 120), and .0625 (RI 240) respectively.**

Table # 18  
 Interresponse Time (sec.)  
 Central Tendency and Variance Indicators  
 Sessions 11 through 15

Random Interval Value (sec.)	FI 15	RI 30	RI 60	RI 120	RI 240
<b>Subject #1</b>					
Arithmetic Mean	1.79	6.48	8.73	12.27	6.08
Standard Deviation	1.72	6.19	8.19	11.21	5.46
Coefficient of Variation	96.08	95.52	93.81	91.36	89.8
Geometric Mean	0.53	1.94	3.03	5.01	2.69
Harmonic Mean	0.15	0.58	1.05	2.04	1.18
<b>Subject #2</b>					
Arithmetic Mean	12.35	18.94	21.66	45.43	30.52
Standard Deviation	10	15.32	17.93	40.19	25.46
Coefficient of Variation	80.97	80.88	82.77	88.46	83.42
Geometric Mean	7.25	11.15	12.16	21.19	16.84
Harmonic Mean	4.25	6.56	6.82	9.88	9.29
<b>Subject #3</b>					
Arithmetic Mean	2.59	5.2	8.16	3	5.36
Standard Deviation	2.45	4.97	7.81	2.75	5.17
Coefficient of Variation	94.59	95.57	95.71	91.66	96.45
Geometric Mean	0.84	1.54	2.38	1.22	1.43
Harmonic Mean	0.27	0.45	0.69	0.49	0.38
<b>Subject #4</b>					
Arithmetic Mean	26.86	8.24	7.04	6.29	6.69
Standard Deviation	23.94	5.82	4.6	3.96	3.84
Coefficient of Variation	89.12	70.63	65.34	62.95	57.39
Geometric Mean	12.2	5.84	5.34	4.89	5.48
Harmonic Mean	5.53	4.13	4.04	3.8	4.48

**Table 19. The distance per response central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the first 5 sessions of the p-manipulation. The left most column of figures represents values obtained for each subject when t - 15 sec. and p - 1.0 (FI 15). Moving left to right the other columns are for t - 15 sec. and p - .5 (RI 30), .25 (RI 60), .125 (RI 120), and .0625 (RI 240) respectively.**

Table #19

**Distance per Response (cm.)  
Central Tendency and Variance Indicators  
Sessions 11 through 15**

Interval Value (sec.)	FI 15	RI 30	RI 60	RI 120	RI 240
<b>Subject #1</b>					
Arithmetic Mean	10.90	11.16	25.46	35.39	25.16
Standard Deviation	10.42	10.60	23.25	29.35	22.73
Coefficient of Variation	95.59	94.98	91.31	82.93	90.34
Geometric Mean	3.22	3.52	10.39	19.79	10.79
Harmonic Mean	0.95	1.10	4.23	11.06	4.62
<b>Subject #2</b>					
Arithmetic Mean	126.84	122.33	149.22	142.67	132.63
Standard Deviation	69.08	74.16	79.98	83.66	63.76
Coefficient of Variation	54.46	60.62	53.59	58.63	48.07
Geometric Mean	106.38	97.3	125.98	115.57	116.30
Harmonic Mean	89.21	77.38	106.35	93.61	101.97
<b>Subject #3</b>					
Arithmetic Mean	41.56	89.53	124.88	57.65	90.88
Standard Deviation	38.38	83.31	121.75	49.64	87.78
Coefficient of Variation	92.34	93.05	97.49	86.1	96.58
Geometric Mean	15.95	32.95	27.82	29.32	23.56
Harmonic Mean	6.12	12.11	6.19	14.90	6.10
<b>Subject #4</b>					
Arithmetic Mean	173.22	166.68	176.04	171.91	169.51
Standard Deviation	66.41	61.46	63.6	57.77	64.1
Coefficient of Variation	38.33	36.87	36.12	33.6	37.81
Geometric Mean	159.99	154.94	164.15	161.92	156.93
Harmonic Mean	147.76	144.02	153.06	152.5	145.27

**Table 20. The speed per response central tendency and variance indicators, measured in seconds, for subjects 1, 2, 3, and 4 are shown here. Values reflect the the combined outcomes of the first 5 sessions of the p-manipulation. The left most column of figures represents values obtained for each subject when  $t = 15$  sec. and  $p = 1.0$  (FI 15). Moving left to right the other columns are for  $t = 15$  sec. and  $p = .5$  (RI 30),  $.25$  (RI 60),  $.125$  (RI 120), and  $.0625$  (RI 240) respectively.**

