

AN INVESTIGATION OF THE RELATIONSHIP
BETWEEN RATE OF RESPONDING DURING
ACQUISITION AND RESISTANCE TO
EXPERIMENTAL EXTINCTION.

by

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ABSTRACT

The aim of the present series of experiments was to show that a direct relationship exists between two measures of response strength - rate of responding and resistance to extinction.

Experiments I and II used a different subjects design, with three pigeons, one at each level of the independent variable. The results of experiment I (fixed interval schedules) and experiment II (variable interval schedules) were similar - no systematic relationship between the two variables under observation was found.

Experiments III and IV controlled individual differences by using multiple schedules of reinforcement. The results of experiment III, where three pigeons were exposed to the same MULT FI schedule yielded a direct function between the two measures of response strength. Experiment IV used a MULT CONJ FI-FR(DRL-DRH) schedule with three pigeons exposed to both levels of the independent variable, so that control could be exercised simultaneously over both number of reinforcements and "time-in-schedule". The trend of the data obtained was in the same direction as that found in experiment III.

It was thus concluded, with individual differences controlled for, that rate of responding and resistance to extinction were directly related, and hence adequately mirror response strength.

SUMMARY

Chapter 1. Introduction.

After a brief introduction to the basic operant conditioning paradigm, the concept of response strength is discussed. Skinner's (1938) early conceptualization of response strength consisted of two parts; (i) the "reflex reserve", a sort of hypothetical store of potential responses and (ii) the "extinction ratio", the ratio of reinforced to unreinforced responses in any schedule of intermittent reinforcement. Skinner believed that rate of responding was proportional to the existing reserve and that resistance to extinction (the number of responses emitted when reinforcement is withdrawn) was related to the extinction ratio.

Recent theorists, such as Herrnstein (1970) and Schoenfeld (1968), believe that there is no need to introduce a hypothetical concept of response strength. Rather the strength of a response can be equated with the measures used to gauge it.

Discussion then turns to the various measures of response strength, and specifically to a description of the two fundamental measures in the operant paradigm - rate of responding and resistance to extinction.

It is then argued that predictions based on Skinner's (1938) account of response strength would indicate that rate of responding and resistance to extinction are directly related. Further, on the basis of Herrnstein's and Schoenfeld's ideas of response strength, it is contended that the two measures would have to be directly related or two conclusions would follow: (a) that either of the two measures do not adequately reflect response strength or (b) that response strength is something more than the measures used to gauge it, as Nevin (1974) and Kling (1971) argue.

Experiments which, either directly or indirectly, studied the relationship between rate of responding and resistance to extinction are then reviewed. Wilson's (1954) data showed no such relationship, whereas data gathered from studies by Boren (1961), Hearst (1961) and Terrace (1968) tended to show that rate of responding and resistance to extinction were well related.

In line with the views of Herrnstein and Schoenfeld - that response strength is nothing more than the measures used to gauge it, the present series of experiments attempts to show, under varying degrees of experimental control, that rate of responding and resistance to extinction, the fundamental measures of response strength, are directly related.

Chapter 2. General Method.

This chapter begins with a discussion of the design

of operant experiments. Special attention is paid to justifying the use, by operant researchers, of small numbers of experimental subjects.

Discussion of the design of this series of experiments centres around a description of the relevant confounding variables which are known to differentially affect resistance to extinction.

This chapter also provides details of those aspects of; the subjects, the apparatus and the procedures used to establish the operant response, which remained unchanged during each of the four experiments.

Chapter 3.

Experiment I - An investigation of the relationship between rate of responding and resistance to extinction utilizing a different subjects design and Fixed Interval Schedules of Reinforcement.

The study by Wilson (1954) is reviewed with special emphasis on his finding that rate of responding and resistance to extinction were not related in any systematic way. Following on from this, sections describing the design, the subjects, the apparatus and the procedure used in the experiment are presented.

The results indicated that individual differences overwhelmed the effect of the rate of responding on resistance to extinction to such an extent that no direct relationship was apparent. In the discussion it is noted that, apart from individual differences, the idiosyncratic characteristics of the fixed interval schedule, could have contributed to the result obtained.

Experiment II - An investigation of the relationship between rate of responding and resistance to extinction utilizing a different subjects design and Variable Interval Schedules of Reinforcement.

The problem of the relationship between probability of reinforcement and time since reinforcement with fixed interval schedules is discussed. The use of variable interval schedules is then proposed, especially the type developed by Fleshler and Hoffman (1962) to eliminate the problem of sequential dependency in VI schedules, mentioned by Anger (1956).

Sections describing the design of the experiment, the subjects, the apparatus and the procedure are presented.

The results show a poor relationship between rate of responding and resistance to extinction, and individual differences are proposed as a possible explanation for this.

Experiment III - An investigation of the relationship between rate of responding and resistance to extinction utilizing a single subjects design and Multiple Schedules of Reinforcement.

The multiple schedule as a way of controlling individual differences in the operant paradigm is introduced. Various studies are reviewed which show the superiority of results gained from single subjects designs over those gained from different subjects designs.

Following on from this, sections describing the design of the experiment; the subjects, the apparatus and the procedure are presented.

The results indicated that a direct function between rate of responding and resistance to extinction exists when individual differences are controlled for. It is noted in the discussion that one possible confounding variable still remains uncontrolled - "time-in-schedule".

Experiment IV - An investigation of the relationship between rate of responding and resistance to extinction utilizing a single subjects design and multiple conjunctive fixed interval - fixed ratio (Differential reinforcement of low rate - differential reinforcement of high rate) reinforcement schedules.

In the introduction, large differences in "time-in-schedule" for each of the schedule lengths (FI 40, FI 60, FI 80) are noted. A multiple conjunctive FI-FR (DRL-DRH) schedule; a modification of a schedule used by Fantino (1968) is proposed. In this way both "time-in-schedule" and number of reinforcements can be controlled simultaneously.

Sections describing the design, the subjects, the apparatus and the training procedures used in the experiment are then presented.

The results indicated a trend which was essentially in agreement with the results of experiment III. It is noted in the discussion that "time-in-schedule" could not have played more than a minor confounding role.

Chapter 4. Discussion.

It is noted in the discussion that the results of experiments III and IV, both realize the predictions of Skinner's early hypothesis, and support the contentions of those theorists who believe that response strength is nothing more than the measures used to gauge it.

The present study is then evaluated under two headings - contributions and criticisms. The next section deals with two other measures of response strength which do not rely upon the relationship between rate of responding and resistance to extinction - relative resistance to change and the Matching Law.

Lastly, various suggestions for future research are noted, both along the lines of the present study and in other areas. In conclusion it is suggested; that, as a result of the relationship between the two measures of response strength found in the present series of experiments, it would not be parsimonious to develop further measures of response strength.

CHAPTER IINTRODUCTION(i) Introduction to Operant Conditioning.

Operant conditioning was originally thought of as both an approach to the study of behaviour and a method by which behaviour could be acquired. As an approach it can be characterized by rigid acceptance of the basic methods and assumptions of natural science - those of determinism, objectivism, operationism, experimentation, observation and measurement. More recently this approach to the study of behaviour has come to be termed 'behaviourism'. Skinner (1974) summarizes the position as "Behaviourism is not the science of human behaviour - it is the philosophy of that science" p.3.

As a method by which behaviour can be acquired "operant conditioning refers to a process in which the frequency of occurrence of a bit of behaviour is modified by the consequences of the behaviour" Reynolds (1968) p.1.

This series of experiments to be reported below attempts to investigate certain aspects of how behaviour can be acquired or modified as a result of its consequences (operant conditioning), utilizing a behaviourist framework.

Descartes (1596-1650) essentially laid the foundation of operant conditioning, by dichotomizing behaviour into two classes - voluntary and involuntary. Involuntary behaviour soon came to be known as reflex behaviour, and was clearly illustrated by the way certain aspects of the physical environment (stimuli) automatically and reliably elicited movements (responses) from an organism, i.e., the withdrawal of the hand from a hot surface is the response by the organism to physical stimulation from the heat source. This involuntary aspect of behaviour was further studied by a series of eminent physiologists including Whytt (1714-1766), Bell (1774-1842),

Magendie (1783-1855) and Sherrington (1857-1952), and culminated in the extensive and systematic study of reflex behaviour by Pavlov (1849-1936) and Sechenov (1829-1905).

Voluntary behaviour, on the other hand, was attributed by Descartes to the mind and was the exclusive property of human beings. Man was thus able to influence his own behaviour. For over one hundred years this dualistic philosophy hindered the development of a scientific study of voluntary behaviour.

In 1859 Darwin published "The Origin of Species" in which human beings were ordered on the same continuum of mental development as animals. Important for the objective study of behaviour was not so much man's position in Darwin's system, but rather the elevation in the status of animals to that of possessing a certain quantity of mental life, albeit less than that of a human being. This led to the beginning of research into mental processes or voluntary behaviour in animals and to the work of E. L. Thorndike (1874-1949).

Thorndike (1898) studied the way in which a cat escaped from a box by operating a latch (reported in 1913). When first put into the box the cat scrambled about until it accidentally touched the latch and was released from the box. In the ensuing trials the time taken before the latch was operated by the cat was gradually reduced, until the cat operated it almost the instant it was put in the box. Thus the consequences of the cat's action - freedom and possibly food, served to form a connection between the stimuli of the box and the particular response, which in the past, had been successful in operating the latch. "Thus, the emphasis was shifted from the purpose of the cat's action to the past consequences of similar actions" Nevin (1973) p.9.

This last statement is particularly important for it serves as the point of departure between the study of voluntary (operant) behaviour and the study of involuntary (classically

conditioned) behaviour. Thorndike disagreed with the principle stated by Watson (1919) that all behaviour could be accounted for in terms of unconditioned or innate, and Pavlovian conditioned reflexes. Instead he realized that one of the most interesting and more frequently appearing characteristics of behaviour was its apparent orientation towards the future, rather than its dependence on some prior eliciting stimulus. Thus only a small fraction of behaviour was believed to be passively awaiting elicitation by environmental stimuli. Rather, behaviour was seen as active and goal directed, it being moulded and shaped by the consequences it has on the environment.

At this time Skinner (1904 -) made clear the operational difference between classical and, the now formally termed, operant conditioning. He devised a more systematic technology (the Skinner box and related equipment) and added his own more rigorous terminology, such as discriminative stimulus and reinforcement, to the study of voluntary behaviour.

The Basic Operant Conditioning Paradigm.

The main features of the basic operant conditioning paradigm can best be illustrated with a simple example, very similar to the original experiment carried out by Skinner in 1938.

The subject, a hungry rat, is placed in the experimental chamber. This chamber is a square box, three walls of which are bare. The fourth wall has a small light on it, below which a small lever protrudes. Beneath this lever there is an opening through which pellets of food can be delivered to the chamber. When the lever is depressed with a certain force an electronic circuit operates to present a food pellet.

When the animal is introduced into this chamber many and varied behaviours occur. The rat noses into the corners, looks at the food tray, scratches itself and

occasionally grooms itself. Quite by accident the animal depresses the lever and a pellet of food is presented. The animal continues its other activities, but not for long, for as soon as it depresses the lever again, food is presented. As a result of this new contingency of food-for-lever-pressing, this response gains special prominence in the animal's repertoire of responses. Soon the frequency of lever pressing increases to such an extent that the other behaviours previously engaged in are rarely produced. In this way the behaviour of the rat has been modified by certain environmental consequences. These consequences in this experiment served to increase the frequency of the class of responses that produced them (lever pressing) and were thus called by Skinner reinforcing stimuli - reinforcing, because they seemed to strengthen the behaviour which follows, and stimuli, because they are part of the environment.

The responses which have reinforcing consequences do not necessarily have to be identical, as long as they are defined as those that produce reinforcement. Therefore, it is more correct to talk of operants as classes of responses, of which each response has the capability of producing a reinforcing consequence.

With the development of the cumulative recorder the direct observation of these changes in the animal's behaviour as a result of their reinforcing consequences could be measured, particularly with regard to the rate at which responses were emitted.

If the light above the lever was turned on every time the rat pressed the lever and was reinforced, and was turned off when the reinforcement circuit was disconnected, the rat would soon learn to respond only when the light was on. Thus the animal learnt to discriminate between a contingency which presented it with reinforcement and a contingency which did not. This light was called by Skinner the discriminative stimulus (S^D), and its function was to set the occasion for

reinforcement to occur.

Just as the presentation of a reinforcement increased the frequency of responding, so its non-presentation decreased the frequency of responding. This reduction in the probability of responding as a result of the withdrawal of reinforcement was termed by Skinner extinction.

To illustrate the effect reinforcement has on the modification of behaviour, Skinner introduced a situation in which reinforcement occurred after a certain period of time irrespective of what the animal was doing at the time of presentation. It was soon apparent that whatever behaviour the animal was engaged in just prior to the presentation of reinforcement its frequency was increased, so that there was a higher probability that this particular response would occur again in the future.

As the system stands only responses in the animal's repertoire can be reinforced and hence modified. However, Skinner devised a technique called shaping, whereby successive approximations to a desired response (which the experimenter determines) were reinforced, gradually bringing the animal to emit the required response.

This then is the basic operant system outlined by Skinner in "The Behaviour of Organisms" (1938). However, most of what has been described above (except for the technical innovations) is nothing more than a rigorous version of what was contained in Thorndike's (1913) "Law of Effect". But Skinner's system did not end here, for his ability to innovate led to, possibly, his most important contribution to the field of operant conditioning - that of schedules of reinforcement.

Every response does not have to be followed by the presentation of a reinforcing stimulus for the frequency of responding to show an increase. Skinner (1938) found this

powerful effect which he termed intermittent reinforcement quite by accident, when his supply of food pellets ran low one weekend. Systematic extensions of this research led Skinner to believe that the way in which intermittent reinforcement was presented, the schedule of reinforcement, was perhaps the most powerful single influence on operant behaviour. He then went on to devise the now well known four basic schedules :

- Fixed ratio (FR) - reinforcement presented after a fixed number of non-reinforced responses.
- Fixed interval (FI) - reinforcement presented for the first response after a fixed period of time during which no responses are reinforced.
- Variable ratio (VR) - reinforcement presented after a varying number of unreinforced responses.
- Variable interval (VI) - reinforcement presented for the first response after a varying period of time during which no responses are reinforced.

Skinner (1938; p.134) found that resistance to extinction (the number of responses emitted when reinforcement was no longer forthcoming), was greater after intermittent reinforcement than after continuous reinforcement. This result, now termed the Partial Reinforcement Extinction Effect (P.R.E.), was attributed by Skinner to what he called the "reflex reserve" (1938; p.84) - a pool of potential responses which could be produced when reinforcement was no longer available. This reflex reserve was then a crude account of what is essentially the "strength" of a conditioned operant, and was, to a large extent, dependent on the "extinction ratio" - the ratio of reinforced to non-reinforced responses. This extinction ratio in turn provided "a relatively precise measure of the effect of reinforcement. By varying the kind or condition of reinforcement we should be able to obtain a direct measure of the result (of reinforcement) in terms of the rate of responding, provided the frequency of reinforcement is held constant" (p.138-9).

With ratio schedules it is impossible to control the rate of reinforcement, for the animal controls this by its rate of responding. With interval schedules, however, the rate of reinforcement can be controlled within limits, and the ratio of reinforced to non-reinforced responses easily measured. It was evident that different rates of reinforcement (i.e. different interval lengths) produced characteristic extinction ratios (or rate of responding if divided by the interval length), Skinner (1938) p.128. The general shape of the function produced was downward sloping, indicating that the greater the interval length, the lower the rate of responding.

There are thus two measures of the effect of reinforcement on behaviour - (i) the extinction ratio, the ratio of reinforced to non-reinforced responses or the rate of responding, if divided by time and (ii) resistance to extinction, measured by the number of responses produced after reinforcement is withdrawn. Both of these techniques reliably assess the effect of reinforcement on operant strength.

These two measures are the fundamental dependent variables used to gauge the effects of a wide variety of independent variables used in operant research, such as schedules of reinforcement, the introduction of drug programs, the effects of punishment, the effects of "time-out" schedules etc. And yet, recently it has been found that these two measures, purportedly measuring the same thing, themselves form a poor relationship. (Nevin, 1974 and Kling, 1971).

" the only persuasive argument for any measure of response strength is to show orderly relations between the parameters of reinforcement - its frequency, quantity, quality and so on - and the designated parameters of behaviour. The traditional measures of response - probability, rate, amplitude (i.e. work or effort), latency, resistance to extinction - have all failed to gain unequivocal support simply because orderly data with quantitative and general significance have not been

forthcoming" Herrnstein (1970) p.246. (underlinings mine).

(ii) Measures of Response Strength.

Before describing in detail the two measures of response strength mentioned in the previous section, some discussion of what is actually meant by 'response strength' is required.

Much of the discussion is centered around the concept "reflex strength" as it is used in the classical conditioning paradigm. It is important that it is described here for the "reflex reserve", which is an essential part of Skinner's analysis of operant behaviour, depends upon this reflex strength.

Skinner believes the concept of reflex strength in its structural or static form can be described by a set of laws. Reflex strength does change, however, as increments are added to it from either the number of CS-UCS pairings in classical conditioning, or the number of presentations of the reinforcing stimulus in operant conditioning. (Note: Skinner (1938) uses the term "reflex strength" for both classical and operant conditioning paradigms).

" it is convenient to have a single term to describe the state of the reflex with respect to all its static properties at once" Skinner (1938) p.15. The term Skinner proposed was "strength" and he went on to state, "The value of the strength of a reflex is arbitrarily assigned to it from the values of the static properties and is never measured directly" p.15. An important point here is that it has to be inferred from the static properties, although its presence can be determined by the known measures of response strength. "The strength of a reflex is not to be confused with the magnitude of the response" p.15.

These static properties which determine the nature

of reflex strength are, according to Skinner, the following laws :

- 1) "The Law of Threshold - The intensity of the stimulus must reach or exceed a certain critical value (called the threshold) in order to elicit a response.
- 2) The Law of Latency - An interval of time (called the latency) elapses between the beginning of the stimulus and the beginning of the response.
- 3) The Law of the Magnitude of the Response - The magnitude of the response is a function of the intensity of the stimulus - the R/S ratio.
- 4) The Law of After-Discharge - The response may persist for some time after the cessation of the stimulus" p.12-13.

These four laws (above) cover the effect of the intensity of the stimulus on the composition of reflex strength.

- 5) "The Law of Temporal Summation - Prolongation of a stimulus or repetitive presentation within certain limiting rates has the same effect as increasing the intensity" p.13.

This law covers the effect of the duration of the stimulus on the makeup of reflex strength. Further influences on the composition of reflex strength come from changes in the state of the static properties.

- 6) "The Law of the Refractory Phase - Immediately after elicitation the strength of some reflexes exists at a low, perhaps zero, value. It returns to its former state during subsequent inactivity" p.15.
- 7) "The Law of Facilitation - The strength of a reflex may be increased through presentation of a second stimulus which does not itself elicit the response" p.16.

This second stimulus has no control over the actual response, but it affects the strength of the reflex of which the response forms a part.

The usefulness of these laws in analyzing reflex strength becomes apparent when some quantitative control is exercised over the stimulus, and some measure of the magnitude of the response is available in a classical conditioning procedure.

Of course what is missing from a complete description of conditioning are the laws concerning the increase and decrease in reflex strength - the Law of Conditioning of Type S and the Law of Extinction of Type S. However, these laws only state how the strength is increased or decreased, and nothing of the nature of the strength itself.

The above, then, is Skinner's attempt to quantify the composition of reflex strength in its structural or static form. Reflex strength at any one time has a further component - the "reflex reserve". "... the strength of a reflex is proportional to its reserve" p.27. This reserve becomes especially important when the operations of elicitation of the CS either increase reflex strength, when paired with a UCS during conditioning; or decrease reflex strength during extinction when the eliciting stimulus is not followed by the UCS. "... this relation between strength and previous elicitation is such that we may speak of a certain amount of available activity, which is exhausted during the process of repeated elicitation and of which the strength of the reflex is at any moment a function" Skinner (1938) p.26.

This reflex reserve is basically a hypothetical entity in Skinner's system, and can be conceptualized as a way of 'storing' reflex strength or potential to respond.

Under operant procedures the reflex reserve is built up as a result of reinforcement. "At any point the rate of

responding may be assumed to be roughly proportional to the existing reserve" Skinner (1938) pps.83-84. Skinner goes further when discussing the reflex reserve as it applies to operant behaviour by introducing the concept of "immediate reserve" (p.85) which is distinct from the total reserve. Rate of responding is then proportional to the immediate reserve, which in turn draws its strength from the total reserve.

Skinner notes that this reserve has an upper limit, and reinforcements become less and less effective in increasing the reserve as a result of the more reinforcements presented. Thus a large increase in the reserve is postulated by Skinner to occur after only one reinforcement, but the reserve certainly does not double as a result of a second reinforcement.

Under behaviour which is intermittently reinforced a further concept has to be included in the analysis of reflex strength - the extinction ratio. This is the ratio of unreinforced to reinforced responses in any schedule of intermittent reinforcement. This ratio assumes special importance in periodic (or interval) schedules, where the presentation of a reinforcement is not directly dependent on the extinction ratio as it is with response based (ratio) schedules.

The fact that behaviour maintained by periodic schedules is more resistant to extinction than that maintained by continuous reinforcement schedules is due to the extinction ratio. Further, Skinner has found that the extinction ratio remained constant for different rates of reinforcement, thereby making it independent of the effects of reinforcement. (p.138).

Skinner also found that the rate of responding and the extinction ratio remained markedly constant from interval to interval, providing the length of the interval (rate of reinforcement) remained constant (p.131). If this rate of

reinforcement remains constant, then the rate of responding and the extinction ratio will be closely related. Thus, if the rate of responding is proportional to the existing reserve (pps.83-84), and if the extinction ratio is related to resistance to extinction (p.138), then the production of a higher rate of responding will result in a higher extinction ratio, and hence a greater resistance to extinction, providing the interval length remains constant.

From this it can be seen that reflex strength, according to Skinner can be measured by either rate of responding (or the extinction ratio) or resistance to extinction. Discussion of the effects on the system of varying the rate of reinforcement will be presented below.

In 1940 Skinner revised his ideas as to the constancy of the extinction ratio, but added that this change would affect only slightly the nature of the reflex reserve (p.423).

At this point it becomes necessary to turn to a discussion of the measures of response strength. This is because Skinner (1953, p.65; 1969, p.91), and some other recent operant researchers such as Herrnstein (1970), Catania and Reynolds (1968) and Nevin (1974) have taken the nature and the measure of response strength to be the same thing. In other words, the rate of responding at a particular time, for example, becomes the strength of the operant at that time. Herrnstein (1970) summarizes this view "To say that behaviour is strengthened is to imply some dimension of behaviour along which it changes when its strength changes" (p.246).

The measurement of behaviour strength was simple enough in Type S conditioning. This was because the strength of the behaviour resulting from the number of CS-UCS pairings could be gauged by withdrawing the UCS, and counting the number of CR's elicited by the CS alone. Rate of responding thus had little place in this system because the rate of production of the CR was completely controlled by the rate of

presentation of the CS-UCS pairs. In the operant situation, on the other hand, the subject was left alone with no intervention on the part of the experimenter. How then could behaviour strength be measured when no control, such as exclusive trials, was exercised? This called for a different measure of the strength of behaviour.

Thus when conditioning of type R (operant) was first proposed as an alternative to conditioning of Type S (Pavlovian) by Skinner in 1938 (pps.19-21), rate of responding was the obvious measure of the effect of reinforcement on behaviour. With the development of the kymograph (now the cumulative recorder) and the introduction of intermittent reinforcement, the rate of responding became an even more important measure of behaviour strength.

Due to the functional nature of the analysis of operant behaviour emphasized by Skinner, topographic or structural changes in behaviour as measures of the effectiveness of reinforcement were not sufficient. Skinner (1969, p.88). More important was a measure which would relate functionally, the effect of the presentation of a reinforcing stimulus and changes in behaviour. The rate of responding served this purpose adequately as it was extremely sensitive to changes in the independent variable (reinforcement schedule), easily observable via the cumulative record, and, above all, easily quantifiable.

Skinner (1953) lists some of the advantages of using rate of responding as the dependent variable in operant research. In summary they are (p.77);

- 1) Frequency of response is an extremely orderly datum.
- 2) The results are easily reproduced. It is seldom necessary to resort to groups of subjects..... The method permits a direct view of behavioural processes which have hitherto been only inferred.
- 3) As a result of 2 (above) the concepts and laws which emerge

from this sort of study have an immediate reference to the behaviour of the individual which is lacking in concepts or laws which are the products of statistical operations. A more direct application to the prediction and control of the individual is thus achieved. The study of frequency of response appears to lead directly to such a system.

- 4) Frequency of response provides a continuous account of many basic processes. This is in marked contrast to methods and techniques which merely sample a learning process, from time to time, where the continuity of the process must be inferred.
- 5) We must not forget the considerable advantage of a datum which lends itself to automatic experimentation.
- 6) Perhaps most important of all, frequency of response is a valuable datum just because it provides a substantial basis for the concept of probability of action - a concept toward which a science of behaviour seems to have been groping for many decades.

"The notion of probability comes closest to being a generally accepted measure of strength" Herrnstein (1970) p.246. Further, this probability of responding must not be thought of as the probability concept used by statisticians, but rather as a measure or index of an organism's disposition to respond over some interval of time and reliably estimated from the rate of responding.

Important, at this stage, is the mention of 'some interval of time' when discussing rate of responding as a measure of response strength. Reinforcement affects the strength of behaviour as reflected in its rate of production. Because of this simple relationship, response rate as a measure of response strength is limited exclusively to interval schedules, where a direct proportionality between rate of responding and rate of reinforcement is not purposely programmed.

This direct relationship between rate of responding and rate of reinforcement can best be illustrated with the situation in which an organism is changed from an interval schedule to a ratio schedule. If the effect of the change is to a higher rate of responding, then the rate of reinforcement will increase. As the rate of reinforcement increases so the rate of responding increases, further strengthening behaviour; this process continuing through a further increase in the rate of reinforcement and so on. If, on the other hand, the move from an interval schedule to a ratio schedule resulted in a lower rate of responding, then the rate of reinforcement would decrease, thus producing a lower rate of responding and so on.

This dynamic circular process arises with ratio and not interval schedules because of the direct proportionality between rate of responding and rate of reinforcement. This process leads to an instability in the long run, producing either maximal responding or no responding at all.

This example is presented here to explain why only interval schedules will be considered in any further discussion of rate of responding as a measure of response strength. With ratio schedules the only reliable measure of operant strength (or the effect of reinforcement on behaviour) is resistance to extinction - the number of responses produced when reinforcement is withdrawn.

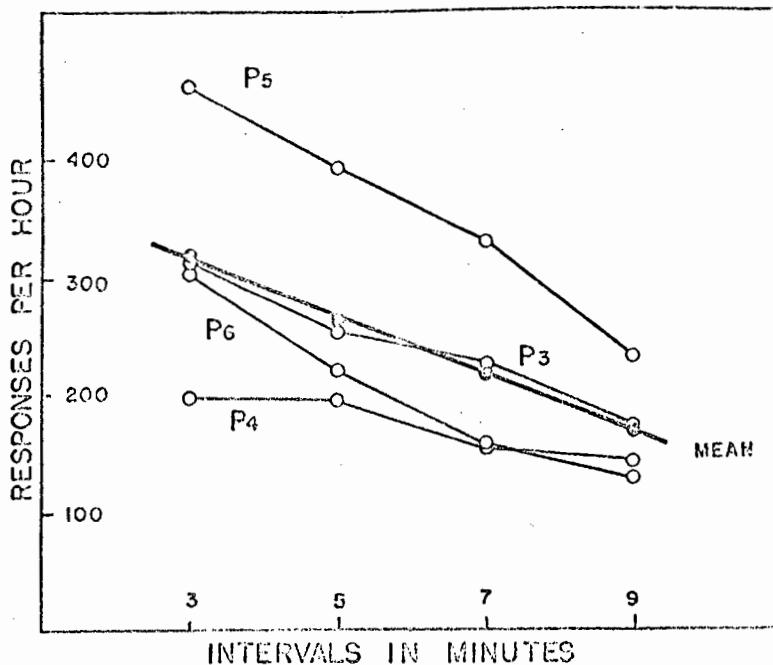
Further advantages of rate of responding as a measure of response strength include; its usefulness in the shaping of new responses, for it provides an effective baseline (this is especially applicable to Premack's (1965) theory); it provides a method of comparing responses of different topography; it can be used very effectively in stimulus generalization and discrimination experiments; and above all, it has been found to be a measure which is reproducible under many different conditions both inside and outside the laboratory, and with many different experimental organisms both animal and human.

Experimental evidence from a number of sources can be used to illustrate some of the advantages of using rate of responding as a measure of response strength.

For example, the orderliness and reproducibility of the rate of responding as an experimental datum can be seen from experiments which have attempted to relate the rate of responding to the rate of reinforcement using interval schedules.

Skinner (1938; p.128) conducted the original experiment and found that the relationship was orderly, downward sloping and approximately linear for averaged data, i.e., the rate of responding decreases with increases in the length of the unreinforced interval.

FIG. (1). Rate of responding as a function of rate of periodic reinforcement. (From FIG.(33) of Skinner (1938; p.128)).



In a similar experiment using periodic (fixed) interval schedules, Wilson (1954; p.53) produced results which were in substantial agreement with those of Skinner, over the range of periodic intervals which Skinner used. Further, Wilson's results showed that the relationship takes on a curvilinear form for intervals below 3 mins. - the lowest value Skinner

FIG.(2). Fixed interval performance by a pigeon.
 (Skinner 1972; p.152).

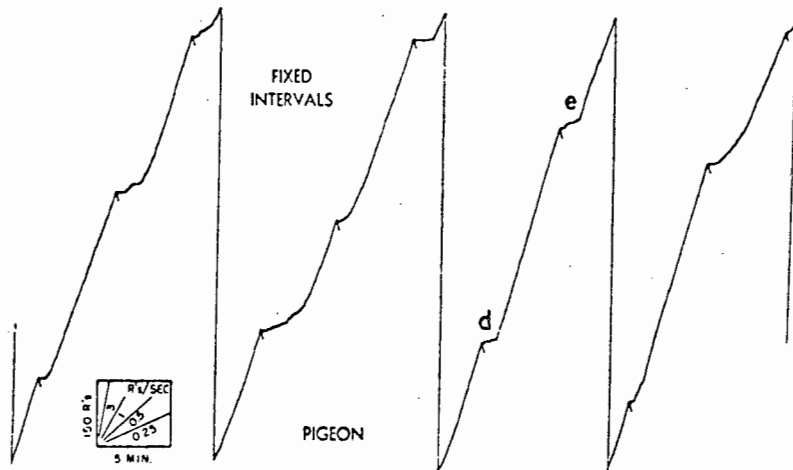


FIG.(3). Fixed interval performance by a human subject.
 (Skinner 1972; p.152).

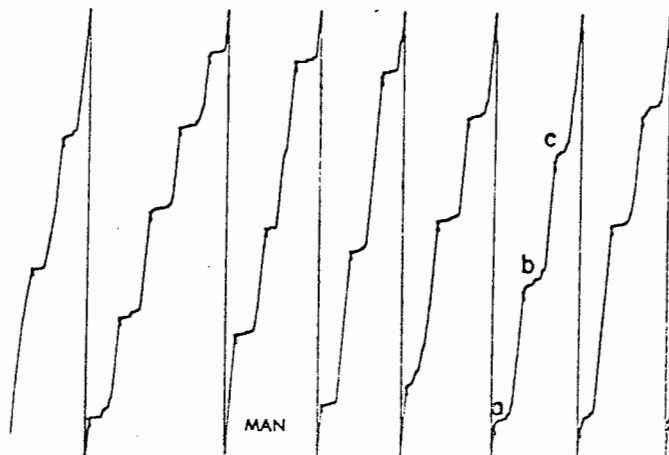


FIG.(4). Typical multiple schedule performance.
(Dews 1968; p.302).

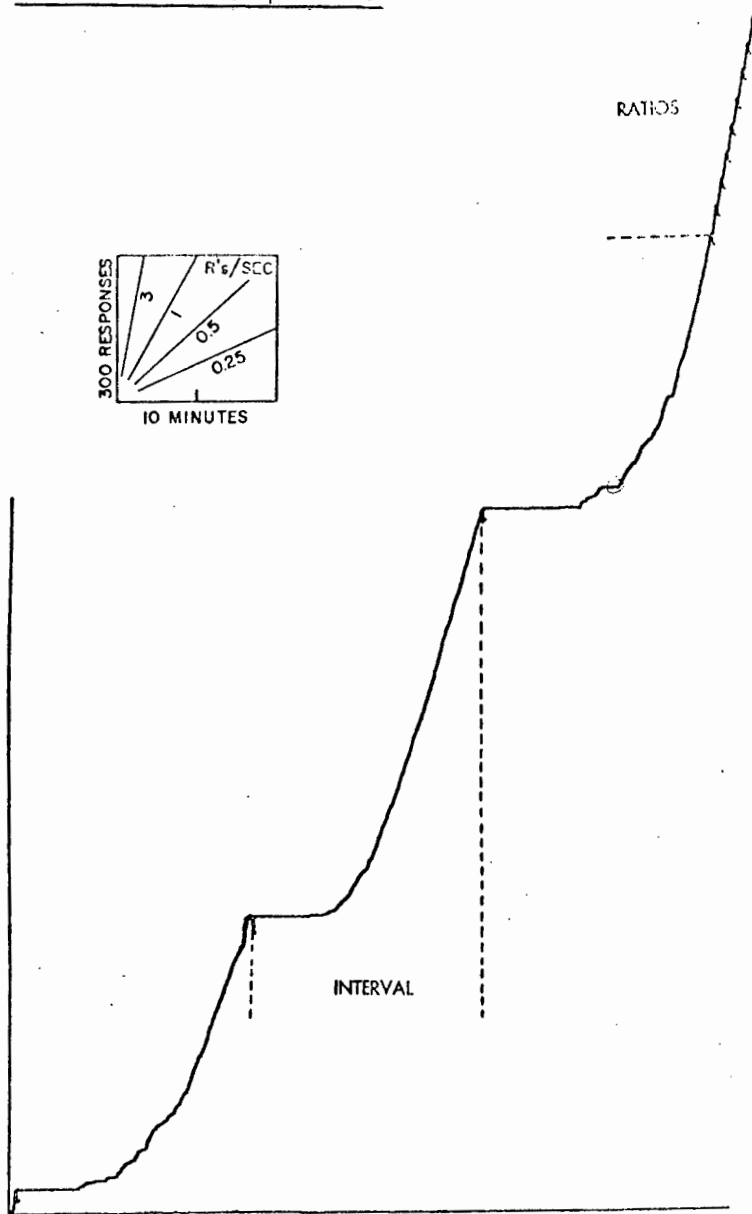
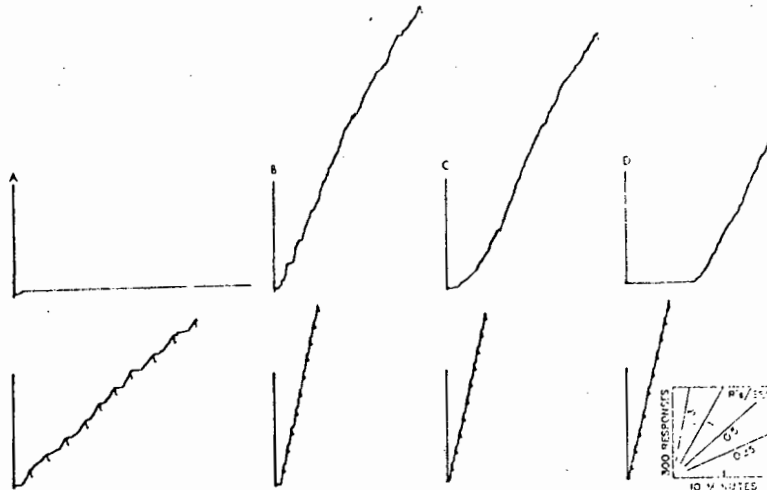


FIG.(5). Performance on a multiple schedule after phenobarbital.
(Dews 1968; p.303).



used. (see page (31) below for an illustration of this function).

Catania and Reynolds (1968; p.357) utilizing an extensive range of rates of reinforcement replicated Wilson's results for both high and low rates of reinforcement.

The above example illustrates the remarkable orderliness and replicability of the rate of responding as an experimental datum. Its reproducibility across different organisms can be illustrated by the effects of a fixed interval schedule on human and animal responding - Skinner (1972; p.152).

In FIGS.(2 and 3) page (17) the absolute rates of responding differ between the two subjects, but remarkable similarity exists in the local rates of responding, where after each reinforcement the rate remains at a low level for a short time, and then rises rapidly as it nears the next reinforcement. The marks at a, b and c for the human subject, and at d and e for the pigeon show how "run-through-reinforcement" occurred with both subjects.

The sensitivity of the rate of responding to slight changes in the independent variable, is a characteristic of this measure that is used to a great extent in drug studies, especially in the formation of behavioural baselines.

Dews (in Catania (1968); pps.302-303) has shown that the drug sodium phenobarbital disrupts both interval and ratio responding during a MULT FR FI schedule.

In FIGS.(4 and 5) page (18), it is evident that compared to baseline performances of an undrugged pigeon, sodium phenobarbital inhibits the characteristic "scallop" effect in the fixed interval component, and produces a much lower rate of responding with far more pauses during the fixed ratio component.

These examples illustrate some of the ways in which

rate of responding has been used as a reliable dependent variable in a number of different operant situations. However, this measure does have a number of shortcomings.

By concentrating on rate of responding as the measure of the dependent variable, it effectively prevents operant researchers from dealing with certain behaviours which are not amenable to a frequency measure. In other words, certain behaviours have a unique occurrence in the life of the organism, and not to record them would be to lose much behavioural detail. Skinner replied to this objection, by stating that such a unique behavioural occurrence would probably not be a simple response, but rather something in the form of an act made up of responses, which could then be measured in terms of frequency.

Another objection centers around the notion that rate of responding is simply a set of latencies, and thus is not a new datum at all. Skinner, again opposed this by stating that because the free repetition of a response yields a rhythmic or periodic datum it is, in fact, very different from simple latency.

Lastly, the effectiveness of rate of responding as a measure of response strength is somewhat limited by the fact that the rate of responding is itself a conditionable property of behaviour. This conditioning of specific rates of responding can be achieved using DRL and DRH schedules of reinforcement (Nevin, 1974).

Thus, rate of responding in the free operant situation offers an extremely sensitive measure of response strength or probability. In summary Skinner (1953) states, "The basic datum in the analysis of behaviour has the status of a probability. The actual observed dependent variable is frequency of response. In an experimental situation in which frequency may be studied, important processes in behaviour are revealed in a continuous, orderly and reproducible fashion.

Concepts and laws derived from such data are immediately applicable to the behaviour of the individual, and they should permit us to move on to the interpretation of behaviour in the world at large with the greatest possible speed" (p.78).

The other measure of response strength is resistance to extinction, obtained in a number of ways, but most reliably by the number of responses produced when reinforcement is withdrawn (see under DESIGN in Chapter 2 (p.49) for a discussion of the other measures of resistance to extinction).

The presentation of a reinforcing stimulus has two distinguishable effects. The first occurs during the conditioning period and generally results in an increase in momentary response strength or probability, made evident by an immediately observable change in the rate of responding. The second effect acts more on the reflex reserve built up from many past reinforcements and measured by its resistance to extinction. "Indeed it could be argued that extinction is the only appropriate measure of conditioning, since it is concerned with the critical defining property of the process, i.e., the presence or absence of a reinforcing stimulus" Skinner (1933) p.420.

It was Pavlov (1927) who first suggested that the number of responses produced without reinforcement could serve as a measure of the amount of conditioning. "..... The greater the intensity of the excitatory process, the more intense must be the inhibitory process to overcome it, and therefore the greater number of unreinforced repetitions necessary to bring about complete extinction" (p.61). This process was utilized by Skinner in 1933 (a) (p.114) and received formal attention in a later publication during the same year - 1933 (b) (p.420). In 1938 Skinner applied it to the measurement of behaviour which had been operantly conditioned.

Extinction in the type R conditioning paradigm is

when the response (or operant) is no longer followed by the reinforcing stimulus, all other conditions remaining as they were during conditioning. The course of extinction follows a characteristically orderly process, and depends almost exclusively on the schedule of reinforcement in operation during conditioning.

For example, after continuous reinforcement (crf) an initially high rate of responding is observed, but this is soon interrupted and followed by fluctuations between high rates and no responding at all. Skinner (1938; p.74) believes this process results from the effect that is produced when the first response fails to produce reinforcement. At the same time it fails to supply the stimulus for the next member of the chain. When this situation occurs the next response is emitted immediately and a high rate of responding is produced during the initial period of extinction.

In contrast the extinction curve following periodic reconditioning (fixed interval reinforcement) is smoother and more prolonged. The reason for this states Skinner (1938; p.133), is that the emotional effect following the production of a response without reinforcement soon adapts out under the periodic schedule, where many responses during the conditioning period are not followed by reinforcement.

FIG.(6). Characteristic shape of an extinction curve after crf (Skinner (1938; p.75)).

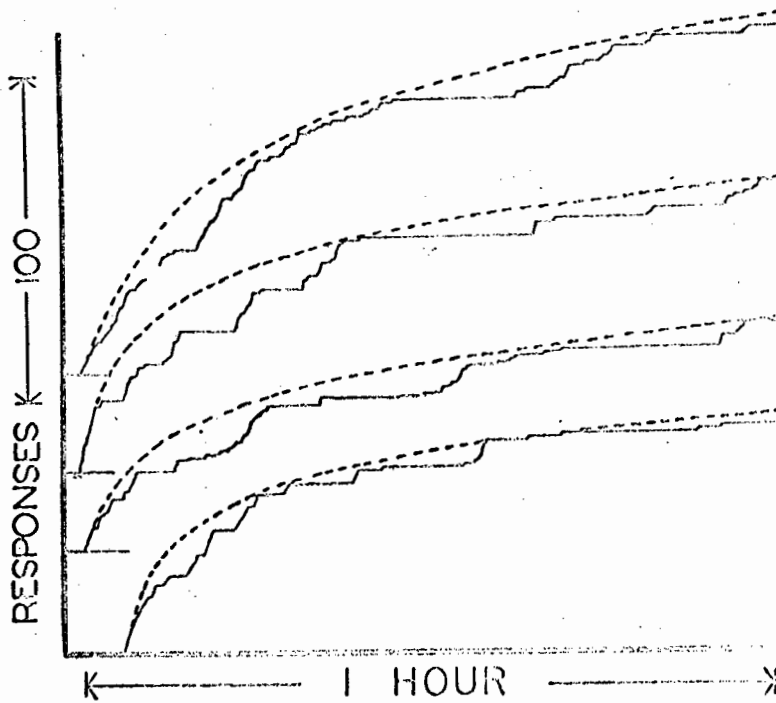
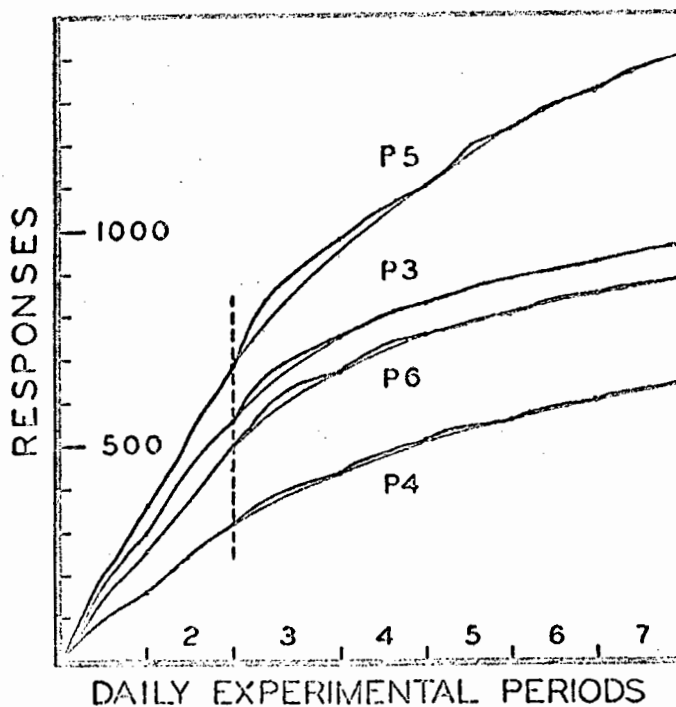


FIG.(7). Characteristic shape of an extinction curve after periodic reconditioning. (Skinner (1938; p.137)).



In their comprehensive qualitative analysis "Schedules of reinforcement", Ferster and Skinner (1957) included sections on extinction after FR, VR and VI schedules of reinforcement. For example, extinction after extended periods of FR training (700 reinforcements at FR 60) showed a high rate of responding during the initial stages of extinction, which remained in the form of local bursts, separated by longer and longer periods of non-responding, throughout most of the extinction session. Ferster and Skinner believe this characteristic curve of extinction reflects the effects of the controlling contingencies arranged by the fixed ratio schedule (pps.57-48).

"Extinction curves following variable ratio performances reflect prior performance" Ferster and Skinner (1957; p.411). The extinction curve after VR is characterized by short bursts of sustained responding, followed by short bursts of no responding at all. The extinction curve after variable interval or aperiodic schedules is very different from the curve after ratio schedule responding. Here the curve shows a smooth slope indicating a constant low rate of responding, which contained no bursts or periods of no responding (except towards the end of extinction) p.347.

The above, then, gives a brief qualitative picture of the nature of the extinction process resulting from continuous and periodic reinforcement schedules. However, as a measure of response strength, the extinction curve does not lend itself to a quantitative analysis. (see also pps.51-54 below).

Resistance to extinction, measured normally by the number of responses emitted during a set period of time when reinforcement is withdrawn and all other conditions constant, provides a much more precise measure of the reflex reserve. Thus conditioning can be regarded as "... creating a certain number of potential responses, which could occur later without reinforcement. During extinction this reserve is exhausted" Skinner (1938; p.83).

Just as rate of responding was found to be a trivial measure of response strength with crf and ratio reinforcement schedules, so also it is with resistance to extinction. This is because with continuous reinforcement schedules resistance to extinction is a direct function of the number of reinforcements (and responses) as in a classical conditioning procedure. Likewise, with ratio schedules resistance to extinction is a direct function of the ratio value. Boren (1961; p.305).

"It can be said that extinction has been the main mirror reflecting response strength in the partial reinforcement situation" Jenkins and Stanley (1950; p.214). In early research resistance to extinction was widely used to measure the effect on response strength of the quantitative differences between continuous and partial reinforcement schedules, and the differences between aperiodic (variable interval) and continuous reinforcement schedules. (see page 215 of Jenkins and Stanley (1950) for a comprehensive review of this research).

An example of the use of resistance to extinction to gauge the quantitative differences between continuous and partial reinforcement schedules is a study by Jenkins and Rigby (1950). In this experiment four groups of rats were given reinforcement according to the following different schedules;

GROUP 1	90 reinforcements at 2min. intervals
GROUP 2	90 reinforcements at 1min. intervals
GROUP 3	2400 reinforcements - continuously
GROUP 4	90 reinforcements - continuously

The resistance to extinction measured by the total number of unreinforced responses produced during a period of three hours for each of the groups was :

GROUP 1	129 responses
GROUP 2	90 responses
GROUP 3	100 responses
GROUP 4	51 responses

The results are clear - only 90 reinforcements on a periodic schedule produces a greater reserve than 2400 reinforcements presented continuously. The reasoning being that what is conditioned in the case of the periodic schedule is "... not only responding followed by reinforcement, but also responding followed by non-reinforcement" Jenkins and Rigby (1950; p.38).

If the number of responses produced during extinction are presented as a percentage of the number of reinforced responses even clearer results are obtained from the P.R.E. effect. GROUP 1, which was presented with reinforcement after only 90 responses produced 143% more responses in extinction. In contrast GROUP 3 which had 2400 responses followed by reinforcement only produced 4,2% of these during extinction. Jenkins and Rigby (1950; p.34).