**Table #20**  
**Speed per response (cm. per sec.)**  
**Central Tendency and Variance Indicators**  
**Sessions 11 through 15**

Interval Value (sec.)	FI 15	RI 30	RI 60	RI 120	RI 240
<b>Subject #1</b>					
Arithmetic Mean	43.52	45.3	68.14	91.25	39.35
Standard Deviation	41.94	43.84	65.84	88.12	36.73
Coefficient of Variation	96.36	96.77	96.62	96.56	93.34
Geometric Mean	11.64	11.44	17.59	23.71	14.12
Harmonic Mean	3.11	2.88	4.54	6.16	5.06
<b>Subject #2</b>					
Arithmetic Mean	262.52	173.62	143.19	162.36	179.19
Standard Deviation	252.20	145.00	128.40	151.4	167.20
Coefficient of Variation	96.06	83.51	89.67	93.24	93.30
Geometric Mean	72.91	95.50	63.39	58.66	64.45
Harmonic Mean	20.24	52.52	28.06	21.19	23.18
<b>Subject #3</b>					
Arithmetic Mean	37.58	51.43	48.5	36.17	55.12
Standard Deviation	29.84	41.55	36.35	19.58	46.54
Coefficient of Variation	79.4	80.78	74.94	54.13	84.43
Geometric Mean	22.86	30.31	32.12	30.42	29.54
Harmonic Mean	13.9	17.86	21.26	25.57	15.83
<b>Subject #4</b>					
Arithmetic Mean	142.19	108.16	105.58	130.09	182.73
Standard Deviation	132.50	94.29	90.49	114.35	170.00
Coefficient of Variation	93.18	87.17	85.70	87.90	93.03
Geometric Mean	51.60	53.00	54.4	62.04	67.02
Harmonic Mean	18.72	25.96	28.02	29.58	24.58

Friedman analyses of variance were also applied to the summary statistics for the first five days of each condition (T-manipulation sessions 1 through 5, P-manipulation sessions 11 thru 15). The values of these points, along with the geometric and harmonic means are presented in tables 15 thru 20. For all measures, under both the fixed interval and random interval conditions, no significant trends across the interval continuum were noted.

## DISCUSSION

The data indicate that human subjects, exposed to periodic and aperiodic non-reciprocal contingencies, show increasing variability in a number of fundamental performance measures as the mean value of the interreinforcement interval is systematically increased by the parameters T (minimal programmed interstimulus interval) and P (probability of stimulus delivery given a response). As in the non-human literature, this relation is most apparent in the case of fixed interval contingencies and attenuated under random interval contingencies of comparable mean interstimulus interval. The results also indicate that variation in an operant class may be determined by the complex manner in which particular characteristics of the reinforcement schedule make contact with variations of the response not explicitly required by the reinforcement contingencies.

The range of individual differences observed among the subjects' interresponse time patterns is not uncommon. In this study two typical human performance patterns, commonly labeled "Adjusting, low-rate" and "Nonadjusting, high-rate" (Lowe, 1979; Weiner, 1983), have been observed. Adjusting rate patterns typically produce broad shifts in response rate as the programmed contingencies are changed. At times the rate shift is the product of intervals with single responses. Nonadjusting response pattern subjects produce high steady rates, often apparently insensitive to schedule type or value, suggesting little or no behavioral control by the differences among schedules. Yet frequently, as in this study, this performance produces maximal reinforcer outcome for the subject at all schedule values. These patterns, reflecting the phenomena of response rate insensitivity given

non-reciprocal interval contingencies, have been noted in non-human studies (Hanson et al., 1962 ; Mechner et al., 1963; Lowe and Harzem, 1977; Urbain, Poling, Milan, Thompson, 1978). Their common occurrence in most schedule studies, using human subjects, has led some (Harzem and Williams, 1983) to suggest the need for more specific accounts of the behavioral processes involved.

It has been argued, for example, that the uncontrolled variety of human subjects' behavioral histories may contribute to these observed differences in rate patterns (Weiner, 1981, 1982). Such approaches suggest that the wide range of response rate patterns between subjects is to be expected given the extent to which the programmed contingencies allow equivalent reinforcement of variants in subjects' response repertoires. Under such circumstances the production of a constant rate of responding, across the temporal and probability continua, could indicate that the experimenter's recording procedures may not include the aspects of responding necessary to detect changes in response dimensions that occur when schedules are changed.