A second example illustrating the use of resistance to extinction as a quantitative measure of amount of conditioning is an experiment undertaken by Jenkins, McFann and Clayton (1950). In this experiment three groups of pigeons were given 200 continuous reinforcements, whilst another three groups were given the same number of reinforcements but on an aperiodic (variable interval) schedule. The number of responses produced during 6 hours of extinction for the three continuously reinforced groups were 647, 745 and 565 responses respectively. During the same period of time those three groups of pigeons on an aperiodic schedule produced 3092, 3128 and 2375 responses respectively, even though they received the same total number of reinforcements.

Also tested in this experiment were three different methods of measuring resistance to extinction over the same six hour period;

- (1) 1 hour extinction, 2 hours rest, 1 hour extinction, etc.
- (2) 6 consecutive hours
- (3) 1 hour per day for 6 days

Intercorrelations were generally high amongst all these different measures ($> 0,64$); and, more important for the present study, were the extremely high correlations between the second two measures above (0,73 to 0,95) (p.163).

More recent researchers using resistance to extinction as a measure of differential conditioning resulting from various schedules include Boren (1961) and Hearst (1961). Boren systematically studied the function relating the size of the fixed ratio and resistance to extinction. He found the function to rise gradually and in a linear fashion. (see FIG.(12) page (36) below).

In contrast, Wilson's (1954) study relating fixed interval length to resistance to extinction, produced a function which was curvilinear, and which rose to an asymptote and then declined as the interval lengthened. (see FIG.(10) page (33) below).

However, individual differences play an important role during conditioning and extinction procedures. Hearst (1961) controlled for this variable by using multiple schedules, where two or more levels of the independent variable were presented in sequence to the same subject, each represented by its own discriminative stimulus.

With individual subjects Hearst (1961 Exp.1) found the function relating number of reinforcements to resistance to extinction to be linear, upward sloping and negatively accelerated (p.136). A similar relationship was found by Williams (1938) and Perin (1942).

Hearst (1961 Exp.2), again using a single subjects design, but with variable ratio schedules, found that

resistance to extinction was an increasing function of the variable ratio requirement during conditioning (p.141). (see FIG.(14) page (37) below).

The results of this sample of experiments which utilize resistance to extinction as a measure of the effects of the schedule of reinforcement on behaviour are markedly consistent. Of the 17 studies cited by Jenkins and Stanley (1950; p.215), comparing the differences in resistance to extinction after continuous and partial reinforcement, only 3 were found not to be statistically significant at the 5% level.

".... you will get out in extinction what you reinforced in conditioning" Schoenfeld (1968) Author's comment p.259. This statement essentially summarizes the position of resistance to extinction as a measure of response strength. For, although the independent variable (reinforcement) cannot be in effect when the dependent variable (resistance to extinction) is measured, its specification in terms of past conditions becomes the independent variable which determines the present conditions of extinction, providing all other objective conditions are controlled.

This section can be brought to a close with a summary of the position as it stands thus far. Early theorists such as Skinner (1938) and Keller (1940) spoke of a reflex reserve, which, in the final analysis, was composed of three elements - the total reserve, the immediate reserve and the momentary probability. Reinforcement added to this reserve in a cumulative, although negatively accelerated, function. When behaviour was reinforced intermittently, the extinction ratio - the ratio of reinforced to unreinforced responses - became an important constituent of the reflex reserve.

Under this early theoretical formulation, the resistance to extinction measured the size of the reserve, by the withdrawal of reinforcement and the measurement of the

number of responses emitted before the reserve became exhausted. Rate of responding as a dependent variable, on the other hand, was found to be an orderly sensitive and consistent measure of the strength of a response at any particular moment - the momentary probability. In Skinner's account this momentary probability was a function of the immediate reserve, which in turn was directly proportional to the size of the total reserve. Via the workings of the extinction ratio (see page (11) above), rate of responding and resistance to extinction both were developed as measures of response strength or "reflex reserve".

Recent formulations in this area (Herrnstein, 1970; Schoenfeld, 1968 (Comment)), have considerably simplified the matter by rejecting the hypothetical entity of a reserve, and by equating the concept of response strength with the measures used to gauge it, in a truly operational manner. "... it is better for science to seek something real to measure than to loiter over invented entities and processes" Schoenfeld (1968) Author's comment p.259.

According to the above, then, operant strength or the effect of reinforcement on operant behaviour is nothing more than the results of the operations used to measure it - rate of responding and resistance to extinction. However, the problem only starts here for Kling (1971) has stated "... rate (of responding) and resistance to extinction rarely are perfectly correlated" p.596.

(iii) The Relationship Between Rate of Responding and Resistance to Extinction.

If response strength is nothing more than the result of the measures used to gauge it; and, if these measures are not very well correlated amongst themselves, as Kling (1971) and Nevin (1974) suggest, and as Wilson (1954) purportedly has shown, then two alternatives remain. The first is that not enough research into the relation between the existing

measures of response strength has been undertaken - this is the stance adopted by Herrnstein (1970; p.246) and Morse (1966; p.78). A corollary to this point of view would be that either of the two measures is faulty and does not accurately measure response strength, or that a relationship does in fact exist between rate of responding and resistance to extinction, and that the data so far presented (Wilson; 1954) fall short of providing comprehensive evidence for the dismissal of such a notion.

The second alternative is to argue, as Kling and Nevin do, that response strength is something more than the measures used to gauge it. "... it is obvious that response strength must refer to something that is related to both, but identical with neither" Kling (1971; p.596).

The aim of the present study, then, falls within the first of the two alternatives above, and is directed toward showing, not that either of the existing measures of response strength is faulty, but that there is a direct relationship between rate of responding and resistance to extinction.

This section review's Wilson's (1954) study and some recent experiments not specifically addressed to this problem, but which nevertheless show that such a relationship as the one envisaged in the first alternative does exist.

Wilson's (1954) study contained two separate experiments. The first was designed to investigate primarily the function relating rate of responding to various interval lengths, for interval lengths less than 3 mins. (the lowest value studied by Skinner (1938). In the same experiment the relationship between PR interval and resistance to extinction, with number of reinforcements equated, was also determined. The second experiment investigated resistance to extinction as a function of the number of reinforcements on a periodic reinforcement schedule. In the present discussion only Experiment I will be reviewed as it has direct bearing on the

relationship between rate of responding and resistance to extinction.

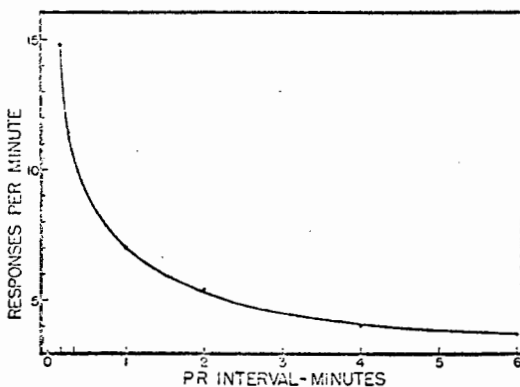
A group of 42 albino rats was divided into 7 smaller groups of 6 rats, each receiving a total of 240 reinforcements according to the following schedule

<u>GROUP</u>	<u>PR INTERVAL</u>	<u>REINFS/DAY</u>
1	0 min	40
2	1/6 min	40
3	1/3 min	40
4	1 min	40
5	2 mins	24
6	4 mins	12
7	6 mins	10

A second group of 42 albino rats was also divided into 7 smaller groups of six rats, and exposed to the same periodic intervals, but these animals were only given 15 reinforcements - mostly on the same day, but with the longer intervals the experiment was conducted over two days.

As the response rates did not reach a stable value until after 80 or more reinforcements, Wilson did not include the response rates of the group which received only 15 reinforcements in the plotting of a function relating response rate to interval length.

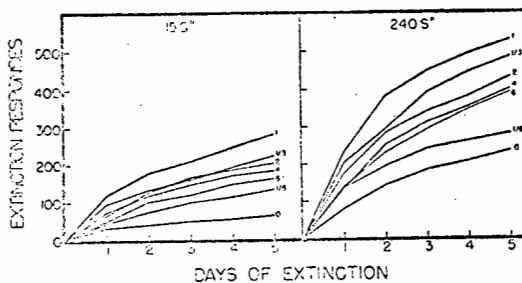
FIG. (8). Mean rate of responding in responses per minute as a function of the PR interval (FIG.1 p.53 Wilson; 1954).



The points on the graph are average rates during the last 35 reinforcements of the 240 reinforcement group. A Mann-Whitney U test was applied to the difference in rate resulting at the 1/6 min. interval, from the rate at any of the other periodic intervals. All the differences were significant at the 0,05 level of confidence, except for the difference between the 1/6 min. group and the 1/3 min. group. Although Skinner (1938) reported a linear function between PR intervals ranging from 3 mins. to 9 mins., the data presented by Wilson are not in disagreement; they simply extend the range of the curve below 3 mins., where it becomes curvilinear.

Cumulative response curves for each of the different PR intervals for the 240 reinforcements and 15 reinforcements groups, showed some variation during the first two days of extinction (50 mins. per day), but thereafter showed little difference in shape.

FIG. (9). Mean cumulative response curves during five 50 min. periods of extinction (FIG.2 p.54 Wilson; 1954).

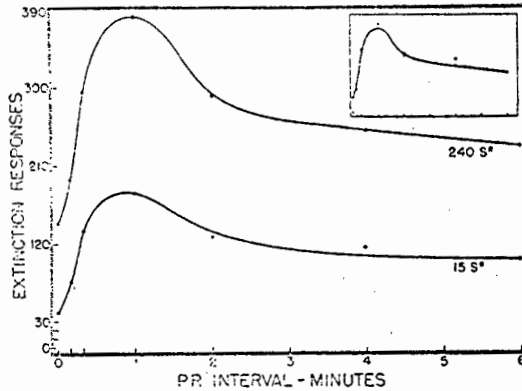


With regard to the number of responses produced in extinction the data can be read, although not very accurately, from the cumulative extinction curves. It is quite noticeable that the 240 reinforcements group produced many more responses in extinction than the 15 reinforcements group.

A clearer picture, however, is obtained from a function relating interval length to number of extinction

responses for one period of 50 mins., obtained from the cumulative curve for day 2.

FIG.(10). Mean number of extinction responses as a function of the PR interval for one 50 min. segment (FIG.3 p.54 Wilson; 1954).

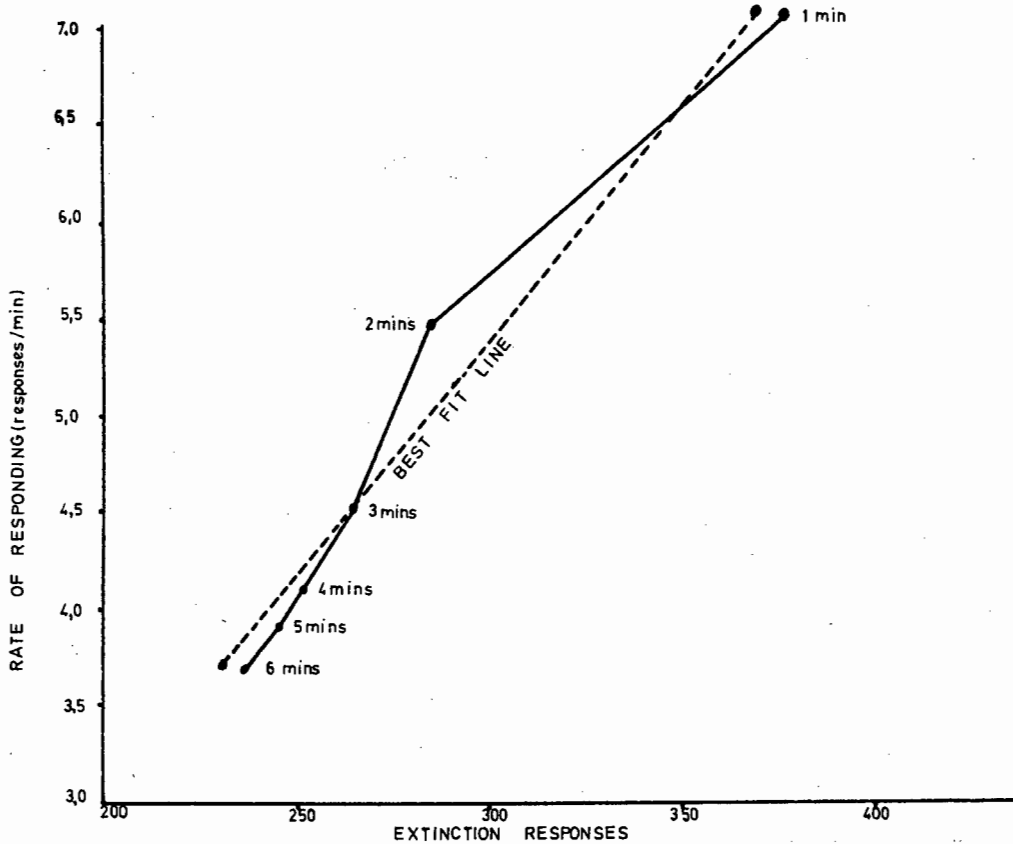


Only the 240 reinforcements group need concern us here, as rate of responding data is not available for the 15 reinforcements group. The function above shows a definite maximum number of extinction responses for a PR interval of 1 minute - it then tails off gradually as the PR interval lengthens.

"To determine the relation between rate of responding during reinforcement and resistance to extinction, the mean extinction responses for the 240 reinforcements group in FIG.3 (FIG.(10) above) were plotted as a function of the mean rates from FIG.1 (FIG.(8) above). The plot showed no consistent relation between these two variables. resistance to extinction is not systematically related to rate of responding during reinforcement" Wilson (1954; pps.54-55).(Underlining mine).

Wilson did not produce such a plot in his report. However, such a function was plotted by reading off the values in FIGS.(8) and (10) above. Although some degree of inaccuracy must be expected from such a procedure, the following function was obtained by plotting rate of responding and resistance to extinction at each level of the PR interval.

FIG.(11). Resistance to extinction as a function of rate of responding at various PR intervals (FIGS.1 and 3 Wilson; 1954, pps.53-54).



The above plot shows a linear increasing relationship between rate of responding and resistance to extinction for different PR intervals - from 1 min. to 6 mins. Data for the very short intervals (1/6 min. and 1/3 min.) were not included in the curve, as the present series of experiments do not include such short intervals. The use of very short intervals is problematic because the amount of time eating and ingesting forms such a large proportion of time spent responding, and consequently rate of responding as an overall measure becomes inaccurate. Boren (1961) found this effect to operate with low valued FR schedules (p.305).

The above reasoning would then possibly account for the lack of a consistent relationship between rate of responding and resistance to extinction found by Wilson (1954; pps. 54-55), for it would seem that he included these very short intervals in his plot. The resulting curve would have been U shaped, for the short intervals produced very high rates of

responding (up to 15 resp/min.), but low numbers of extinction responses (approx.140).

A linear regression analysis was applied to the plot in FIG.(11) above, and a Pearson Correlation Coefficient of $r=0,984514$ was obtained. A best fit line with a regression equation $Y=41,5359(X)+78,5125$ was drawn onto this graph. Although not too much emphasis should be placed on this statistical analysis because of the limited number of X, Y pairs (6), the correlation coefficient does indicate that the two variables of rate of responding and resistance to extinction are highly related for different PR intervals.

Thus Wilson's data, for intervals larger than 20 secs., yield a consistent function between rate of responding and resistance to extinction. If data for the intervals of 20 secs. and less are included, then the curve becomes U shaped, and statements concluding a lack of consistent linear relationship between these two variables have some basis. However, for the reasons mentioned above measures of rates of responding for intervals of such short length are inaccurate, and are liable to produce unreliable results. Wilson himself (p.53) found that the difference in rate of responding resulting from the difference between an interval of 1/6 min. and 1/3 min. was not significant, whilst all the other differences were.

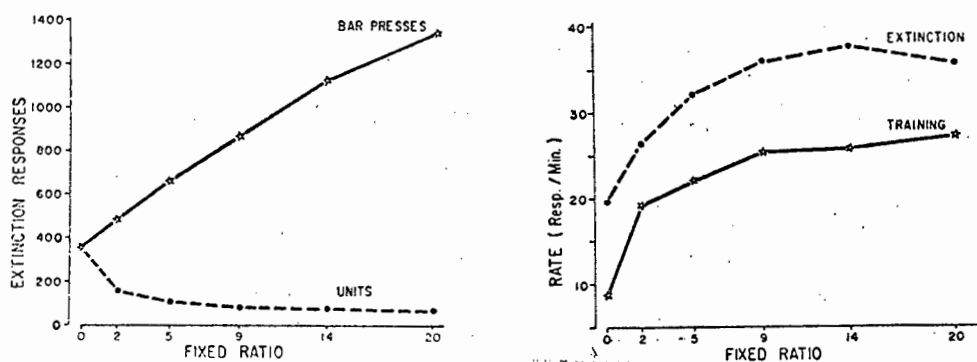
This relationship does not only hold for interval schedules as Boren (1961) and Hearst (1961) have shown. Although the curve relating ratio requirement to rate of responding is upward sloping and negatively accelerated (Boren; 1961, FIG.1 p.305), as opposed to downward sloping with regard interval length in time-based schedules, the function relating rate of responding to resistance to extinction is of a very similar order to that produced from Wilson's (1954) data above.

Boren (1961) used a different subjects design with six rats being assigned to six different fixed ratio

schedules FR1,FR2,FR5,FR9,FR14 and FR20 - but each receiving the same total number of reinforcements (560).

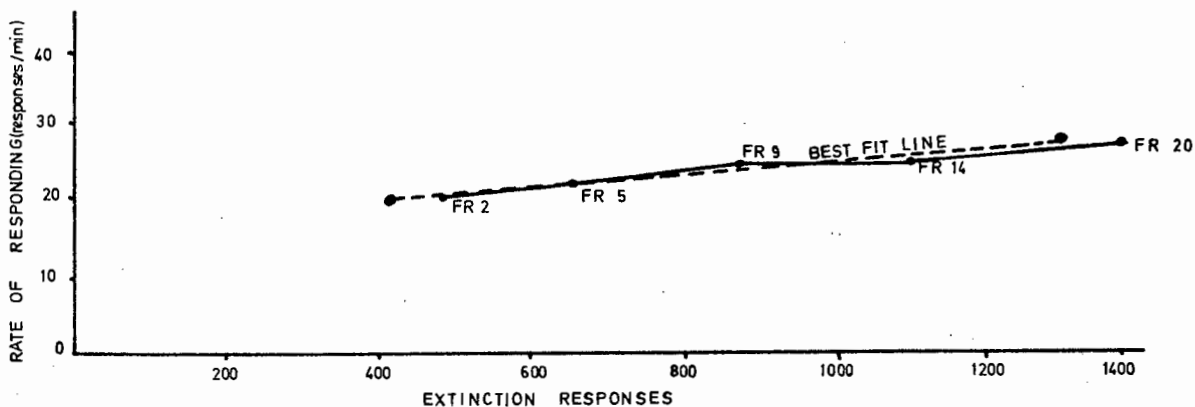
The following two curves were obtained for averaged data.

FIG.(12). Rate of responding (left) and resistance to extinction (right) as a function of the Fixed Ratio (Boren; 1961, FIGS. 1 and 3 pps.305-306).



When points were read from the rate of responding axis and the extinction responses axis, at each level of the FR, the following curve was obtained.

FIG.(13). Resistance to extinction as a function of rate of responding at various Fixed Ratios (FIGS.1 and 3 of Boren; 1961, pps.305-306).

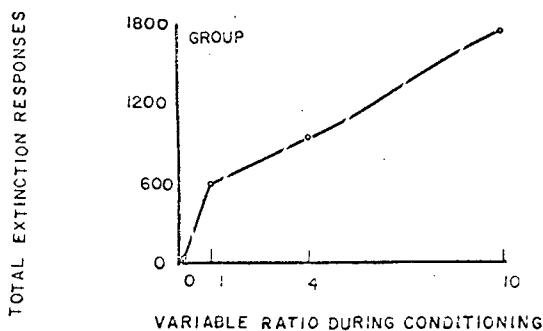


The above plot again shows a linear increasing relationship between rate of responding and resistance to extinction, this

time for different fixed ratio values. A linear regression analysis applied to this data revealed an $r=0,950425$ and a best fit line with equation $Y=104,591(X)+-1577,8$. Even within the limits of the small number of X,Y pairs used, rate of responding and resistance to extinction are highly related measures of the amount of conditioning (response strength) under fixed ratio schedules.

Hearst (1961) used variable ratio schedules and, more importantly, a single subjects design. Four pigeons were exposed to the same conditioning procedure, being presented with four different key colours, each representing a different value of the variable ratio. Hearst reported the following function relating the value of the variable ratio to resistance to extinction (the data are averaged across four birds).

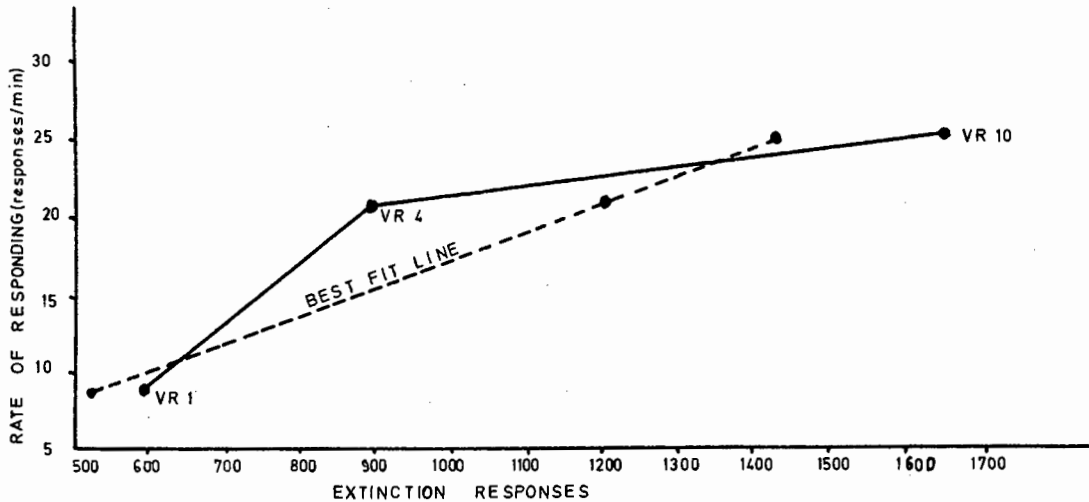
FIG.(14). Resistance to extinction as a function of the variable ratio during conditioning. (FIG.3 of Hearst; 1961, p.141).



However, the graph relating rate of responding to resistance to extinction (below), is more speculative in nature, as Hearst presented no data as to the relationship between variable ratio requirement and rate of responding. This data has been collected by assuming that the rate of responding following VR reinforcement will be very similar to that following FR reinforcement at the same ratio values. This is, in fact, not an altogether inaccurate assumption to make as Ferster and Skinner (1957; pps.407-410) have shown overall rates of responding to be similar to variable and fixed ratio schedules

which program the same rate of reinforcement (i.e., the same ratio values eg. VR 20 FR 20).

FIG.(15). Resistance to extinction as a function of rate of responding at various variable ratios (FIG.3, p.141 of Hearst; 1961).



The plot above shows a similar relation to those found for fixed ratio schedules (Boren) and fixed interval schedules (Wilson). Linear regression analysis produced a coefficient of correlation $r=0,858119$ and a regression equation of $Y=52,2152(X)+110,127$. Although this coefficient is slightly lower than the previous examples (probably because only 3 X,Y pairs were used), it is high enough to be able to state that rate of responding and resistance to extinction are closely related.