All schedules of reinforcement differ in terms of the degree to which they permit variation in a repertoire to exist. Under contingency arrangements which specify little in terms of response properties a wide range of behavioral characteristics can and do make contact with the reinforcing event. Non-reciprocal contingency schedules (Allison, 1983), like those used in this experiment, simply set minimal limits on the instrumental performance necessary for reinforcer availability. Such contingencies can encourage the persistence of "history related" responding by providing reinforcers for constant response rates irrespective of

interreinforcement durations. It is known that persistence in a response measure dimension will be more likely when the contingencies provide comparable reinforcement for a wide variety of rates and patterns of responding (Weiner, 1983). Under such conditions "nonadjusting" patterns in central tendency, so often encountered in human schedule work, are not unexpected. As Nevin (1979) has indicated, with regard to magnitude and delay of reinforcement manipulations, response rate may not always be a sensitive index. Any number of the possible response dimension characteristics may and do come to have their probability of occurrence altered in a fashion indicating schedule control yet contributing to a uniform rate function. The data of this study demonstrate that apparent insensitivity to the programmed contingencies reflected in one measure, as in the case of interresponse times under random interval contingencies, can be the product of concurrent schedule controlled change in other response dimensions, such as distance traveled and velocity, which are "adventitiously" reinforced and conjointly determine rate of responding. Skinner's "superstitious" conditioning demonstrations have also made salient the actual power of the reinforcement process while reminding one of the difficulty associated with the measurement of behavior in the tradition of rate. An operant can and should be conceptualized as a changing topographical arrangement of the organism. Such a conceptualization redirects one's attention to the task of identifying categories of measurement which will be useful in the analysis of operations influencing the organisms' actions. Operant classes can be conceived as consisting of hierarchically arranged levels with "broader" molar measures occupying each higher level. For this author the natural press of events seems against simplicity with respect to issues of measurement.

Typically, past analyses of such arrangements have focused on a particular measure, leaving the relational aspects of behavioral measures implicit or unappreciated. Several authors (Shimp, 1982; Pear & Rector, 1979) have criticized these unidimensional analyses. They have argued that discrete responses like bar or key presses are not appropriate units of behavior. These discrete measures do not incorporate behavioral patterns occurring "between" responses under schedule control. Some have suggested the assessment of the probability of occurrence of a specific discrete response by means of response rate and the probability of the occurrence of the spatiotemporal patterns, in which the discrete response is embedded, by the proportion of time allocated to the pattern (Shimp, 1974; Pear, Rector, Legris, 1982). In fact many of these spatiotemporal variations are not adequately reflected in response rate or in time allocation measures when each is the sole measure. In this study the control of mean distance traveled and the covariation of variability in the other derivable measures under the random interval conditions exemplify this fact.

That several response characteristics can be developed and maintained simultaneously, both among and within individuals, by the same schedule of reinforcement is considered by some to be a useful but inadequately documented notion (Pear, 1985; Iversen, 1986). Throughout Schedules of Reinforcement, Ferster and Skinner (1957) displayed cumulative records which suggested a wide range of momentary response variants visible as local rate changes in response rates that were equivalent overall. In the instance of variable interval schedules, which "...almost invariably produced sustained and relatively constant over-all rates" (page 337), these authors noted several varieties of "common deviation" in local rate changes produced by the same

programmed contingencies that sustained the equivalent overall rate. In human studies of variable interval performance response rates have been reported to be high and constant despite different overall reinforcement rates, as in the instance of concurrent variable interval schedules, while the distributions of responses to some other schedules have varied with reinforcement rate and with changes in other schedule parameters (Bradshaw, Szabadi, Bevan, & Ruddle, 1979). Such findings suggest that schedule controlled changes within dimensions of the response, neglected in traditional measurement, may be occurring while overall response rates remain constant. In this study the significant covariation of the distance measures, under the random interval contingencies, and the variance of distance and speed with fixed interval value, despite uniform response rate, confirm this assumption. The reported covariation of several response measurements with schedule value and type indicates a need for more detailed examination of response properties if an adequate understanding of the extent and nature of schedule control is to be attained.