Indirect evidence for the linear relationship between rate of responding and resistance to extinction can be obtained from studies of behavioural contrast and stimulus discrimination. In a normal discrimination procedure responding to one particular discriminative stimulus is always reinforced (S^D+) and responding to another discriminative stimulus is never reinforced (S^D-). During a generalization test a number of different S^D 's including the two test S^D 's are presented without reinforcement. A gradient of generalization can then be obtained which usually has its maximum at the point of the S^D+ ,

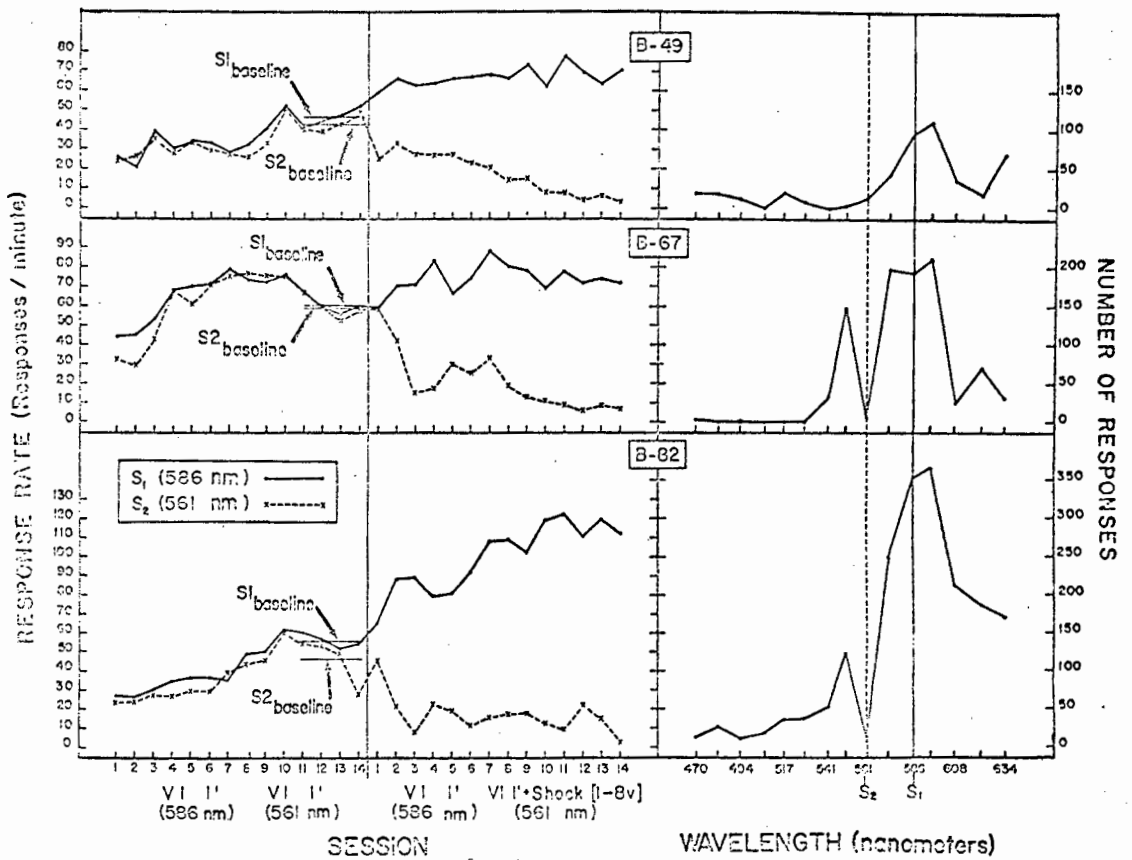
and its minimum at S^{D-} , with the number of responses increasing with the degree of similarity between the S^{D-} and the S^{D+} .

One type of discrimination procedure is the successive discrimination which is achieved by using multiple schedules of reinforcement. The original successive discrimination procedures were carried out by Guttman (1959), Reynolds (1961 a, b, c and d) and Catania (1961). For example, Reynolds (1961 a) formed a discrimination by first reinforcing a pigeon on a two component multiple variable interval schedule, where each schedule was represented by its own S^D . After the rates of responding under each component were stabilized the schedule was changed to either a MULT VI EXT or a MULT VI DR0. Reynolds noted that when responding in the second component was extinguished, rate of responding in the first component increased, even though this component was not altered in any way. Reynolds (1961 a) called this positive behavioural contrast, and proposed (1961 b) that the change in the relative rate of reinforcement caused the contrast to occur.

During subsequent generalization tests the peak of the generalization gradient was found to have shifted away from S^{D+} . Hanson (1959) called this phenomena the "Peak Shift", and the operation of behavioural contrast was proposed by Terrace (1966) to be the cause of it. This early research on behavioural contrast need not interest us here. What is more important, however, are some of the systematic extensions of the behavioural contrast paradigm. Many researchers have criticized Reynolds' (1961 b) "relativity of reinforcement rate" concept as a probable reason for behavioural contrast - they include Terrace (1968), Brownstein and Newsom (1970), Brownstein and Hughes (1970) and Halliday and Boakes (1971).

One particular extension is the production of behavioural contrast when reinforcement rates in the two components remain unchanged. Terrace (1968), Weisman (1969) and Brownstein and Newsom (1970) have found that a simple reduction in response rate in the second component will produce

FIG.(16). Rates of responding to S1 and S2, before and after discrimination training in which responses to S2 were punished, and subsequent generalization gradients (Terrace ; 1968, Exp.II p.734).



an increase in rate of responding in the first component, even though the rates of reinforcement in each of the components remained unchanged.

What is important for the present study is that although the peak of the generalization curve was shifted away from the component S^D which remained unchanged, the number of responses emitted in extinction to this S^D was far greater than the number emitted to the other component S^D . It would seem, then, that the schedule S^D which produced the higher rate of responding during acquisition also produced the more responses in extinction.

The critical experiment showing behavioural contrast resulting from simple response rate reduction was conducted by Terrace (1968; Experiments II and III). In experiment II, the rate of responding to S_2 (the S^D of the manipulated component) was reduced by using a punishment technique. The experiment utilized pigeons as subjects and the punishment procedure comprised an internally administered electric shock. Before this response rate reduction was carried out, response rates in the two components S_1 and S_2 were stabilized and equated to form a baseline.

The left hand panel of FIG. (16) on page (40) shows the baseline where rates of responding were equated, and then as a result of the introduction of punishment to S_2 , the rate of responding to that S^D is seen to decrease. Behavioural contrast occurred here as the rate of responding to S_1 increased, even though there was no change in the reinforcement schedule.

More important for the present study is the right hand panel showing the generalization gradient of extinction. Although the peak in all cases was shifted to the right of S_1 , the number of responses emitted in extinction were greater for S_1 than for S_2 .

FIG.(17). Rates of responding to S1 and S2, before and after VIDRL training, and generalization gradients of wavelength of those subjects that showed contrast (Terrace; 1968, Exp.III p.736).

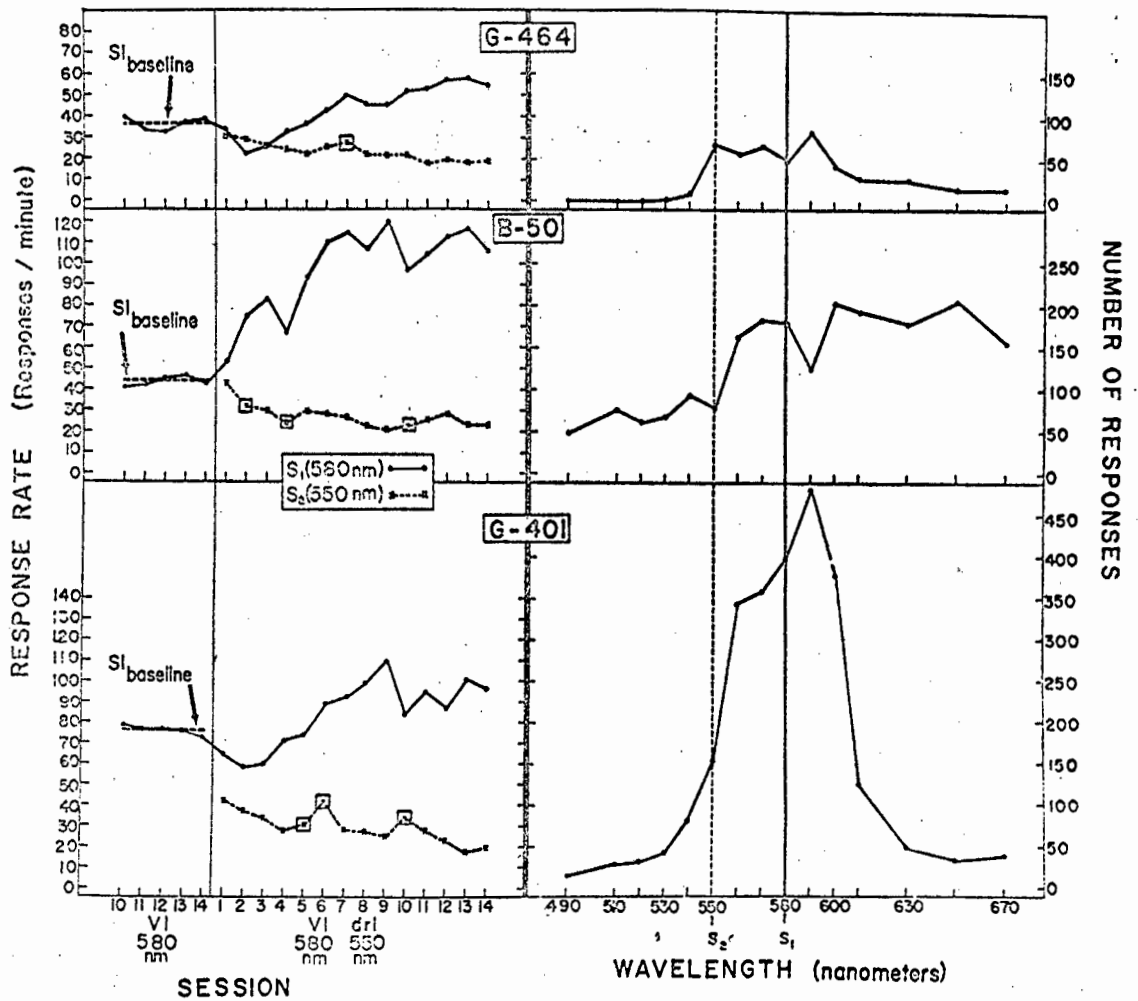
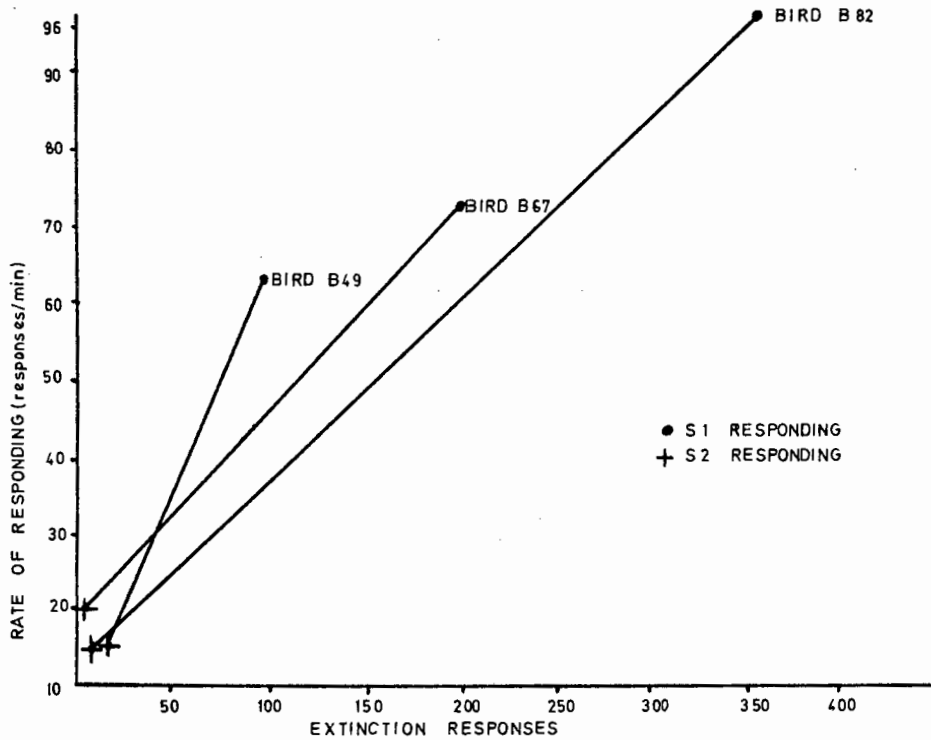


FIG.(18). Resistance to extinction as a function of rate of responding for three different subjects (Terrace; 1968, Exp.II p.734 - FIG.(16) above).



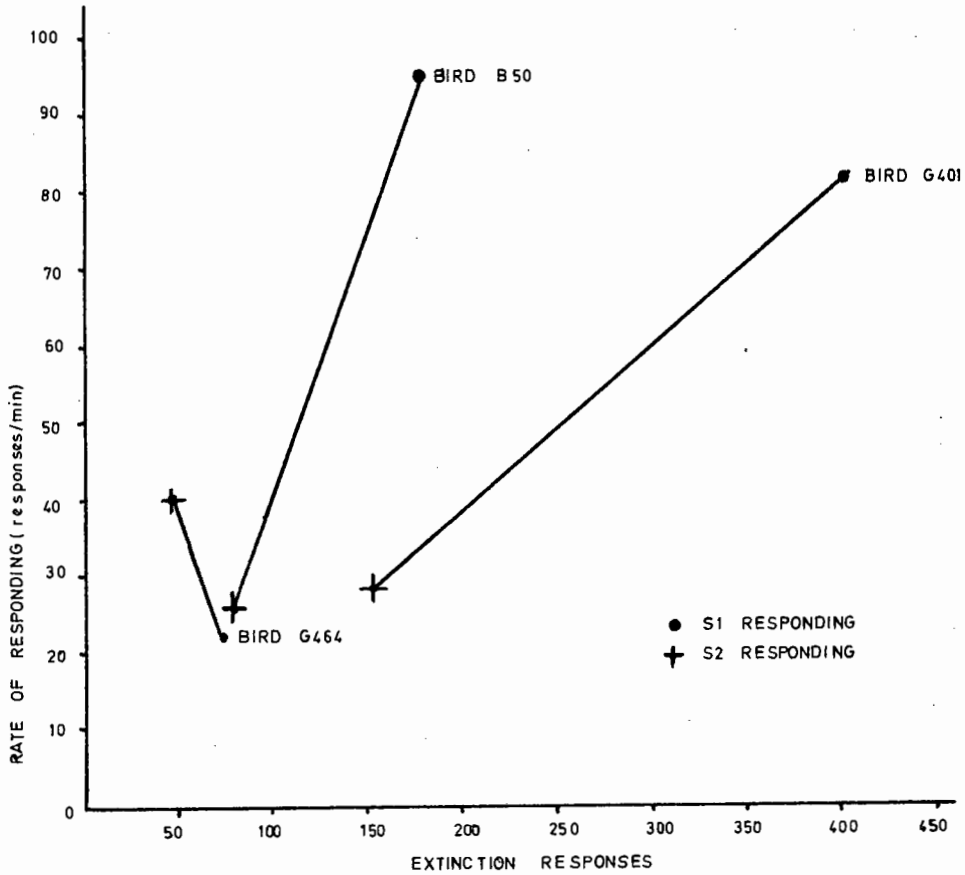
The graph above relates mean rate of responding over the last 14 days of discrimination, where the response rates were made to differ, to resistance to extinction made in the presence of a number of different S^D 's, but including S1 and S2. Although only two points were plotted for each bird (this is because only one schedule of reinforcement - a VI schedule - was used throughout), the trend of each of the functions is apparent. They are all linear and upward sloping.

In experiment III Terrace used a DRL (Differential Reinforcement of Low-rate) schedule, which differentially reinforced long IRT's to produce a lower rate of responding to S2. At the same time he managed to equate the rates of reinforcement in the two components, by adjusting the DRL requirement to the rate of reinforcement produced by the VI schedule in S1.

From FIG.(17) page (42) it is again apparent that the peak of the generalization gradient was shifted away from S1. However, the number of responses produced in extinction

to S1 were generally (there was one exception - bird G464), greater than those emitted to S2.

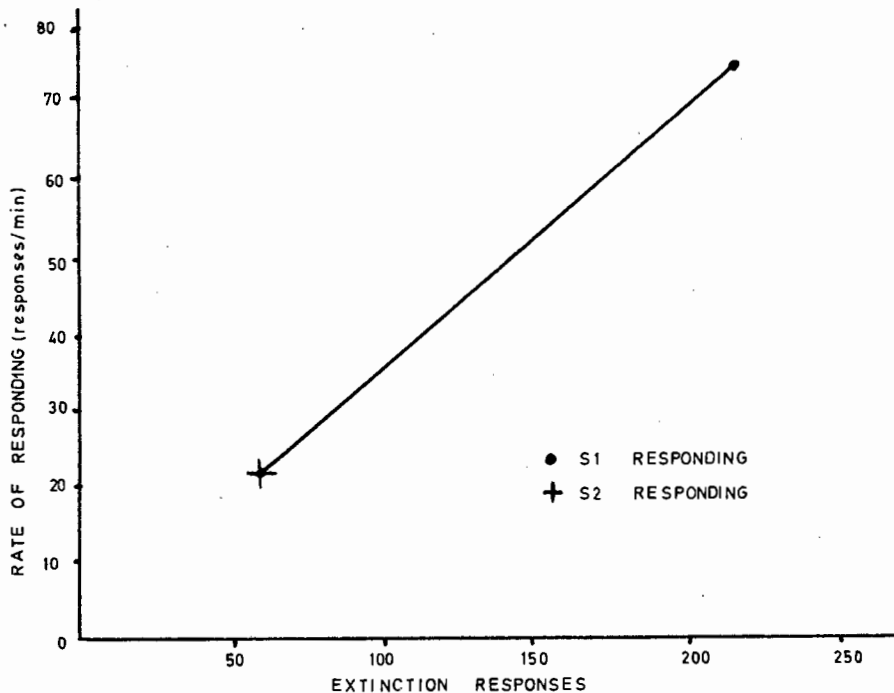
FIG.(19). Resistance to extinction as a function of rate of responding for three different subjects (Terrace; 1968, Exp.III p.736 - FIG.(17) on page (42) above).



With the exception of bird G464, the curves show a linear upward sloping function between rate of responding and resistance to extinction.

If all of the rates of responding under S1 and S2, and numbers of responses produced in extinction to S1 and S2 are averaged, the following summary graph is obtained:

FIG.(20). Resistance to extinction as a function of rate of responding averaged for six subjects (Terrace; 1968, Exps.II and III pps.734-736 - FIGS.(18) and (19) above).



With the averaged data the trend is again clear - rate of responding and resistance to extinction form a function which is characterized by its linear and upward sloping nature.

In summary, then, the data presented above to support the present contention - that rate of responding and resistance to extinction are related in some orderly way, all share one common characteristic - their objective was not to measure such a relationship. Thus, except for possibly the Wilson (1954) study, all the evidence as to such a relationship is indirect. It is therefore pertinent to repeat a statement quoted in the first section of this chapter by Herrnstein (1970) - "The traditional measures of response strength - probability, rate, amplitude (i.e. work or effort), latency, resistance to extinction - have all failed to gain unequivocal support simply because orderly data with quantitative and general significance have not been forthcoming" (p.246). (Underlinings mine).

Aim of the Study.

It is thus the aim of the present study to show that such an orderly, quantitative and general relationship does indeed exist between two of the more fundamental measures of response strength - rate of responding and resistance to extinction.

In the chapter following various aspects of the experimental design are discussed, together with a general description of the subjects, the apparatus and the training procedures used. In the third chapter a series of four experiments are presented in an ascending order of tighter control over the relevant variables, in an attempt to show under systematically controlled conditions that rate of responding and resistance to extinction are directly related.

CHAPTER 2GENERAL METHOD(i) Design.

The actual designs of each of the experiments varied considerably - Experiments I and II were different subjects designs, whilst Experiments III and IV were single subjects or repeated measures design. A fuller description of each of these designs will be given in Chapter 3.

There are, however, many interesting aspects to the design of operant experiments in general, and to this series of experiments in particular.

Firstly - the number of subjects used in the experiments.

The basic tenet of operant methodology with regard to this question is "... instead of studying a thousand rats for one hour each, or a hundred rats for ten hours each, the investigator is likely to study one rat for a thousand hours" Skinner (in Honig, 1966, p.21). Due to advances in operant technology and methodology the intense study of individual organisms is possible. For instance, electro-mechanical recording and programming equipment ensure that the experimenter does not have to be in attendance all the time. Also, the cumulative record provides a finely detailed picture of the organism's behaviour over long periods of time.

With regard to methodology, operant procedures have been carefully chosen. For example, the operant response - be it a key peck or a lever press has been selected from the organism's repertoire for the relatively low effort required to produce it, and its simple repetitive quality.

Further arguments in favour of the use of small numbers of subjects in operant research centre around the concepts of reversibility and reproducibility or uniformity.

Reversibility refers to the fact that with operant studies ".... the performance characteristic of one schedule may be recovered after the organism has been exposed to other schedules or conditions. This usually makes it possible to establish a baseline, introduce a variable, and return again to the baseline in such a way that the organism serves as his own control" Ferster and Skinner (1957; p.38). This then makes operant studies especially conducive to repeated measures designs, although the above would still apply for different subjects designs.

"The ultimate test of uniformity or reproducibility is not to be found in the methods used but in the degree of control achieved, a test which the experimental analysis of behaviour usually passes easily" Skinner (1966; p.21). What Skinner means by control is the direct and immediate effect on the cumulative record, resulting from the introduction of some independent variable. As the cumulative graph plots behaviour over time, stable baseline performances can be easily achieved. As a result, any introduction of the independent variable can be noticed immediately as a change from the baseline condition.

Secondly - the absence of inferential statistics.

Skinner's argument here is based on the fact that behaviour can be observed directly i.e., no inferences have to be made about it. "If statements about the inner system cannot be directly confirmed, hypotheses must be set up, and theorems deduced and tested, following established practices in logic and scientific method" Skinner (1966; p.20).

Another argument against the role of statistics in the experimental analysis of behaviour is that statistical results themselves do not constitute a basic process; whereas

an increase in rate of responding shown by a steeper curve on the cumulative record as a result of, say, an increase in rate of reinforcement can be regarded as such. This fundamental principle, Skinner believes, does not require statistical methods to show its efficacy. "Statistical techniques may eliminate noise, but the dimensions are still faulty" Skinner (1966; p.20).

Lastly, experimental design terms prescribed by statisticians have been stated by Skinner to be not very fruitful when employed in the experimental analysis of operant behaviour. He believes, in fact, a design such as the Latin Square might be a severe handicap to the operant experimenter.

In this series of experiments terms such as 'different subjects designs', 'Independent Variable', 'Dependent Variable', 'Extraneous and Confounding Variables', taken from experimental design literature are used, but the formal logical designs of the statistical school are not strictly adhered to.

Thus in the following four experiments the independent variable is the rate of responding during acquisition maintained by the subjects. In experiments I, II and III the rate of responding was not manipulated directly. The schedule of reinforcement was manipulated in the belief that the schedule (Interval schedules) and the rate of responding vary directly, as shown by Skinner (1938; p.128). In the fourth experiment the rate was manipulated directly using rate based reinforcement schedules.

In all of the experiments the dependent variable was not the familiar rate of responding as in most operant studies, but rather the number of responses produced within a certain period of time without reinforcement - Extinction.

Many different measures of resistance to extinction are available - i.e., number of unreinforced responses within a certain period of time, a low criterion rate of responding

or time taken to reach a zero-rate of responding. Early investigators such as Finan (1940), Williams (1938) and Koch and Daniel (1945), who used resistance to extinction as a measure of operant strength, all stated that the number of non-reinforced responses produced during a certain period of time proved the most reliable measure. Youtz (1938), Skinner (1938) and Strassburger (1950) also favoured the use of this measure.

Thus in the present experiments resistance to extinction was measured by the number of responses produced during four consecutive days (approximately one hour per day) of continuous non-reinforcement.

Control of all extraneous or confounding variables in any experimental design is of utmost importance, for it allows one to categorically state (if they are well controlled), that any change in the dependent variable is the direct result of the manipulated change in the independent variable. Operant experiments are no exception, and simple physical extraneous variables, such as; sudden noises, light, movements etc. are screened out using the Skinner Box and related equipment (see part (iii) of this chapter).

More importantly, however, are the procedural and other methodological factors that could become confounding variables depending on the particular aspect of behaviour under study. In this series of experiments where resistance to extinction is the dependent variable, any variable known to effect this dependent variable, other than the independent variable, must be controlled for. These known variables include; the schedule of reinforcement, the number of reinforcements, the number of responses, the amount of reinforcement, the level of deprivation, the number of acquisition trials, and the amount of similarity between acquisition and extinction conditions - the "Generalization Decrement Hypothesis" of Mowrer and Jones (1945). A further possible confounding variable was noticed during the first three experiments, and

its control was attempted in the fourth experiment. This variable was termed "Time-in-Schedule".

A SHORT SUMMARY OF THE RELEVANT CONFOUNDING VARIABLES AND THE METHODS USED TO CONTROL FOR THEM.

1) The Schedule of Reinforcement.

The influence of the gross effects (e.g., Partial v continuous reinforcement), on resistance to extinction have been well documented. Jenkins and Stanley (1950) in an exhaustive review conclude "All other things being equal, resistance to extinction after partial reinforcement is greater than after continuous reinforcement, when behaviour strength is measured in terms of single responses" (p.222). In their table III (p.215) showing studies comparing the effects of partial v continuous reinforcement on resistance to extinction, only three of the cited seventeen studies reported results opposite to that concluded by Jenkins and Stanley.

An important qualification of their conclusion (above) is the phrase "All things being equal". This is because the number of reinforcements presented is a contaminating variable. However, studies by Humphreys (1943) and Jenkins and Rigby (1950) with number of reinforcements equated, still found differences significant at the 1% to 5% levels between continuous and partial schedules with regard resistance to extinction. Obviously with any comparison between continuous and partial schedules, the time the animal spends under experimental conditions will be different. However, the influence of this variable in the Jenkins and Rigby (1950) study seemed to be minimal and they concluded "This analysis holds, if the present contention is valid, that time in the experimental situation per se is not the critical variable" (p.38).

Differences, other than those numerically measured also exist between the effects on resistance to extinction of partial versus continuous reinforcement. Skinner (1938)

showed qualitative differences in the shape of the curve produced by the cumulative recorder during extinction. After partial reinforcement (in this case periodic or fixed interval), the extinction curve seemed to rise more slowly, reach a higher asymptote, fall-off more slowly and lack much of the fluctuation associated with extinction curves after continuous reinforcement (p.138).

Some explanation of these differences in resistance to extinction is offered by Schoenfeld (1968). The reasoning is that with regular or continuous reinforcement there is a high probability after a response has been produced that a similar response will be emitted to produce the next reinforcement.

With partial reinforcement (fixed interval), on the other hand, an extinction period follows the reinforced response, during which a number of responses will not be reinforced. During this time argues Schoenfeld (p.260) the response form is weakened until the strength of the form of response which produces reinforcement is no greater than other competing response forms - "in this way continually expanding the number or range of equally strong sub-categories from among which, one will finally produce reinforcement" (p.260).

Thus, when extinction proper begins there will be a great variety of response forms, and responding will continue for a longer period of time. This reasoning also explains why, in general, resistance to extinction as a result of aperiodic (variable interval) is even greater than that of periodic schedules. For here the response variability for the long intervals during acquisition is a result of the fact that more different forms of response (or sub-categories as Schoenfeld calls them) have been conditioned.

This conveniently leads to a discussion of differences in resistance to extinction which result from the patterning of reinforcements in a partial reinforcement schedule. Only the four basic schedules (FR, FI, VR and VI) will be dealt with here.

schedule of reinforcement was exercised in all comparisons across subjects - i.e., within any one experiment the same schedule of reinforcement was presented to all subjects, differing only in the rate of reinforcement each produced. (Note: in Experiments III and IV the schedules presented to each subject are identical, although the discriminative stimuli associated with each of the components varied from subject to subject).

2) The Number of Reinforcements.

This variable has already been mentioned as a control in experiments comparing differences in resistance to extinction resulting from continuous versus partial reinforcement.

A systematic study into the relationship between number of reinforcements and resistance to extinction was performed by Williams (1938). His conclusions were clearcut - "The greater the reinforcement the greater the resistance to extinction" (p.510).

A further study into the relationship between these two variables was reported by Wilson (1954, Exp.II). Wilson used five values on the number of reinforcements variable, and found that the resulting function, plotted against number of responses in extinction was linear and negatively accelerated, as did Williams (1938).

Thus, control for this variable was exercised by equating numbers of reinforcements between subjects in the different subjects designs, and between schedule components in the single subjects designs. In experiments I and II 50 reinforcements per day were presented, in experiment III 54 were presented (3 components of 18 reinforcements each) and in experiment IV 48 were presented (2 components of 24 reinforcements each).

3) The Number of Responses.

With ratio schedules the relationship between response requirement and resistance to extinction has been found to be similar to that between reinforcement and resistance to extinction - i.e., a linear and negatively accelerated function (Boren, 1961 and Hearst, 1961).

With interval schedules, however, the number of unreinforced responses still remains an important influence on resistance to extinction, but one which generally cannot be systematically controlled.

Thus, in the present series of experiments response rate was used as the independent variable. This counters the effect of total number of unreinforced responses on resistance to extinction by dividing the number of responses by the time taken to produce them. In these experiments the overall rate of responding was used as the independent variable, although local rates of responding were measured and recorded.

4) Amount of Reinforcement.

The effect of amount of reinforcement on rate of responding during acquisition and maintenance of behaviour has been studied by a number of investigators (Guttman, 1953; Jenkins and Clayton, 1949; and Keesey and Kling, 1961). The influence of this variable on maintained responding and resistance to extinction is far from clear.

Keesey and Kling (1961) report results from preliminary experiments which ".... suggest that the stable rate of responding which results from continued exposure to a given reinforcement schedule is relatively insensitive to manipulations of the reinforcing substance" (p.126). Even after procedural modifications included in their 1961 study they still concluded that amount of reinforcement had no effect on response rates, once these response rates had been stabilized on a day to day basis.

Guttman's (1953) results are more pertinent to the present study, for he included resistance to extinction as one of his dependent variables. The general finding with regard resistance to extinction was that amount of reinforcement (here measured as sucrose concentration) had a positive effect early on in the extinction procedure, but its influence waned as extinction was prolonged. "Resistance to extinction in terms of rate of responding in the initial 15 mins. of extinction is an increasing monotonic function of the concentration used in conditioning. For the first 5 mins. the relationship is approximately logarithmic" (p.223).

As the time involved, during which amount of reinforcement does have an effect, the first 15 mins. is small in relation to the period of extinction in the present experiments (4 X approx. 1 hour), it was seen not to be an important confounding variable.

More as a result of convention in operant methodology than any influence it has on the dependent variable, the amount of reinforcement in the following experiments was controlled for - 4 secs. free access to grain in all of the experiments.

5) Level of Deprivation.

With partial reinforcement schedules the level of deprivation has an important influence upon rate of responding during acquisition. Clarke (1958) studied the effect of deprivation on acquisition responding using variable interval schedules and found that: "In general, equal increments in rate of responding where frequency of reinforcement was higher" (p.227). Within each schedule and with reinforcement frequency kept constant, Clarke found that the higher the level of deprivation the higher was the rate of responding (FIG.1, p.224; 1958).

With regard the influence of level of deprivation on resistance to extinction Strassburger (1950) concluded, "....

... there is no clear evidence of a trend toward greater resistance to extinction of the reflexes reinforced under more intense drive" (p.482).

However, there are a number of studies which have produced results which conflict with those of Strassburger's, namely Sackett (1939), Perin (1942) and Skinner (1938; pps. 390-402). With reference to these studies Strassburger argued that their conclusions can only be valid if the unconditional rate of responding of the animal is unaffected by an increase in drive. According to Strassburger, these investigators did not obtain a measure of operant level to establish a control condition and thus their results merely show the effect of drive on operant level, rather than on resistance to extinction.

Again, the results of experiments showing the effect of drive on resistance to extinction appear inconclusive. The balance, however, must be weighed in favour of drive having some effect on resistance to extinction, and thus in the present experiments this variable is controlled for.

Following traditional practice drive levels have been standardized using percentage body weight - all the subjects in each of the experiments was maintained at 80% (\pm 15 grams) of their ad libitum body weight.

6) Number of Acquisition Trials.

Wagner (1961) reports "there were no reliable differences between the experimental groups receiving only these 16 acquisition trials and those which subsequently received 44 additional trials" (p.237).

However, in this study by Wagner a factorial design involving amount of reinforcement, percentage reinforcement and number of acquisition trials was utilized. The findings here were that with large rewards the resistance to extinction was greater as a result of a higher number of acquisition trials.

With small rewards the reverse was found to be true.

In the present series of experiments the number of acquisition trials always remained the same for the subjects participating in each experiment. For purely practical reasons the number of trials (1 per day) in the experiments varied from 20 to 45.

The number of reinforcements (or intervals plus one) was always the same for subjects within each experiment, but varied slightly from experiment to experiment.

TABLE (1) NUMBER OF TRIALS, NUMBER OF REINFORCEMENTS FOR EACH EXPERIMENT.

	Schedule	No.of Trials	No.of rein- forcements in each trial
EXPERIMENT I	FI	45	50
EXPERIMENT II	VI	40	51
EXPERIMENT III	MULT FI	41	55
EXPERIMENT IV	MULT CONJ FI FR (DRL) FI FR (DRH)	20 (at criterion level)	49

7) "Time-in-schedule".

The problem with this variable is that if a partial reinforcement schedule is to be used as an independent variable it is almost impossible to control both number of reinforcements and "time-in-schedule". Wilson (1954) was forced to state "Lacking experimental evidence, we felt that the number of reinforcements was the more important variable, and this was held constant" (p.52).

There is some indirect evidence which suggests that time in the experimental situation has no effect on resistance to extinction. This evidence comes from Jenkins and Rigby (1950) who stated "Time in the experimental situation during conditioning could hardly have been playing more than a minor role as a concomitant of the method of partial reinforcement employed" (p.38).

In the present series of experiments time in the experimental situation, for the most part, was not controlled for. In experiment IV, however, in an attempt to isolate any critical factors which might affect purely the influence of rate of responding on resistance to extinction, "time-in-schedule" was controlled for using a modification of the schedule used by Fantino (1968) and here called a MULTIPLE CONJUNCTIVE FI FR (DRL), FI FR (DRH).

8) The Generalization Decrement Hypothesis.
(Mowrer and Jones, 1945).

This hypothesis refers to the amount of generalization between training conditions and extinction conditions. It briefly states that if the acquisition period resembles to some extent the extinction period (as is the case with long FI schedules or VI schedules), the subjects will find it increasingly difficult to discriminate between the two conditions so that the rate of responding during extinction will not be greatly affected by the transition from acquisition to extinction. In contrast a clear differentiation between conditioning and extinction exists for a schedule in which each response is reinforced during acquisition.

According to this view, then, caution should be exercised when studying the effects of interval schedules on resistance to extinction, to make sure that the difference between the interval lengths is not so great as to allow the generalization decrement hypothesis to play some confounding role. In the present series of experiments differences between scheduled intervals was kept to 20 seconds.

Taking cognizance of these confounding variables and their suggested controls outlined above, the experiments described in the following chapter attempt to investigate the relationship between rate of responding during acquisition - the independent variable, and resistance to experimental extinction - the dependent variable.

(ii) Subjects.

All 12 subjects used in this study were male homing pigeons aged between 1 and 3 years. The age restriction was enforced so as to ensure a uniform body structure, and hence to some extent, a uniform weight distribution between the birds.

The birds were housed in standard Lopis Pet Products cages measuring 0,92m by 0,37m by 0,28m. There were approximately 40 pigeons at any one time housed in the pigeon room which measured 3,1m by 3,02m. The floor of the cages was covered with newspaper which was replaced twice weekly. Fresh water from a half-litre bottle, and supplied through a Lopis Water Dispenser was available at all times to the birds.

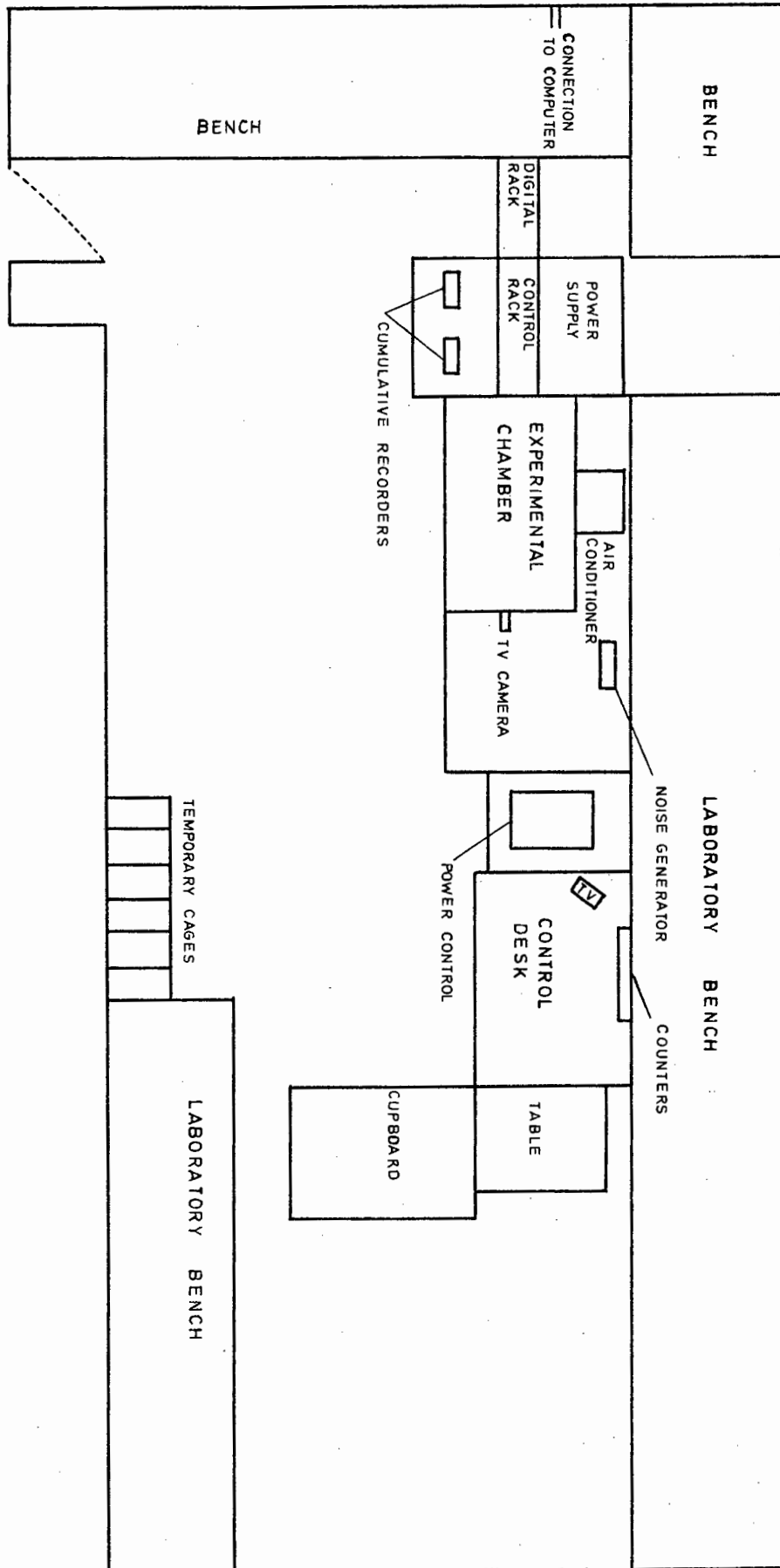
The food for the experimental birds consisted of mixed grain of standard size (approximately 0,2 cm). The mixture comprised vetch, crushed maize and hemp seed. The same grain mixture was used both for feeding the birds in their cages, and for reinforcement in the operant chamber.

Identification of the birds was accomplished through the use of metal bands on their legs, and numbers marked on the back walls of their cages.

During the running of an experiment the birds' weights were recorded daily using a beam balance, on which a container holding the bird was placed. Handling of the birds was minimized by using this container to transport them to and from the operant laboratory - a distance of about 25 metres.

FIG (21) PLAN OF LABORATORY

SCALE 1 M= 30mm.



(iii) General Apparatus.

This section consists only of a description of the equipment used throughout the present series of experiments. However, under the "Apparatus" heading in each of the experiments reported in chapter 3 there will be a description of the programming equipment used in that experiment.

The apparatus used in all of the experiments can be placed in the following five categories:

- A) The Operant Laboratory.
- B) The Outer Sound-Proofed Chamber.
- C) The Inner Operant Chamber.
- D) Control Equipment.
- E) Recording and Monitoring Equipment.

A) The Operant Laboratory.

This was a large room measuring 7,7m by 3,92m, set aside for operant research and situated in a building adjacent to the Department of Psychology. This building housed a number of laboratories for experimental psychology, a workshop and a computer room.

As the "double-box" technique was employed in this study, the recording, programming (except for the computer) and monitoring equipment, and the operant chamber itself were situated in the same room. The laboratory was airconditioned and slightly sound attenuated, in the form of carpeted floors and sound proofing around the door joints. (see FIG.(21) for a floor plan).

B) The Outer Sound-Proofed Chamber.

The basic construction consisted of a double aluminium angled frame (2,4cm x 2,4cm x 0,25cm). The outer walls were hardboard (0,8cm thick) and measured; length 1,07m,

width 0,73m and height 0,78m. The inner walls were aluminium sheeting (16 gauge) and measured; length 0,91m, width 0,53m and height 0,61m. The chamber was made soundproof by packing the space between the walls with polystyrene.

The front wall was hinged by two brass piano hinges and served as an entrance to the chamber. Where this door joined the chamber there was sponge-strip soundproofing. This door was held shut by magnetic catches.

Into a hole cut from the back wall of this outer chamber was fitted an Amana Refrigeration Incorporated Portable Air Conditioner. The capacity of this unit was 6000 B.T.U's at 1200 watts and its moisture removal rate was 0,909 litres per hour. Cool air was blown into the space between the outer chamber and the inner or operant chamber, and had the effect of indirectly cooling the air in the inner chamber. The temperature inside the inner chamber was thermostatically controlled to vary between 20°C (68°F) and 22,2°C (72°F).

C) The Inner Operant Chamber.

This was a standard B.R.S. Foringer (P.H.series) 3-key Pigeon Chamber measuring 0,74m x 0,51m x 0,42m outside and 0,685m x 0,42m x 0,355m inside. The actual dimensions of the chamber in which the pigeon was housed during the running of an experiment were 0,50m x 0,42m x 0,36m - the remaining space contained the front panel ("operant panel") and related equipment.

On the front panel were three plexiglass response keys 1,8cm (3/4") in diameter, which required a force of 15 grams to activate the switch closure. Ouring the present series of experiments the two outer keys were blanked off by aluminium covers - only the centre key was utilized.

The distance from the centre of the middle key to the mesh floor was 20,5cm, and to the food hopper opening 13,0cm.

The food hopper opening itself was 5,6cm long and 4,5cm wide. The distance from the centre key to the outer key was 10,0cm, and that from the centre to the walls of the chamber 18,0cm.

Behind each response key was an Industrial Electronic Engineering Incorporated In-Line Digital Display (I.D.D.) unit. This unit could project onto the key any of the following colours or patterns: red, turquoise, green, white and yellow; triangle, square, circle, cross, plus-sign, horizontal line and vertical line.

Also housed behind the front panel was the feeder mechanism and its associated control circuitry. The feeder tray was raised mechanically by a solenoid operating off 110v.A.C. The solenoid itself was energized via a switch closure controlled by a reinforcement timer on the control rack (see Appendix 3)

Also mounted behind the front panel was a speaker for the white noise generator. Although outside noise up to about 20-30 db was attenuated by the soundproofing of the inner and outer chambers, white noise of 72 db was introduced into the operant chamber. This was accomplished using a Grason Stadler Model 901B Noise Generator, and was presented continuously during the running of the experiments.

The floor of the operant chamber was 10 gauge wire mesh mounted on a frame of aluminium and standing 8cm above the floor of the chamber itself. Under this mesh newspaper was spread for ease of cleaning. The mesh was used for it provided the pigeon with a surface on which it could stand and walk easily.

A small water container (9,5cm by 5,0cm by 4,5cm) was placed in the corner of the chamber furthest from the front panel, and was supplied with fresh water throughout the experiments.

The chamber was illuminated by a 220v 60 watt strip

light mounted on the opposite wall to the front panel. It was found that the 60 watt light operating on full power was too bright for the box, and dissipated a great deal of heat. Thus the voltage to this light was dropped to 110v, which made it compatible with the reinforcement relay to which it was connected. The two 28v 6 watt lights mounted above the keys on the front panel, and supplied by the manufacturer, were not used as the wattage was too low for the closed circuit television camera to operate efficiently. This strip light was wired via the reinforcement relay so that when reinforcement was presented, and the 28v 6 watt reinforcement light activated, the houselights were switched off.

Also mounted behind the front panel was a "noisy" 28v relay, which was connected to the pecking key circuit. This provided auditory feedback to the pigeon in order to stabilize its response topography.

The walls of the operant chamber were painted matt white, to help with illumination and to avoid reflection. The front panel was brushed aluminium - also a protection against reflection and glare.

Adjacent to the outer chamber was a cage measuring 93cm by 28,5cm by 32cm, with six small compartments (width 15cm), which was used for the temporary housing of the experimental subjects either prior to their being placed in the operant chamber or just after they had been taken out. (see FIG.(21)).

D) Control Equipment.

In this section only the control equipment which remained unchanged throughout the experiments will be discussed. This equipment essentially consisted of three parts (i) key control, (ii) reinforcement control and (iii) general control. (see Appendix 3)

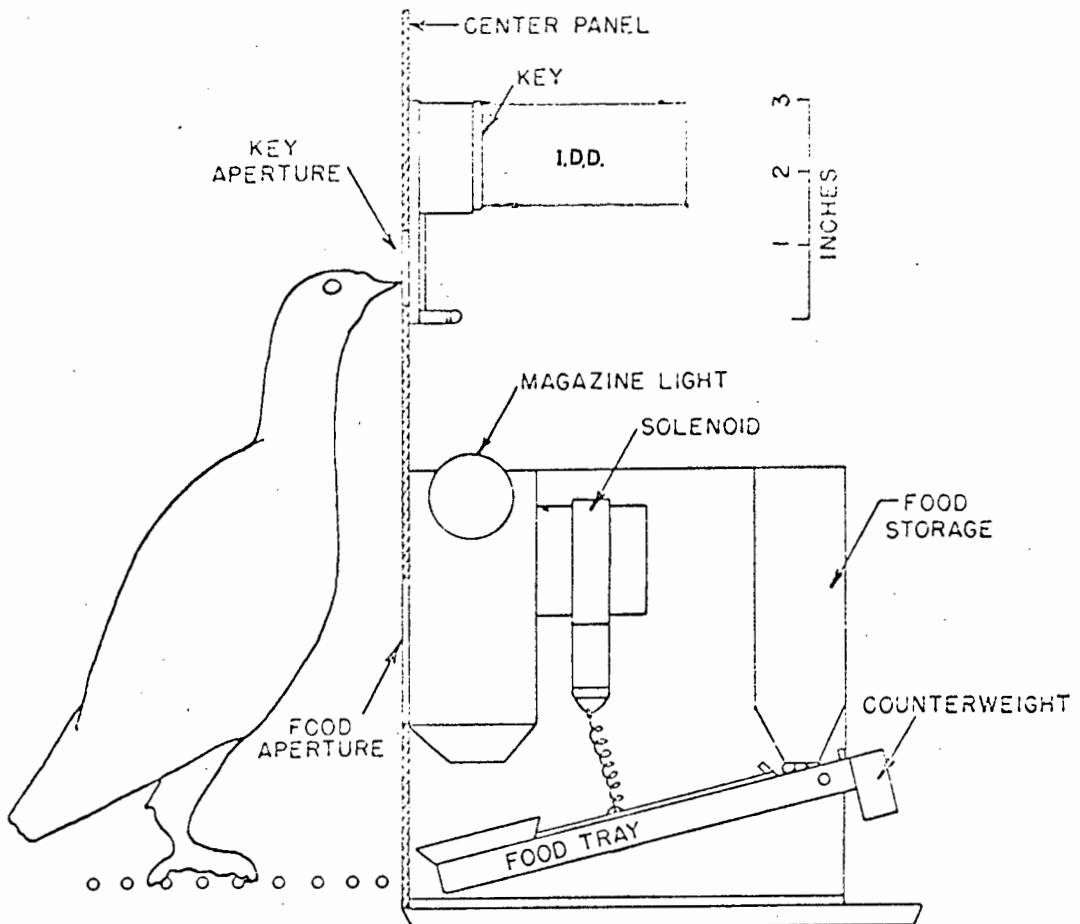
i) Key Control.