Shimoff et al. (1981) have argued that sensitivity to contingencies is best thought of as a property of a particular response dimension within a particular context and that it is misleading to suggest that an organism or behavior class, in all its variants, is or is not sensitive. The time (T) it takes for an organism to move itself and the distance (D) it travels, in its repetitive attempts to effect change in the environment, are fundamental determinants of rate of responding. From these two physical quantities, with the additional measurement of mass (M), the speed ( $DT^{-1}$ ), acceleration ( $DT^{-2}$ ), momentum ( $MDT^{-1}$ ), force ( $MDT^{-2}$ ), work ( $MD^2T^{-2}$ ), power ( $MD^2T^{-3}$ ) and other quantifiable aspects of a response can be determined in addition to frequency

(T-1).

Any of these measures noted above can be influenced by the reinforcement process by virtue of the experimenter's description of the experimental contingencies or adventitiously because they necessarily make contact, at some value or other, with the reinforcer that follows when the current experimental requirements for reinforcer delivery are met. Failure to note change in one response dimension, like mean interresponse time, does not deny other significant variation in other dimensions of the subject's behavior. Change may occur in any of the many interrelated physical dimensions which in combination may produce "uniform rate." The data of this study support this interpretation by the demonstration that apparent insensitivity to the programmed contingencies reflected in one measure, the case of interresponse times under random interval contingencies, can be the product of discernible change in several other response dimensions which are "adventitiously" supported by the schedule. The covariation of such measures allows, in a number of combinational ways, for the occurrence of invariant interresponse time distributions while allowing for contact with the contingencies of reinforcement by other measurable variants of responding which reflect orderly change in behavior. Together these functional relations constitute an accurate account of the manner in which schedules change behavior.

The results of this experiment do not refute the value of response rate as an index of performance control; however, they do imply that other measures and their higher order products may be of value, easily calculated and of some theoretical interest in an accounting of the subjects actions. The coefficient of variation, a measure of relative variation, is a case in point. In the present

work the mean and standard deviation of the subject's response or activity distributions are proportional to the interval to which the subjects were exposed. Such a relation indicates a constant coefficient of variation ( Gibbon, 1977 ) unlike Absolute or Poisson timing models which have been proposed by others (Kristofferson, 1974; Getty, 1975). For the range of values examined in this study both Absolute and Poisson timing models would predict decreases in the coefficient of variation as the interval value increases given predicted uniform absolute variance or nonproportional increments across the temporal values.

As outlined above, a broader analysis of response variation, inclusive of Skinner and Schoenfeld's basic arguments, suggests that when an organism behaves in a way that modifies its environment such acts are more likely to be repeated because the altered environment selectively favors these productive behavioral configurations. New behavioral structures emerge as modifications of the preexistent structure and reflect the acquisition of an equivalent or new function by that structure as in the shaping process. The manner in which this is reflected in data, suggestive of schedule control, does not require change in the behavioral index's central tendency measures. Change in variability in a fashion suggesting the expansion of a core distribution across the interval values would appear critical to the validity of this account. The reported overlap of the skewed interresponse time, distance and speed per response distributions across schedule values under the Fixed Interval condition, in this experiment, support and exemplify this process of expansion from a core distribution. The distance per response measures of the Random Interval condition also exemplify this process and further suggest that the effects of reinforcement scheduling procedures are such that

detailed changes in behavior may exist under schedule types and values thought to be insensitive to manipulation of reinforcement parameters (Schoenfeld & Cole, 1972) when schedule performance is indicated exclusively by mean interresponse time or its reciprocal response rate .

Behavioral change is the result of a shift among the many variables that are inherent to the organism's physical structure and the environment occupied by the organism. These variables may operate concurrently on a number of response properties to keep the response at an equilibrium frequency reflecting previous behavioral history and the particular context. However, as Weiner (1981) and Nevin (1979) have indicated, not all schedules are equal in terms of producing orderly and predictable performances. "Ordinary" schedules, those with which we are all so familiar and comfortable (non-reciprocal periodic and aperiodic) leave much in the determination of the particular behaviors that precede the delivery of reinforcers to adventitious relationships, to previous training, and to biological predisposition (Shimp, 1982).