A switch closure originating at the pecking key (see Appendix 3) on the front panel of the operant chamber was transformed into a negative going pulse of approximately 10 milliseconds and outputted through the N.O. (Normally Open) contacts of each key. This was achieved by connecting GROUND (-28v) to the key COMMON (see Appendix 3)

Also part of key control was the control of the stimulus projectors. Each stimulus had its own connecting plug and was projected onto the key when the plug was connected to -28v. In the computer controlled experiments switch closures from the interface were used to control the stimulus presentations.

The ground connection to operate the key lights was wired through the AT REST function of the reinforcement timer. Thus the key lights (or patterns) remained on whenever the timer was not operating.

FIG.(22). Side view of experimental chamber and associated apparatus (Ferster and Skinner (1957; p.15).



ii) Reinforcement Control.

Reinforcement presentation was timed in experiments I and II by a Lehigh Valley Electronics Incorporated (No. 253-21) Universal Timer. A switch closure between the START and -28v (GROUND) contacts of the timer began its operation. During the timing sequence a set of contacts (TIMING and COMMON) remained closed and caused the feeder solenoid to be activated. A hand reinforcer was also connected between the START and -28v contacts, for manual reinforcement.

This reinforcement timer also controlled the houselights (except in experiments III and IV), through its AT REST contact. This meant that whenever the timer was not in operation, the circuit for the houselights was closed. When the timer was in operation (i.e., when a reinforcement was being delivered) the circuit for the houselights was interrupted.

iii) General Control.

A switchboard controlling current flow to all the apparatus was located near the control desk (see FIG.(21) - plan of laboratory). This board contained a master switch which could, at the termination of an experiment, switch off all of the controlling equipment.

Also part of the control rack was a bank of twelve 28v, 20 milliamp double pole relays which carried out numerous functions. These functions will be covered under the heading "Recording and Monitoring Equipment" in this section and under "Apparatus" in each of the experiments in chapter 3.

E) Recording and Monitoring Equipment.

The recording of all responses and reinforcements was accomplished using Hengstler digital counters (28v, 210 ohm,

25 impulses/second). As these counters were operated by positive going pulses, the negative pulses originating from the key control had to be transformed. This was achieved using one of the bank of 28v relays. The negative going pulse from key control operated the relay. A positive (+28v) source was fed into the COMMON contact of the relay, and when switched by a key peck, outputed a +28v pulse to the counter. All the counters were at a common ground (negative).

Reinforcements were counted in a similar way. The COMMON contact of the END PULSE function of the Universal Timer was connected to GROUND (-28v). At the end of the reinforcement period this negatively going pulse was outputed through the N.O. contact of the END PULSE. This was then transformed into a +28v pulse to operate the reinforcement counter using a relay in the same manner as the response counter circuit.

Two Gerbrands cumulative recorders (Model C3-SHS, 110v AC) were used in the present study. One functioned in its normal capacity, plotting cumulative responses over time. The other was used to show local response rate, and was reset to the baseline after each reinforcement.

The response and reinforcement steppers of the cumulative recorders required digital pulses. These were supplied via the "digital rack" (see Appendix(3) - programming circuit for VI schedules). Switch closures obtained by the application of a negative going pulse from the key to a 28v relay, were fed into a input shaper on the digital rack. This input shaper transformed the switch closure into a digital pulse (approx. 200 milliseconds) which then stepped the response pen.

The reinforcement stepper operated in a similar manner. A negative going pulse from the END PULSE function of the Universal Timer closed the COMMON and NO (Normally Open) contacts of a 28v relay. This closure was fed into an input shaper which transformed it into a digital pulse. A similar operation was performed for the RESET function of the local response rate cumulative recorder.

PRECISION TIMER
R.A.T. TIMER

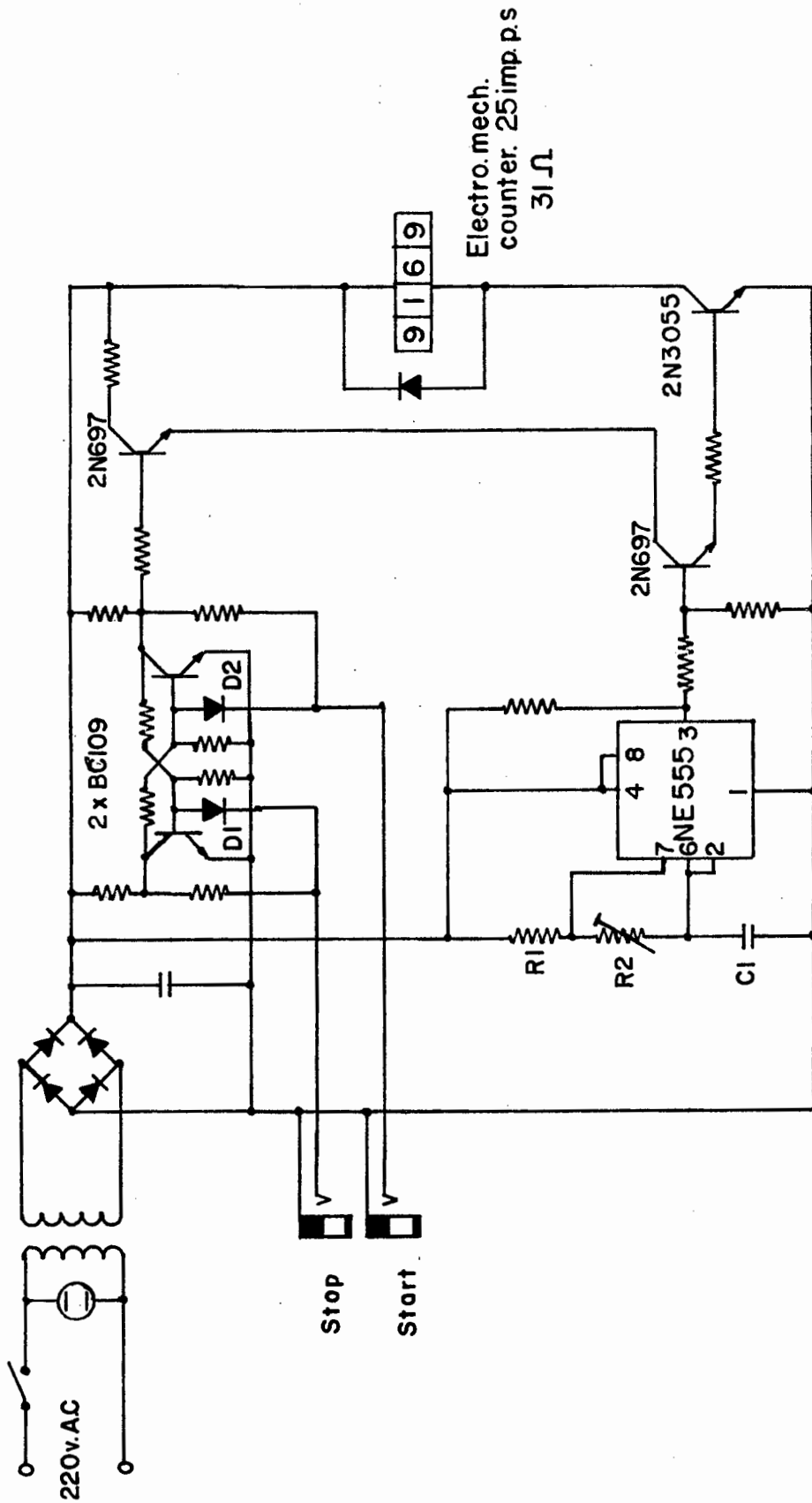


FIG. 23

In studies utilizing interval schedules of reinforcement, there is a period of time when the schedule interval has ended, but the subject has not made the required response to produce reinforcement.

In the present study this period of time was called "Reinforcement Availability Time" (R.A.T.) and was recorded in experiments I and II using an R.A.T. timer. In experiments III and IV this was recorded by computer.

This timer was activated by a switch closure originating from the END PULSE of the interval timer in the fixed-interval schedule, and by a switch closure from the computer interface in the variable interval schedule. The timer's operation was halted by a switch closure from the END PULSE of the reinforcement timer.

It was thus necessary to subtract reinforcement time (this was always constant - number of reinforcements multiplied by reinforcement time (4 secs.)), from the total recorded R.A.T. in order to calculate the actual R.A.T. Originally the STOP phase of the R.A.T. timer was connected to a circuit which recorded the first response after the end of the interval. However, it was found during a preliminary experiment that occasionally this period was so short (<0,10 seconds) that the timer could not switch fast enough.

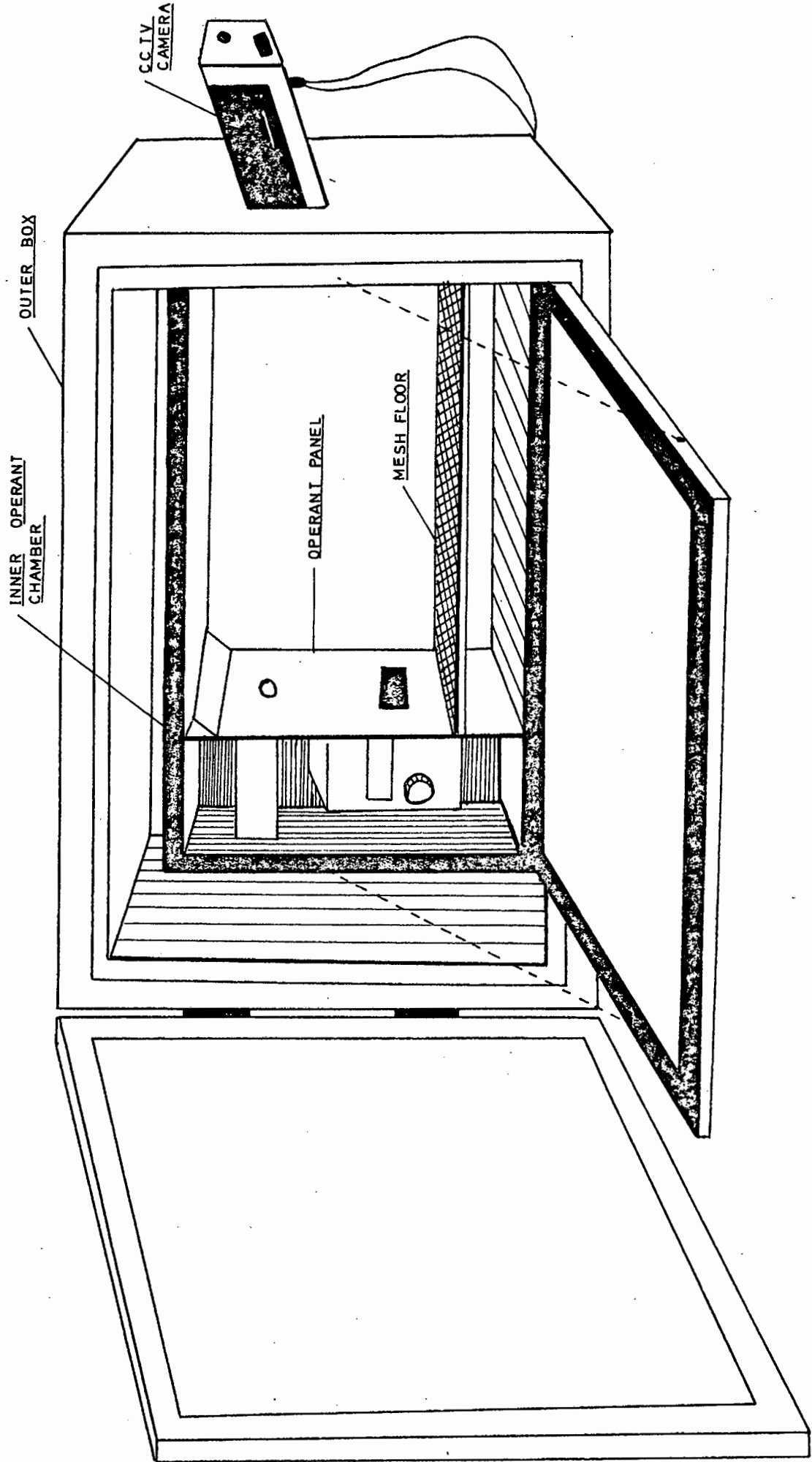
The timer itself was designed and constructed in the Psychology Department Workshop. The circuit utilized a SIGNETICS NE555 integrated circuit connected in the astable mode. In FIG.(23) the circuit triggers itself and free runs as a multivibrator. The frequency of oscillation was set by the formula

$$F = \frac{1}{T} = \frac{1,44}{(R1 + 2R2)C}$$

where;

F	=	frequency
T	=	time
R	=	resistance
C	=	capacitance
1,44	=	manufacturer's constant.

FIG(24) SKETCH OF THE "DOUBLE BOX"



NOT TO SCALE

the bird's back, the three response keys and the feeder opening - the last image being important for the detection of any malfunctioning of the hopper light.

iv) Procedure.

The method of per cent body weight (Ferster and Skinner (1957; p.29) for controlling deprivation was used in this study. In common with much of the recent literature in the field of the Experimental Analysis of Behaviour a deprivation level of 80% of ad libitum (full body) weight was used throughout the study.

The procedure used to arrive at the 80% body weight level was similar to that of Ferster and Skinner (1957; p.29). The birds were first weighed over a period of five days, during which they had free access to food, to establish a uniform ad libitum weight. When this weight was roughly constant, the 80% target weight was calculated.

The deprivation procedure began with a period of two days during which the bird was not fed at all. On the third day approximately 5 grms of grain were given to the birds (at the same time each day) until their weights had reached the target weight.

This 5 grams was given to each bird in the operant chamber. During this orientation period, which lasted approximately four days, the birds were placed in the operant chamber with the houselights and white noise on, but with no other stimuli present. The 5 grams of food were placed on a small piece of card directly below the reinforcement hopper opening. This was done to facilitate the second period of training - namely feeder training.

This second period of training began when the bird had reached its 80% target weight. When this occurred each bird was given 12 to 15 grams of food per day, depending on

body weight in order that the 80% level be maintained. In accordance with other studies in this area 80% deprivation level was given limits of \pm 15 grams.

Feeder training sessions began with the placement of a small amount of grain on a card in front of the feeder as before. When the bird had nearly finished this grain the hopper was raised for 30 seconds. During this 30 second reinforcement the houselights were switched off and the hopper light was on. Only in a few cases did the bird eat from the hopper on its first presentation. When the bird did not eat immediately it was left to finish the food in front of the hopper. The hopper was then raised for 30 seconds every minute, until the bird began to eat from it. When this happened the hopper was left up for up to 2 minutes, depending on the amount of emotionality shown by the bird. The length of time the hopper was raised was gradually reduced to 10 seconds by the end of the first day of feeder training.

The second day of feeder training comprised 30 reinforcements of 10 seconds each, and 30 reinforcements of 5 seconds. In the event of any emotionality on the part of a bird when exposed to only five seconds reinforcement, the hopper was kept up for a longer period of time.

After 3 days all 12 birds had managed to eat from the hopper, and to move rapidly toward the hopper when its discriminative stimuli were presented.

This then led to the third and final phase of initial training - the acquisition of the key peck response. This was accomplished using the Ferster and Skinner (1957; p.31) technique of placing a piece of grain on the pecking key. (In this study the pecking key was lighted during this training). A continuous reinforcement or FR1 circuit was in operation, so that any closure of the contacts behind the pecking key, gave immediate reinforcement. Thus the first day of key peck training consisted of the above procedure for 60 reinforcements. All

the birds pecked the key and were reinforced on FR1 during this first day.

The second day of key peck training consisted of 60 reinforcements with the grain removed and the discriminative stimulus present. This second day of FR1 training completed the initial training period.

Even during this initial training period every possible effort was made to ensure that all birds had the same number of reinforcements. Occasionally this proved extremely difficult, when individual differences in speed of acquisition of these elementary responses was in evidence. However, this time period (approximately 2 days) in relation to the time span of the complete experiment (35-45 days) was very small, and its influence on the consequent schedule minimal.

The third day of training normally consisted of 60 reinforcements on an FR1 schedule. There were, however, differences in procedure from this stage onwards, and discussion of these further training procedures will be found under PROCEDURE in each of the four experiments in chapter 3.

CHAPTER 3

EXPERIMENT I - An investigation of the relationship between rate of responding and resistance to extinction utilizing a different subjects design and Fixed Interval Schedules of Reinforcement.

i) Introduction.

Wilson (1954) using periodic (fixed) intervals ranging from 10 secs to 6 mins, found; firstly, that rate of responding was related in a downward sloping curvilinear fashion to the length of the periodic interval; secondly, that resistance to extinction was related to periodic interval length in a generally upward sloping fashion; and thirdly, that rate of responding and resistance to extinction were not related in any systematic way (see FIGS.(8), (9) and (10) above).

Catania and Reynolds (1968) found that individual differences confounded any generalized statement as to the relationship between rate of responding and rate of reinforcement (interval length) with fixed interval schedules, although a trend towards higher rates of responding with higher rates of reinforcement was apparent. (p.357). They presented no data as to the relationship between rate of responding and resistance to extinction with fixed interval schedules.

The present experiment attempted to replicate Experiment I of Wilson's (1954) study, utilizing several modifications in procedural detail. Firstly, pigeons were used as the experimental subjects, mainly because numerically their rates of responding and their number of responses to extinction are higher than rats, thus allowing more detailed analysis of the results.

Secondly, the now standard procedure of fixed interval scheduling was used, rather than the external clock method used by Wilson (1954; p.52). In fact, Wilson mentioned two alternative methods of scheduling periodic reinforcements -

the interval could be timed from each reinforced response, or timed by an external clock from the beginning of the experimental session.

Timing by external clock provides reasonably accurate interval lengths, but makes the calculation of local response rates extremely difficult. The other alternative mentioned by Wilson was that the interval be timed from the previous reinforced response. This again introduces difficulties for the minimum specified interval length must be extended to include the reinforcement presentation time.

Ferster and Skinner (1957; p.133) mentioned two further alternatives. Firstly, the interval could be timed from the end of the previous interval, thus maintaining the designated fixed interval length. Again this interval will be eroded by reinforcement time and reinforcement availability time. The second alternative presented by Ferster and Skinner (1957; p.133) was the one adopted here. The interval was timed from the end of the previous reinforcement, thus eliminating the need to add on reinforcement time to the interval length. The reinforcement availability time was measured by a R.A.T. timer (see page (69) above) and was added to the interval length in the calculation of response rates.

ii) Design.

A different subjects design was utilized here, with each subject being assigned to a specified value of the independent variable.

The independent variable was the rate of responding, which was controlled by manipulations of the interval length. The relationship between interval length and rate of responding (see pps. (12) to (21) above) was utilized to achieve control over the rate of responding.

The measure of rate of responding was obtained by dividing the total number of responses produced in each experimental session, by the product of the interval length and the number of intervals, to which was added total R.A.T.

$$\text{Rate of responding} = \frac{\text{TR}}{(\text{I} \times \text{N}) + \text{T.R.A.T.}}$$

where TR = total number of responses in each session.
 I = interval length (minutes).
 N = total number of intervals in each session.
 T.R.A.T. = total reinforcement availability time in each session.

The dependent variable was resistance to extinction, measured by the number of responses produced during 4 hours of extinction (no reinforcement) - 1 hour per day for four days.

TABLE (2). Design of the experiment.

SUBJECT	SCHEDULE	EXTINCTION
B6	FI 40	4 hours
B5	FI 60	4 hours
B7	FI 80	4 hours

iii) Subjects.

Three experimentally naive male homing pigeons - numbers B5, B6 and B7 were used. (For more details see section (ii) of Chapter 2 above). During the running of the experiment they were kept at 80% of their ad libitum weight (\pm 15 grams) according to the following schedule;

TABLE (3). Schedule of Body-weight reductions (grams).

SUBJECT	AD LIBITUM WEIGHT	80% TARGET WEIGHT
B5	503	402
B6	467	374
B7	446	357

iv) Apparatus.

All the apparatus used in this experiment has been described above (section (iii) Chapter 2), except for the fixed interval programming equipment, which essentially consisted of adding another Lehigh Valley Inc. Universal Timer to the reinforcement timer already in operation.

The fixed interval schedule specifies that a certain minimum period of time must pass when no response can produce reinforcement, after which the first response emitted is reinforced. In the present experiment this was achieved by connecting the pecking key circuit, through the AT REST phase of the interval timer, to the START phase of the reinforcement timer. This meant that whenever the first timer was in operation (i.e., when timing the fixed interval) the circuit between the pecking key and the reinforcement timer was interrupted. When the timer had completed timing the fixed interval, the circuit was closed and the negative going pulse of the first response was allowed free passage to the START phase of the reinforcement timer.

Control over the discriminative stimulus, which throughout this experiment was a red light on the pecking key, was achieved by connecting the S^D circuit through the AT REST phase of the reinforcement timer, so that whenever the timer was not in operation (i.e., not timing a reinforcement presentation) the S^D was on.

The reinforcement availability time (R.A.T.) timer's START phase was connected to the END PULSE of the interval timer. To stop the timer the END PULSE of the reinforcement timer was used. This meant that total reinforcement time had to be subtracted from total R.A.T. to give the actual R.A.T. FIG. (23) on page (69) shows the circuit diagram for the fixed interval schedule.

v) Procedure.

Initial training of the pigeons was as described in section (iv) Chapter 2. Following on from this four days of continuous reinforcement (60 reinforcements per day) to the S^D were given to each bird.

Fixed interval training began with FI 10 secs., and was raised by 10 secs- per day, until each bird achieved its target schedule;

BIRD	B5	FI	60 seconds
BIRD	B6	FI	40 seconds
BIRD	B7	FI	80 seconds

To equate the number of trials, B6 was put onto extinction two days before B5, who was put on two days before B7.

Extinction sessions were started when the pigeons attained behavioural stability. This was defined as - the state in which the response rate for the previous 10 days, varied by less than 20% from the mean response rate over that 10 days. This behavioural stability criterion is obviously arbitrary, but its presentation here answers a criticism of operant studies by Cumming and Schoenfeld (1960; p.71), that most of the researchers have implicit criteria, but fail to make them explicit.

Extinction consisted of the disconnection of the

TABLE (4)	MEAN NUMBER OF RESPONSES PER REINFORCEMENT	
BIRD NO.	SCHEDULE	RESPONSES/REINF.
B 6	FI 40	21,96
B 5	FI 60	26,40
B 7	FI 80	71,91

TABLE (5)	TOTAL AMOUNT OF TIME SPENT IN EACH SCHEDULE "TIME-IN-SCHEDULE" *	
BIRD NO.	SCHEDULE	TOTAL TIME
B 6	FI 40	24hrs 30m.
B 5	FI 60	36hrs 45m.
B 7	FI 80	49hrs 0m.

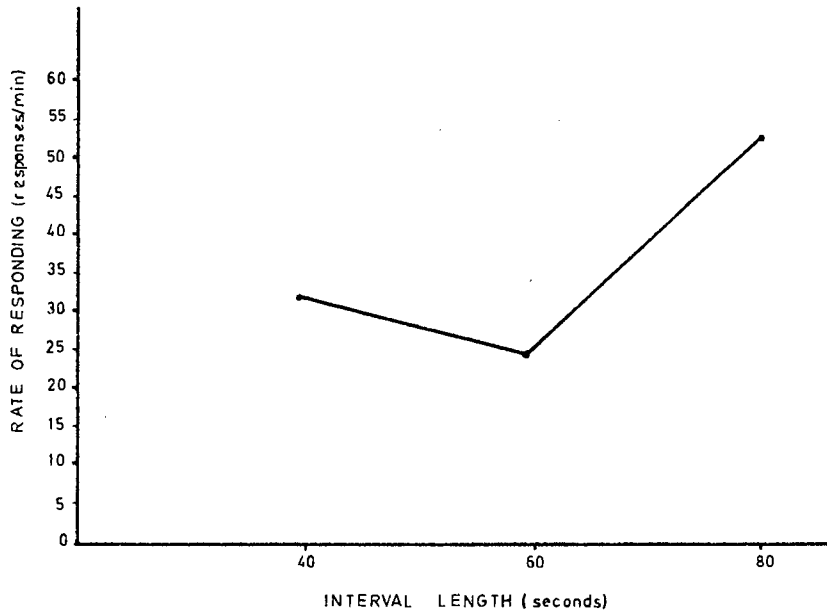
* NOTE: This time is theoretical length and does not include "Reinforcement Availability Time" (R.A.T.).