In human schedule studies much of the variation observed in response rate pattern, both between and within studies of interval performance, has been attributed to the experimenter's instructions and subjects' concurrent verbal behavior as reflected in their post hoc accounts of contingencies. In one study (Lippman and Meyer, 1967), subjects were exposed to fixed interval schedules and one of three sets of instructions: Minimal- containing no information regarding the nature of schedules, Response-based - indicating that a number of responses were required and Temporally-based - indicating that an interval of time passage was necessary for point delivery. Temporally-based instructions produced adjusting, low-rate patterns. Response-based

instructions generated nonadjusting high rates. Minimal instructions produced an equivalent proportion of subjects engaging in one or the other of these alternative patterns. Following the experimental sessions, individuals who deviated from these instructions related outcomes were asked to describe the conditions they thought necessary for gaining points. Their responses suggested a self-produced verbal reformulation of the experimenter's instructions which could account for their discrepant patterns. The importance of self-produced instruction sets was further supported in a later study (Leander et al., 1968) in which only minimal experimenter instructions were used. Of the 80 subjects exposed to fixed interval contingencies 62 subjects reported temporally-based self-instructions out of which 57 produced low-rate patterns. The remaining subjects reported response-based self-instructions and produced high-rate patterns. Wearden and Shimp (1985), in an investigation of temporal patterning and sensitivity to selective reinforcement of terminal interresponse times, reported approximately equal numbers of adapting and nonadapting subjects. They observed that "accurate adaptation" of the temporal patterning of behavior, as reflected by percentage increase in target class interresponse times to the schedule contingency, tended to be accompanied by accurate post session verbal accounts of the contingency. Inaccurate verbal descriptions of the contingencies accompanied several types of maladaptive temporal patterning. Pre-session shaping and explicit response spacing instructions appeared to have little or no impact on overall response pattern outcome. Shimoff, Catania and Matthews (1981) have argued that such insensitivity is in fact a defining property of instructional control and that low rate performances, produced by non-minimal instruction sets, will also show insensitivity to contingency

changes, as have instructed performances characterized by high steady response rates.

In this study the subject's verbal formulation of the schedule task was also correlated with response rate pattern. A minimal instructional set was used providing no cues regarding the temporal or response probability contingencies. As in the studies cited above, minimal cues produced an equivalent proportion of both the adjusting and nonadjusting rate patterns. In post experiment interviews subjects 1 and 2, who produced the adjusting rate functions for the fixed interval schedules, indicated that during the course of the experiment they came to believe point delivery was in part temporally based. Each reported attempting some form of covert verbal activity or visual imagery to estimate the passage of time. Those subjects who produced high steady rates, subjects 3 and 4, reported specific motor patterns which they believed to be instrumental in point acquisition and made no attempt to engage in time estimation strategies. All indicated that point delivery became erratic with the institution of random interval contingencies and each reported resorting to idiosyncratic motor strategies. These observations indicate that unless the contingencies establish specific topographic repertoires, contact with the current differential contingencies of reinforcement may not be sufficient to produce "adaptive or significant" change in a desired behavioral index.

Other theories regarding population structures (Wright, 1968), unlike those of Schoenfeld or Skinner, suggest a shifting balance theory of population structures and class differentiation in which the class is not viewed as a homogeneous entity (i.e., a response) but rather a multidimensional mosaic of local topographic populations differentiated from

one another by stochastic environmental and biological contingencies. By extension, the "response class" may be visualized as being distributed among different locations on a contingency/behavior dimensions contour in its most elementary form reflecting the dimensions of distance and duration. Such a contour might consist of a large number of adaptive peaks (surface maxima) or valleys (surface minima) interrelated by surface gradations. Each selective peak (qualifying response configuration) represents a temporarily stable set of coadaptive properties that function synergistically to produce various behavioral traits that are the object of "reinforcement". The extent to which one observes uniformity in these structures will be dependent upon the extent to which the experimenter defined contingencies demand uniformity in order for the organism and its behavior to exist. The wide range of correlations among the measures recorded in this study are suggestive of this process. Both within and across subjects, as well as schedule types and values, unique response dimension combinations produced the maximal number of reinforcers per unit time in each case. In this light it is misleading to define "schedule control" by a change in response rate alone in that it converts response selection and variation from a large class of causal factors that can be discovered only empirically to a class defined by a singular measure in a multileveled, dynamic process. The reduction of significant correlations under random interval contingencies may be viewed as adaptation to contingencies which call for and allow a broader range of response dimension interrelations if maximal earnings (i.e. reinforcers) per unit time are to be maintained. In contrast to the fixed interval schedules, where the fixed or regular pattern of stimulus delivery establishes a correlation between behaviors and reinforcement, no single feature of the subject's behavior is

likely to acquire discriminative properties under the random arrangement of reinforcement (Ferster and Skinner, 1957). However, this need not be construed as ineffective reinforcement if accompanied by the detailed analysis of behavior already mentioned.