TABLE (6)	MEAN RATE OF RESPONDING OVER ALL ACQUISITION TRIALS (45).	
BIRD NO.	SCHEDULE	RESPONSES/MIN.
B 6	FI 40	32,45
B 5	FI 60	24,75
B 7	FI 80	52,93

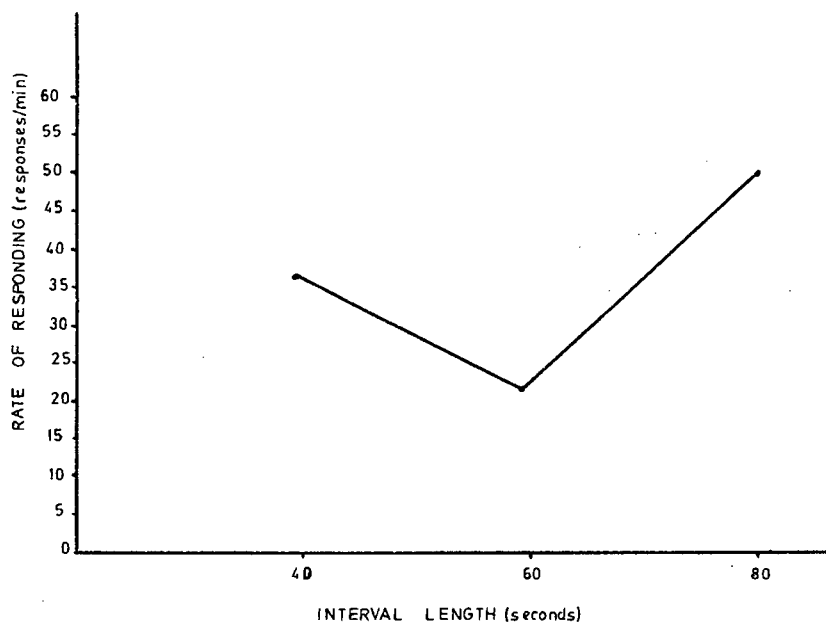
TABLE (7)	MEAN RATE OF RESPONDING OVER LAST 10 ACQUISITION TRIALS.	
BIRD NO.	SCHEDULE	RESPONSES/MIN.
B 6	FI 40	36,48
B 5	FI 60	21,70
B 7	FI 80	49,35

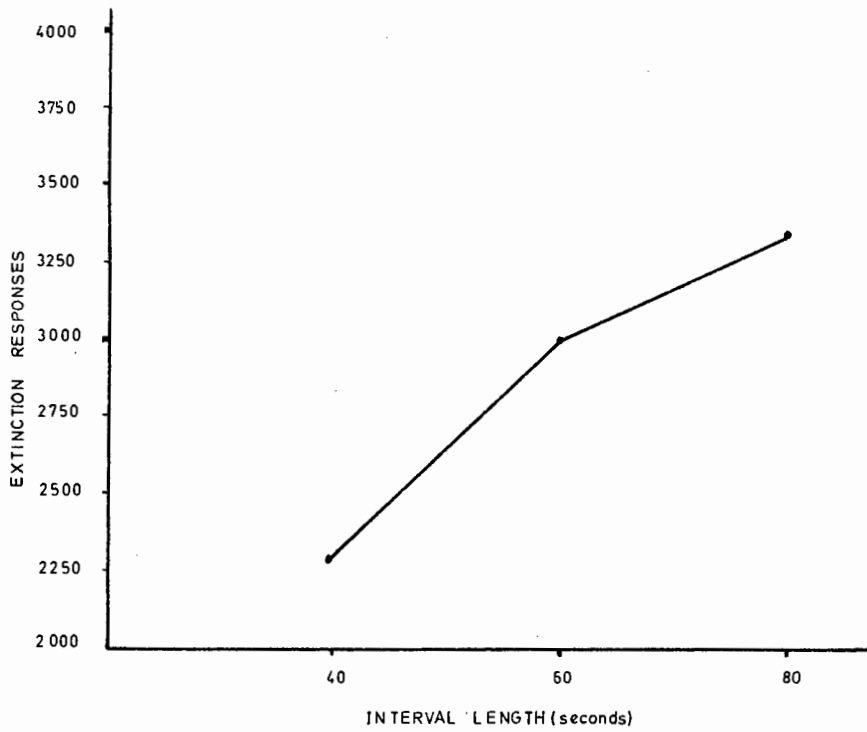
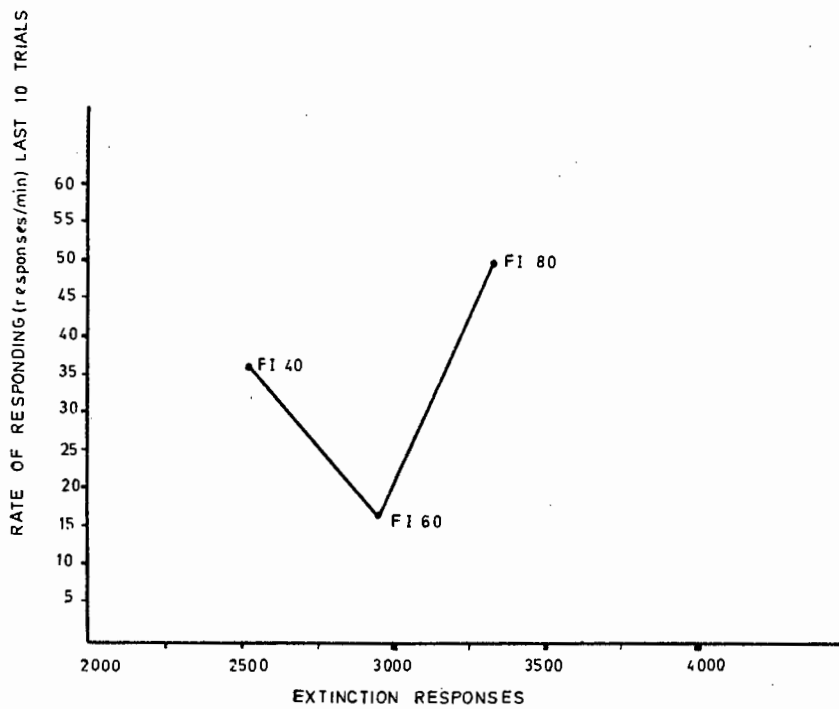
TABLE (8)	TOTAL NUMBER OF RESPONSES MADE DURING EXTINCTION (4 DAYS - 1 HOUR PER DAY).	
BIRD NO.	SCHEDULE	RESPONSES
B 6	FI 40	22,81
B 5	FI 60	29,53
B 7	FI 80	33,10

FIG(25) RATE OF RESPONDING v INTERVAL LENGTH OVER ALL TRIALS



FIG(26) RATE OF RESPONDING v INTERVAL LENGTH OVER THE LAST 10 TRIALS



FIG(27) EXTINCTION RESPONSES v INTERVAL LENGTH**FIG(28) RESISTANCE TO EXTINCTION AS A FUNCTION OF RATE OF RESPONDING AT VARIOUS FIXED INTERVALS**

reinforcement timer and the presentation of the S^D for 1 hour per day for 4 days. When the extinction trials were over the birds were returned to their home cages and fed enough to return them to their ad libitum weights.

vi) Results.

Tables (4) to (8) on pages (81) and (82) show the results obtained in this experiment. The last two tables of data are not directly relevant to the experiment but were recorded for interest. Table (4) shows how the number of responses per reinforcement changed with changes in the schedule length. Table (5) shows the total time each bird spent in each schedule, to which must be added reinforcement availability time.

Tables (6), (7) and (8) are the ones most relevant to the present study. Rate of responding, read from Tables (6) and (7) does not seem to be a consistent function of interval length as FIGS. (25) and (26) on page (83) illustrates over both the last 10 acquisition trials and all 45 acquisition trials.

Table (8) shows the relationship between resistance to extinction and interval length and is illustrated in FIG. (27). Here the relationship is of a more consistent nature, indicating that the less frequent the reinforcement, the greater will be the resistance to extinction.

The important result for the present study was the relationship between rate of responding and resistance to extinction - FIG. (28), which did not produce any consistent linear function.

vii) Discussion.

The lack of a consistent linear relationship between rate of responding and resistance to extinction is clear from FIG. (28).

A number of reasons can be postulated to account for this. Firstly, the relationship shown in FIG. (26) between rate of responding and interval length shows a function quite different to that obtained by Wilson (1954; p.53). Although only three intervals were used, instead of eight in Wilson's experiment, they were chosen so that they would span FI 60, where Wilson (p.54) found a maximum resistance to extinction. In the present experiment both rate of responding and resistance to extinction were at a minimum at FI 60. FIGS. (25), (26) and (27).

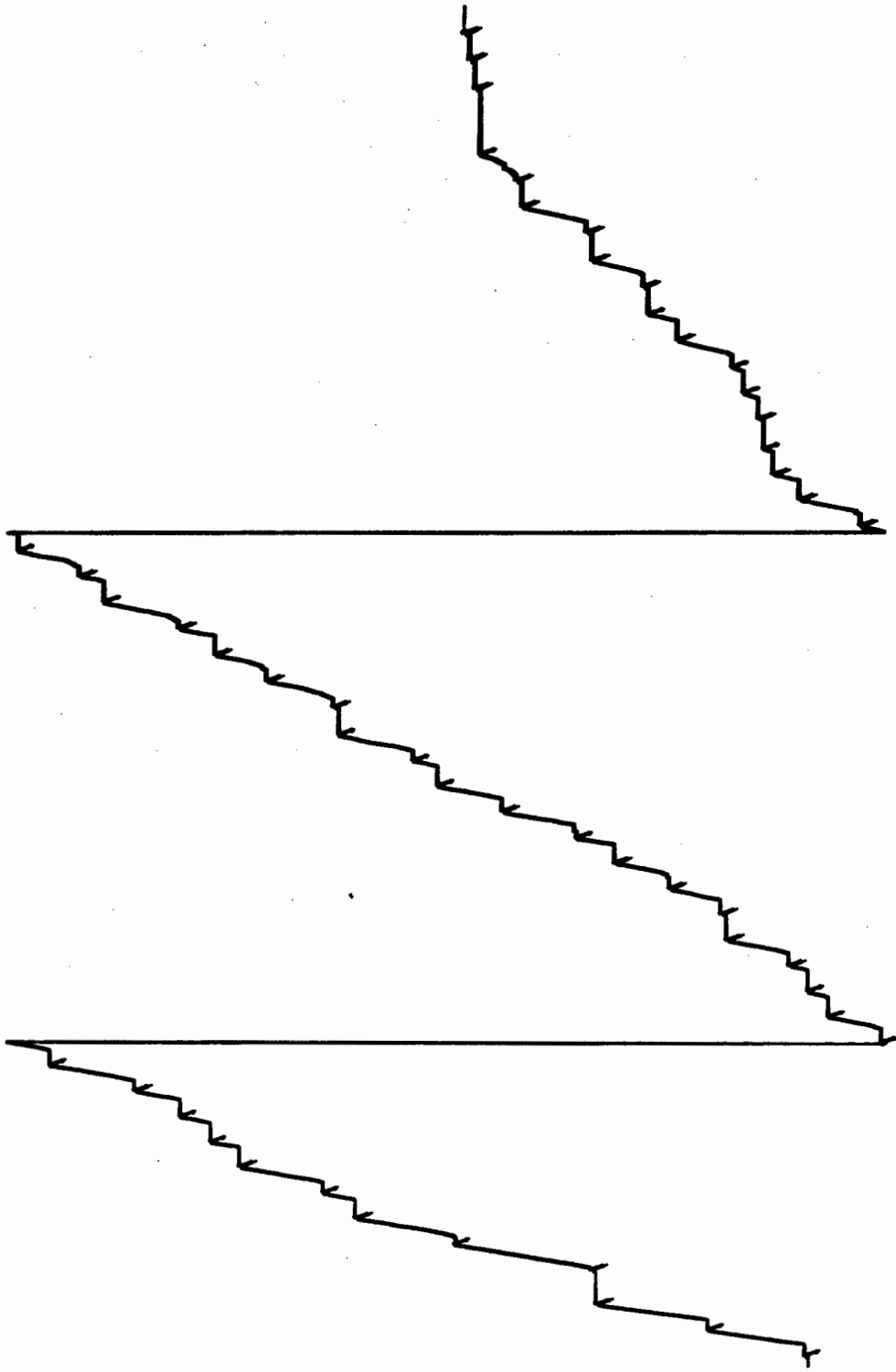
The results of the present study are also incompatible with those obtained by Skinner (1938; p.128), with regard the relationship between rate of responding and interval length. Likewise they do not agree with the results of an experiment by Kaplan (1952; pps.538-549), who found a maximum resistance to extinction with interval schedules of approximately one minute.

The results presented here are, however, in agreement with those of Catania and Reynolds (1968; p.355), who concluded that no systematic relationship was evident between rate of responding and interval length. A tentative reason for these anomolous results could possibly be the different performance characteristics of the organisms involved. Perhaps the rat produces an asymptotic response strength to a schedule of approximately 60 seconds, whilst a pigeon does not.

Individual differences played an important role in the present experiment, where each different level of the IV was assigned a different subject. For example Bird B6, on the lowest schedule FI 40, did not respond at greater than 42,6 responses/min. at any time during the experiment. This can be contrasted with the data presented by Catania and Reynolds (1968; p.357), where for an equivalent rate of reinforcement the lowest rate of responding was well over 50 responses/min. Further, Bird B5 on an FI 60 schedule managed an overall response rate of only 24,75 responses/min. compared

Experiment I, Bird B6, 13/12/74

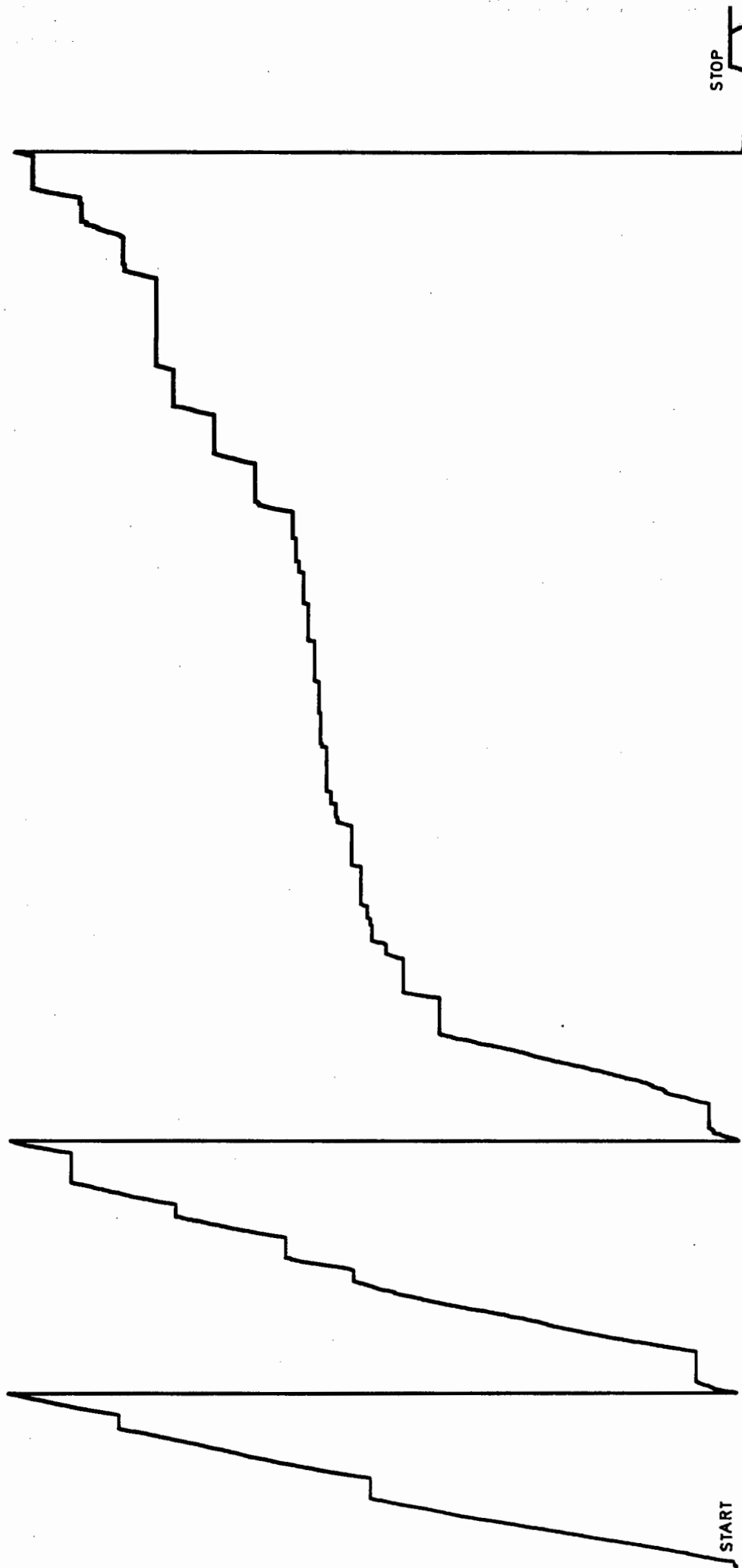
TYPICAL ACQUISITION RESPONDING ON AN FI SCHEDULE.



FIG(23)

FIG(30)

TYPICAL EXTINCTION PERFORMANCE AFTER FI SCHEDULE RESPONDING. Experiment I, Bird B6, 18/12/74



to an overall response rate for the same schedule shown by the Catania and Reynold's study of about 65 responses/min. On the other hand Bird B7 produced a rate of responding well above those in the Catania and Reynolds study on the same schedule of reinforcement.

Lastly, the fixed interval schedules themselves could have been playing an important role, for FI schedules in general, differentially reinforce long IRT's and thus tend to suppress rate of responding. Evidence for this is the fact that response rates of over 70 responses/min. for VI 40 can be attained as compared to 36 responses/min. for FI 40 in the present study. Further the "scallop" effect, - where there is virtually no responding or a very low rate for the first part of the interval and then higher rates as the schedule nears reinforcement - could have affected rate of responding and resistance to extinction. This "scallop" effect is known to generally lower overall rates of responding, and to produce characteristic extinction curves where bursts of responding are followed by periods of no responding and so on. (See FIGS. (29) and (30).

With the above criticisms in mind then it was decided to conduct another experiment using a different subjects design, but this time with variable interval schedules instead of FI schedules. Using these schedules it was hoped to be able to remove the "scallop" effect, and also the effect that this has on resistance to extinction and the nature of the extinction curve.

viii) Summary and Conclusions.

A different subjects design where three pigeons were put onto three different valued Fixed Interval Schedules was utilized. Rate of responding and resistance to extinction were measured at each value and were found to be not consistently related. Possible reasons for this were mentioned - (i) the lack of a consistent relation between rate of responding and

rate of reinforcement (interval length) in the single key situation, (ii) individual differences in performance amongst the pigeons and (iii) the idiosyncratic effects, in the form of scallops during acquisition and extinction, which Fixed Interval schedules have on behaviour.

EXPERIMENT II - An investigation of the relationship between rate of responding and resistance to extinction utilizing a different subjects design and Variable Interval Schedules of Reinforcement.

i) Introduction.

The relationship between rate of responding and interval length with variable interval schedules was found by Catania and Reynolds (1968; p.331) to be consistent, monotonically increasing and negatively accelerated. They presented no data as to the relationship between rate of responding and resistance to extinction.

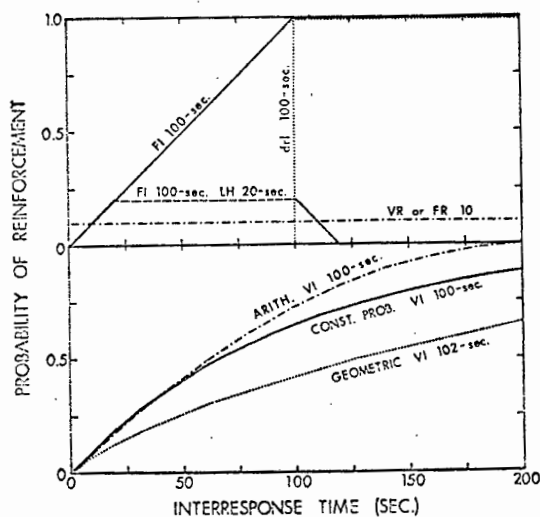
Jenkins, McFann and Clayton (1950) found that aperiodic (variable interval) schedules produced a far greater resistance to extinction than continuous reinforcement schedules. They did not, however, vary the interval length.

Ferster and Skinner (1957; pps.327-335) presented comprehensive data to show that rate of responding during VI performance lacked the sort of fluctuations associated with fixed interval performance. The shape of the acquisition curve was smooth and exhibited constant high rates of responding. The extinction curve was likewise affected (pps.346-351), where the course of extinction was marked by a gradual smooth decline in the response rate.

What accounts for these differences during acquisition and extinction between fixed interval schedules (Experiment I) and variable interval schedules; and how could these differences affect the relationship between rate of responding and resistance to extinction? The answer to these two questions lies in the different effects that these two schedules have on the distribution of Inter-response times (IRT's).

With fixed interval schedules the probability of reinforcement is a direct function of the preceding IRT as FIG.(3) below illustrates;

FIG.(31). The relationship between probability of reinforcement and IRT for various schedules (from Catania and Reynolds (1968; p.372)).



For example, with an FI of 100 secs., an IRT of 100 secs. or more will have a probability of being reinforced of 1 or certainty. IRT's of 50 secs. have a 0,5 or 50% chance, and IRT's of 25 secs. have a 0,25 or 25% chance of being reinforced. In contrast, with ratio schedules the probability of reinforcement increases only as a function of the preceding number of responses and the IRT has no effect on probability of reinforcement.

Thus with fixed interval schedules it is in the organism's own interest to respond at a low rate, for the longer the time interval between responses (IRT), the greater the chance of obtaining a reinforcement. The extreme case, then, would be the situation in which the organism discriminated time accurately and responded only after the IRT was greater than the interval length, thereby obtaining the same rate of reinforcement but with the absolute minimum output of behaviour.

As the pigeon cannot discriminate time one hundred per cent effectively the "scallop" effect develops after extended training on FI schedules. Thus as the probability of reinforcement increases merely as a function of elapsed time since the previous reinforcement, the pigeon increases its rate

of responding so as to ensure that when the non-reinforced interval is completed a response will be available immediately to produce the reinforcement.

With variable interval schedules, on the other hand, no such relationship between mere passage of time and probability of reinforcement is programmed (see FIG.(31) above). These schedules have, in the past, been formed on the basis of a distribution of intervals based on an arithmetic or geometric progression. With arithmetic VI schedules an arithmetic progression of programmed intervals with given minimum and maximum values and a stated mean value is first formed. Then these intervals are sampled randomly and presented to the organism. The geometric VI schedule is formed in the same way, except that the population of intervals is in the form of a geometric progression. For example, an arithmetic progression with mean 40 secs. might look like this: 0secs., 10secs., 20secs., 30secs., 40secs., 50secs., 60secs., 70secs. and 80secs. When presented to the organism the sequence of variable intervals could be 60secs., 80secs., 20secs., 30secs., 0secs., 50secs., 70secs., 10secs., 40secs. Thus with these schedules no simple dependency on time since previous reinforcement exists. In the above hypothetical schedule an IRT equivalent to the mean interval length would only be reinforced 50% of the time, compared to 100% with fixed interval schedules.