In science one measures. Knowing what, where and how to measure may not be obvious. Somewhat simplistic attempts have been made to relate a behavioral effect to changing environmental parameters with the working assumption that there is or may be a single best measure with which to work. It is unlikely that there will ever be any one best and all-purpose measure that reflects behavioral complexity accurately; different measures will be suited to different purposes and their functional significance may emerge from the combinational properties of lower or same order measures. Without the evaluation of combinational properties incomplete description will occur, with greater prospect of improper interpretation, whenever the specified class is composed of two or more dimensions. Each may have its own source of influence that can mask control due to the contrasting effect on the collateral response being measured (Johnston and Pennypacker, 1980).

Behaviors which are similar topographically may not belong to the same operant class and members of the response class can consist of behaviors differing from each other quite radically. Observation indicates that the class members may and do differ from one organism to the next and from one occasion to another in the same organism. Despite consistency in experimenter-defined contingencies, only a fragment of the organisms' actions are preselected for the procurement of a reinforcer, and it is only the functional similarity of consequence which has been critical to their inclusion in an operant class. An oft-used classroom example of an operant

response which leads to a measurable environmental event, the opening of a door, may in fact consist of knocking, calling out, turning a handle and pushing, inserting and turning a key, etc. The fact that varying topographies are bundled into a functional class as a result of their common consequence may prompt one to reconsider the criteria by which one defines an operant (Lotka, 1956; Glenn, 1985) and the nature of reinforcement.

One last-related issue should be broached. In this study the data show that for each subject, change does occur in the slopes and absolute values of the response measure functions across sessions. Behavioral stability across sessions has been a neglected area of operant research. McDowell and Sulzen (1981) have reported the need for an average of 28 sessions, in some cases as many as 40, on the same interval ramp schedules before the overall rate measures in human subjects appeared stable. The nature of these findings, in conjunction with similar findings noted for ratio type schedules using nonhuman subjects (Sidley & Schoenfeld, 1964; Korber et al, 1981), suggests the use of caution in the interpretation of results based on data collected from subjects exposed to contingencies whose presentation are sequentially ordered across sessions. Although other session order effects could have come to influence the nature of results observed in this study, the data suggest that subjects responded in a differential fashion both within and across schedule types even when the covariation of the dependent measures produced a uniform rate of responding across the interval continuum.

Future efforts might be directed to the determination of the functional relations describing the covariation of the elements that are parameters of the rate equation (time, distance, and speed) as they are systematically controlled. How those functions are influenced by greater specificity in

scheduled contingencies will need to be addressed. Consideration of their utility in providing a calculated estimate of the energy expended by the organisms' acts would establish a common metric between other related biological/ social research efforts (i.e., optimal foraging theory or labor supply theory) and "reinforcement process" theories. One would hope that consideration of such idemnotic measures , with their broadened applicability to the phenomena of nature, would soon emerge within psychology and the experimental analysis of behavior.

## Summary and Conclusions

1. The results of this parametric study indicate that a number of measurements of response dimensions covary with the manipulation of interreinforcer interval and probability of reinforcer, given a response, even when the customary index (mean response rate) does not.

2. As discussed in the preceding section, the effect of reinforcement is such that its production of adventitious influence on circumstantial properties of the subject's action allows for the covariation of these dimensions to account for apparent instances of insensitivity of the rate index. Uniformity in measures of central tendency across a dimension, as reported in many human operant investigations, may simply reflect the stabilizing impact of reinforcement on the manner in which the subjects behavior effectively satisfy the experimental contingency for production of maximal reinforcer frequency. In turn, the systematic change in variance and other measures reflect the actual manner in which different loci in a set of interdependent descriptive continua are concurrently influenced to produce the outcome indicated in the experimenter's rate index.

3. Response acquisition and differentiation are in part determined by the factors which occasion the maintenance of variant members in a population of responses, as well as the absolute changes in the numbers and diversity of the response population over time. The differentiation process is defined by the manner in which the basic experimental contingencies are refined to

make contact with the reinforcer which in turn influences the differential survival of class members.

4. This document has reviewed and demonstrated instances in which the selection of a metric dimension has not proven to be effectively sensitive to the programmed contingencies. Also noted are instances in which selection of a sensitive sub-index was obtained and others in which a measure was effective in some but not all subjects leading to difficulty in the interpretation of results. In this study the demonstration of the concurrent adventitious control which reinforcement exerts over numerous response subclasses or dimensions demonstrates the need for experimenters to reformulate and refine their basic experimental contingencies to include specification of these parameters if they wish to insure greater control over the naturally occurring response dependencies which develop as part of the reinforcement process.

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