However, these arithmetic and geometric schedules are far from satisfactory as Anger (1956) has pointed out. With these schedules sequential dependencies as Weiss, Laties Siegel and Goldstein (1966) call them, alter the IRT-probability of reinforcement relationship. Sequential dependency means that the organism alters its performance (its distribution of IRT's or IRT/opp as Anger calls it) in accordance with the sequence and distribution of intervals it has received in the past.

Thus, after extended training on an arithmetic or geometric variable interval schedule the organism begins to

form a relationship between probability of reinforcement (reinf/opp) and time since last reinforcement. In other words, with a schedule formed in the way described above the probability of the next reinforcement will be greater if the preceding reinforcement was followed by a long interval, than if it was followed by a short interval.

An example of this effect was presented by Fleshler and Hoffman (1962; p.529). An arithmetic variable interval schedule programmed in a random sequence the following progression of intervals; 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10secs. After extended presentation each interval will occur with a fixed relative frequency of 1/10. As with any arithmetic progression the probability of reinforcement increases at an increasing rate as a function of time since reinforcement. Thus the probability of reinforcement during the first second of the schedule is 1/10, since 10 intervals equal or exceed 1sec., and one of these is programmed to yield reinforcement after one second. The probability of reinforcement during the 2nd second is 1/9, because a reinforcement occurs during one of the nine intervals equaling or exceeding the second period of one second. Thus probability of reinforcement will increase with each succeeding second until it reaches 1 or certainly in the 10th second.

To avoid this situation it was necessary to develop a schedule in which the probability of a short interval following a long interval was made equal to the probability that a long interval will follow a short one. Such a schedule was developed by Fleshler and Hoffman in 1962 (for more details see section (iv) - "Apparatus" of this section under computer - software), and was utilized in the present experiment using an on-line digital computer to time and present the intervals.

Further, the computer presented a different sequence of intervals each day, thus preventing any chance of sequential dependency occurring.

ii) Design.

A different subjects design was utilized, where each subject was assigned to a particular value of the independent variable.

The independent variable was again rate of responding, controlled by manipulations of the interval length. Rate of responding for each trial was obtained by dividing the total number of responses produced in each session by the product of the number of intervals (in each session) and the mean interval length, to which was added total R.A.T. in each session.

$$\text{Rate of responding} = \frac{\text{TR}}{(\text{MI} \times \text{N}) + \text{T.R.A.T.}}$$

where;

TR = total number of responses in each session.

MI = Mean interval length (minutes).

N = total number of intervals in each session.

T.R.A.T. = total reinforcement availability time.

The dependent variable was resistance to extinction, measured by the number of responses produced during 4 hours of non-reinforcement (1 hour per day for four days).

TABLE (9). Design of the experiment.

SUBJECT	SCHEDULE	EXTINCTION
L10	VI 40	4 hours
L 9	VI 60	4 hours
L 4	VI 80	4 hours

iii) Subjects.

Three experimentally naive male homing pigeons -

numbers L4, L9 and L10 were used in this experiment (see section (ii), Chapter 2 for more details). During the running of the experiment their weights were kept at 80% of their ad libitum weights (± 15 grams) according to the following schedule ;

TABLE (10). Schedule of body weight reductions.

SUBJECT	AD LIBITUM WEIGHT	80% TARGET WEIGHT
L 4	399	320
L 9	465	372
L10	464	371

iv) Apparatus.

Apart from the apparatus mentioned in section (iii) Chapter 2, two further pieces of equipment were required to program variable interval schedules - (a) a digital relay rack and (b) a digital computer.

a) The Digital Relay Rack.

A switch closure of approximately 600ms originating at the computer interface was fed into an input shaper on the digital rack which converted it into a digital positive going pulse of approximately 200ms in length. This pulse was fed into the input side of the 0 state of a flip-flop. Switch closures originating from a relay which was operated via a negative going pulse from the pecking key were fed into another input shaper. Positive going digital pulses from this input shaper were fed into the input side of the 1 state of the flip-flop.

Thus, when an input arrived from the computer interface to the 0 state of the flip-flop, it changed to the 1 state. The first pulse (transformed key peck) arriving at the now

energized 1 state, changed the state of the flip-flop back to the 0 state, and outputted from the output side of the 0 state. This output was then fed into a one-shot, which had an external capacitance of 4 M.F.D. This one-shot determined the pulse length of the output from the flip-flop.

The output of the one-shot was in turn fed into a Schmidt Trigger which delivered the required pulse to a relay which outputted a switch closure. This closure was then connected across the START and GROUND contacts of the reinforcement timer to begin the timing of the reinforcement presentation.

Reinforcements were counted from the END PULSE of the reinforcement timer and responses were counted from the pecking key relay (see section (iii) of Chapter 2).

The R.A.T. timer was started by the switch closure originating from the computer interface at the end of the timed interval. It was stopped by the END PULSE of the reinforcement timer. Reinforcement time thus had to be subtracted from total R.A.T. to give the actual reinforcement availability time.

The S^D was controlled in the same way as described in the previous experiment (p. 79) and was, throughout this experiment, coloured green.

Appendix (3) shows the circuit diagram for variable interval schedules of reinforcement.

b) The Digital Computer.

Hardware.

The computer used in the present experiment and in the experiments to follow was a Hewlett Packard 2114B with 8k memory. Standard peripherals included in the system were; an HP model 2752A teleprinter, an HP model 2748A Paper Tape Reader and an HP model Facit 8100 High Speed Paper Tape Punch.

Specific hardware for the on-line control of the experiments included an HP model 12551-6001 Relay Out Register,

an HP model 12604B Data Source Interface kit and an HP model 12539A Time Base Generator. These components were in the form of slot-in cards, thereby providing a flexible system which could be extended or modified at will. Connected by cable to the Data Source Interface card was the interface board itself, containing 16 input and 16 output jack plug sockets.

The computer and peripherals were mounted on a movable trolley as it served various experimental settings. In the present series of experiments it was housed in a small room adjacent to the operant laboratory - a number of wires joining the interface to the digital and control racks. This particular computer did not require any special environmental control.

Software.

See Appendix 1A for program listings and documentation.

The software for this experiment was designed to generate a progression of intervals according to the specifications of Fleshler and Hoffman (1962), and then to present them in a random sequence.

The FORTRAN main program first set up the parameters required by the Fleshler and Hoffman equation (p.529) - mean interval length and number of intervals. It then generated the progression of intervals by solving the following equation N times (where N = number of intervals).

$$\bar{t}_n = [-\log_e(1-p)]^{-1} [1 + \log_e N + (N-n) \log_e (N-n) - (N-n+1) \log_e (N-n+1)]$$

where

- \bar{t}_n = nth term of the progression.
- N = total number of terms (intervals).
- p = fixed probability of the event within a unit interval.
- $[-\log_e(1-p)]$ = value of the VI mean.

The main program then called for two further parameters to be specified - the output channel and the random generator start integer. This program then called in the random generator subroutine (in FORTRAN) to randomly select an interval from the progression of intervals developed above. When this had taken place the main program called in an ASSEMBLER (input/output) subroutine to transfer information from the main program to the output channel and to set up the characteristics of the outputted information (a 600ms switch closure).

At this point program operation was halted to await an input from the input channel. When input was received via the ASSEMBLER subroutine, the computer clock (Time Base Generator) began timing. When the length of the timed period was equal to the interval length previously randomly selected from the progression of intervals, a 600ms closure was outputted along the specified output channel.

v) Procedure.

After initial training and four days of FR1 - continuous reinforcement (60 reinforcements per day) all three pigeons were put onto VI 10sec. schedules, where the maximum interval length was set at 20secs. Each day the mean interval was increased by 10secs. until the birds reached their criterion schedules;

L10	VI 40 (Mean interval 40 secs.)
L 9	VI 60 (Mean interval 60 secs.)
L 4	VI 80 (Mean interval 80 secs.)

To equate the number of trials each bird received, BIRD L10 was put onto extinction two days before L9, who was put on two days before L4.

A behavioural stability criterion of less than 20% variation from mean response rate over 10 days was again used to determine when extinction sessions were to begin. Extinction

TABLE (11)	MEAN NUMBER OF RESPONSES PER REINFORCEMENT	
BIRD NO.	SCHEDULE	RESPONSES/REINF.
L 10	VI 40	23.46
L 9	VI 60	30,11
L 4	VI 80	71,55

TABLE (12)	TOTAL AMOUNT OF TIME SPENT IN EACH SCHEDULE "TIME-IN-SCHEDULE" *	
BIRD NO.	SCHEDULE	TOTAL TIME
L 10	VI 40	22hrs 13m.
L 9	VI 60	33hrs 20m.
L 4	VI 80	44hrs 26m.

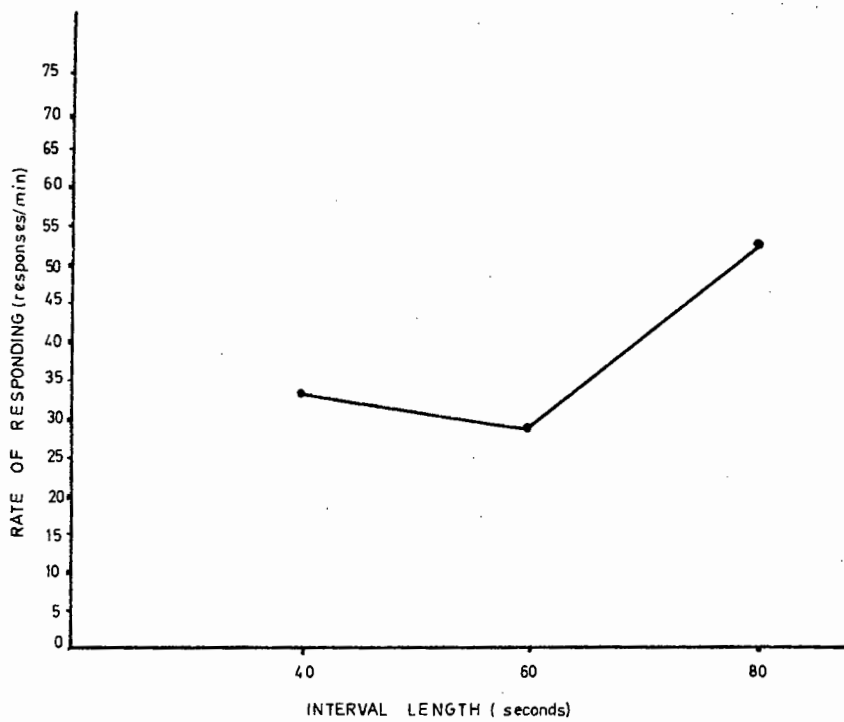
* NOTE : This time is theoretical length and does not include "Reinforcement Availability Time" (R.A.T.).

TABLE (13)	MEAN RATE OF RESPONDING OVER ALL ACQUISITION TRIALS (40).	
BIRD NO.	SCHEDULE	RESPONSES/MIN.
L 10	VI 40	34,52
L 9	VI 60	29,58
L 4	VI 80	52,95

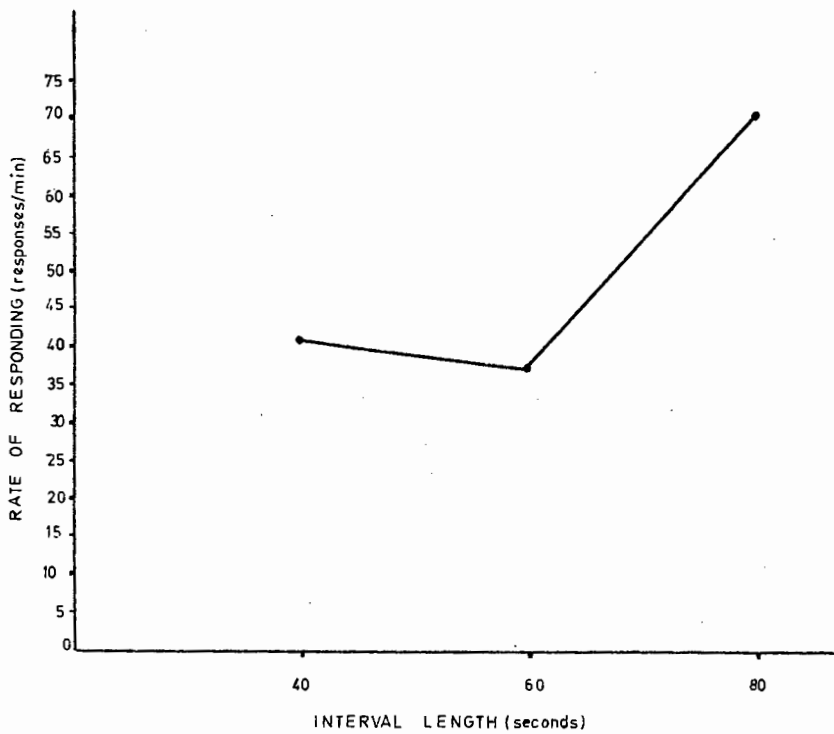
TABLE (14)	MEAN RATE OF RESPONDING OVER LAST 10 ACQUISITION TRIALS.	
BIRD NO.	SCHEDULE	RESPONSES/MIN.
L 10	VI 40	41,00
L 9	VI 60	37,09
L 4	VI 80	70,16

TABLE (15)	TOTAL NUMBER OF RESPONSES MADE DURING EXTINCTION (4 DAYS - 1 HOUR PER DAY).	
BIRD NO.	SCHEDULE	RESPONSES
L 10	VI 40	1754
L 9	VI 60	1984
L 4	VI 80	2673

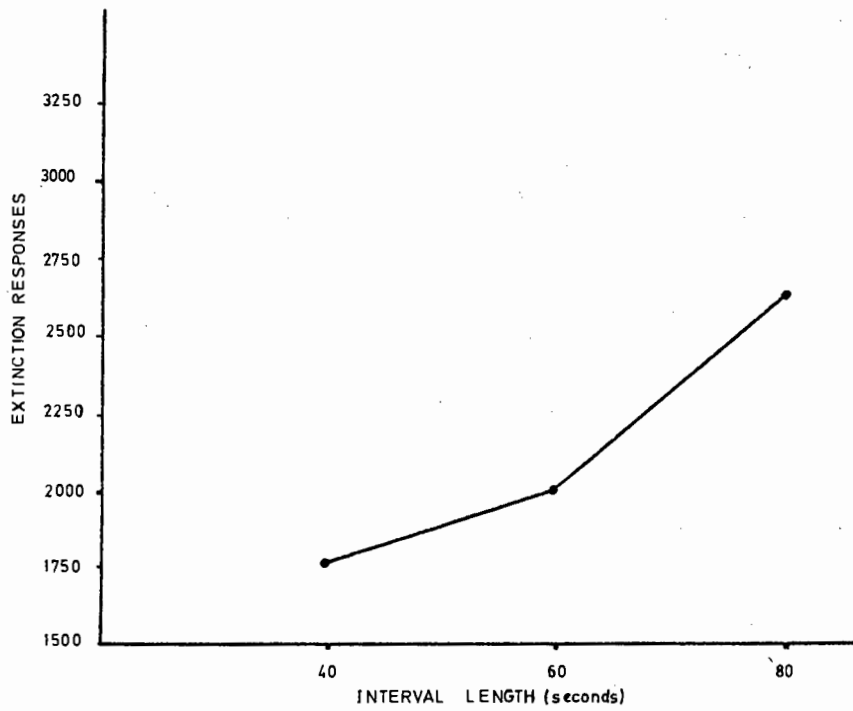
FIG(32) RATE OF RESPONDING v INTERVAL LENGTH OVER ALL TRIALS



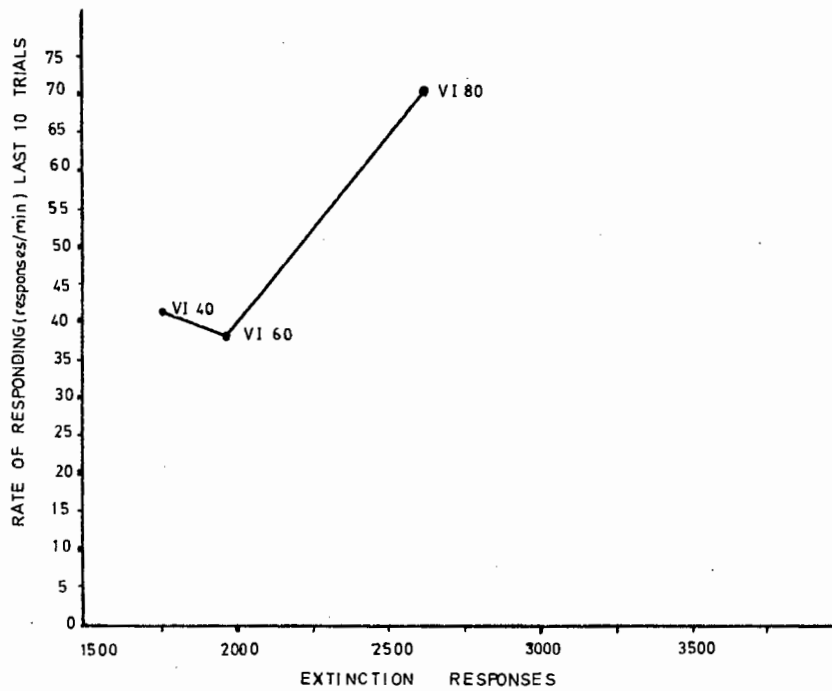
FIG(33) RATE OF RESPONDING v INTERVAL LENGTH OVER THE LAST 10 TRIALS



FIG(34) EXTINCTION RESPONSES v INTERVAL LENGTH



FIG(35) RESISTANCE TO EXTINCTION AS A FUNCTION OF RATE OF RESPONDING AT VARIOUS VARIABLE INTERVALS



consisted of four days (one hour per day) of non-reinforced responding with the S^D presented continuously.

After the extinction trials were over the birds were returned to their home cages and were given enough food to return them to their ad libitum weights.

vi) Results.

Tables (1) to (15) and FIGS.(32) to (35) summarize the results of this experiment. As in the previous experiment the first two tables of data were included, although they had no direct relevance. Table (11) again shows that the number of responses emitted per reinforcement seem to be a function of the length of the interval. Total "time-in-schedule" is less in this experiment than it was in experiment I, as only 40 trials instead of 45 were presented. (Table (12)).

Tables (13) and (14) show the relationship between rate of responding and interval length over all acquisition trials and over the last 10 trials when the behavioural stability criterion was operating. FIGS.(32) and (33) graphically show this relationship, and again illustrate that rate of responding and interval length were not consistently related in a linear fashion.

Table (15) and FIG.(34) show the relationship between resistance to extinction and interval length. The relationship here is more consistent, indicating a general trend toward greater resistance to extinction with increases in interval length, with numbers of reinforcements equated.

Lastly FIG.(35) shows the relationship between rate of responding and resistance to extinction at each mean interval length. The shape of the curve is remarkably similar to that obtained in the previous experiment with fixed interval schedules, (FIG.(28)).

vii) Discussion.

The most interesting aspect of the results obtained in the present experiment were their remarkable similarity to those obtained in experiment I. The relationship between rate of responding and interval length in each of the experiments bears striking resemblance - FIGS.(25) and (26) on page (83) for fixed interval schedules and FIGS.(32) and (33) on page (102) for variable interval schedules. Both of these sets of curves show that rate of responding is at a minimum level for an interval length of 60 secs. Why this depression in rate of responding occurs for intervals of 60 secs. is not altogether clear. A possible explanation for this phenomenon is again the problem of individual differences. It is quite possible that the two pigeons who naturally responded at a lower rate than others were chosen, quite by chance, to be put onto the 60sec. interval. For example, Catania and Reynolds (1968; p.331) achieved a rate of responding of between 50 and 80 responses/min. for an arithmetic variable interval schedule, compared to only 37,09 for VI 60 in the present experiment. However, Catania and Reynolds (1968; p.331) were themselves plagued by individual differences in rate of responding, for BIRD 121 only achieved 20 responses/min. at approximately 60 rfts. per hour (VI 60).

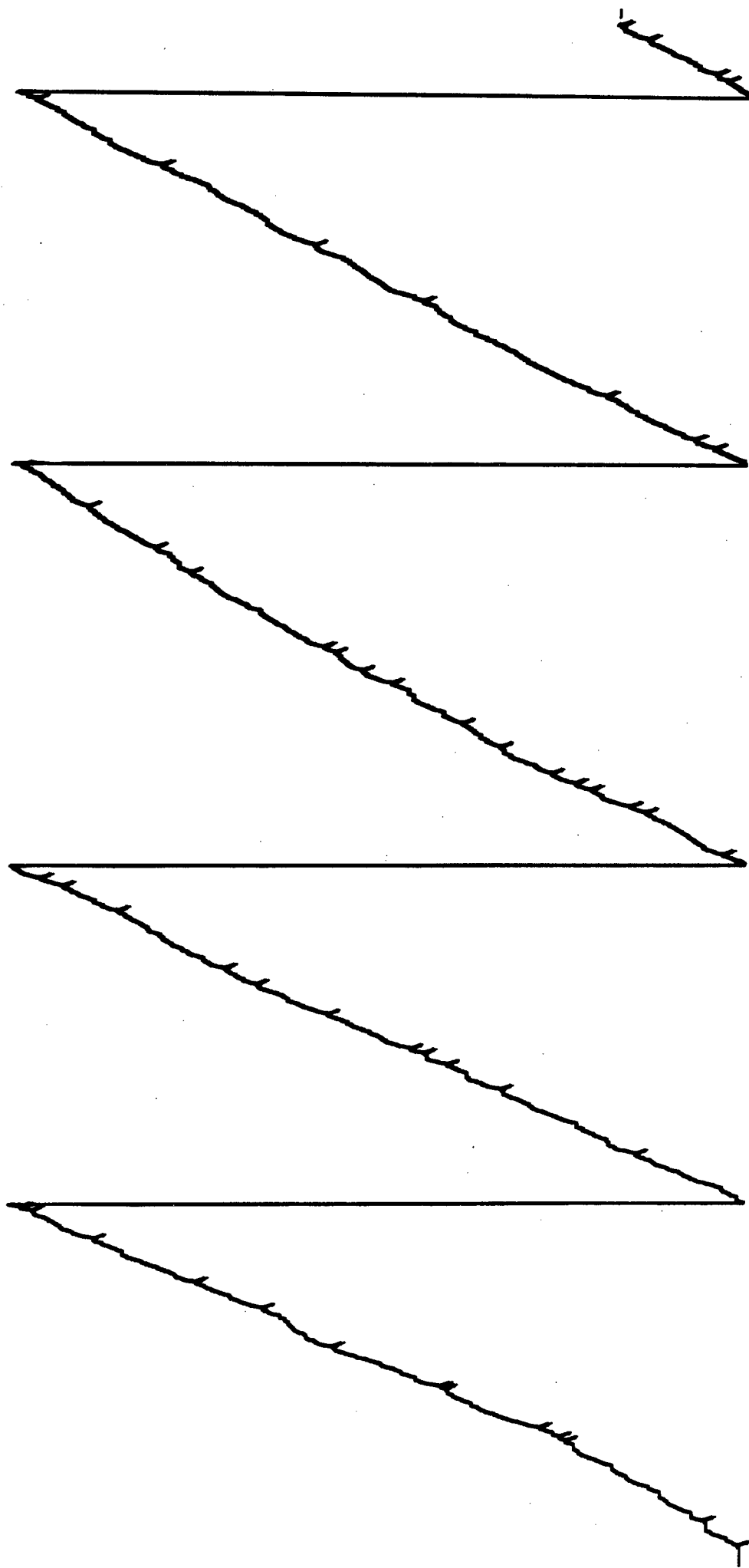
The function relating resistance to extinction and interval length - FIG.(34) - showed a slightly concave shape in the present experiment. This can be contrasted to the slightly convex shape of the function relating the same variables in experiment I - FIG.(27). However, both of these functions differ from the one obtained by Wilson (1954; p.54), as no maximum resistance to extinction was evident in either of the experiments for interval lengths of 60 secs.

The relationship between rate of responding and resistance to extinction again was U shaped with a minimum point at VI 60secs. in the present experiment, although the severity of the change in slope about 60secs. was not as great as that found with fixed interval schedules. FIGS.(35) and (28).

FIG (36)

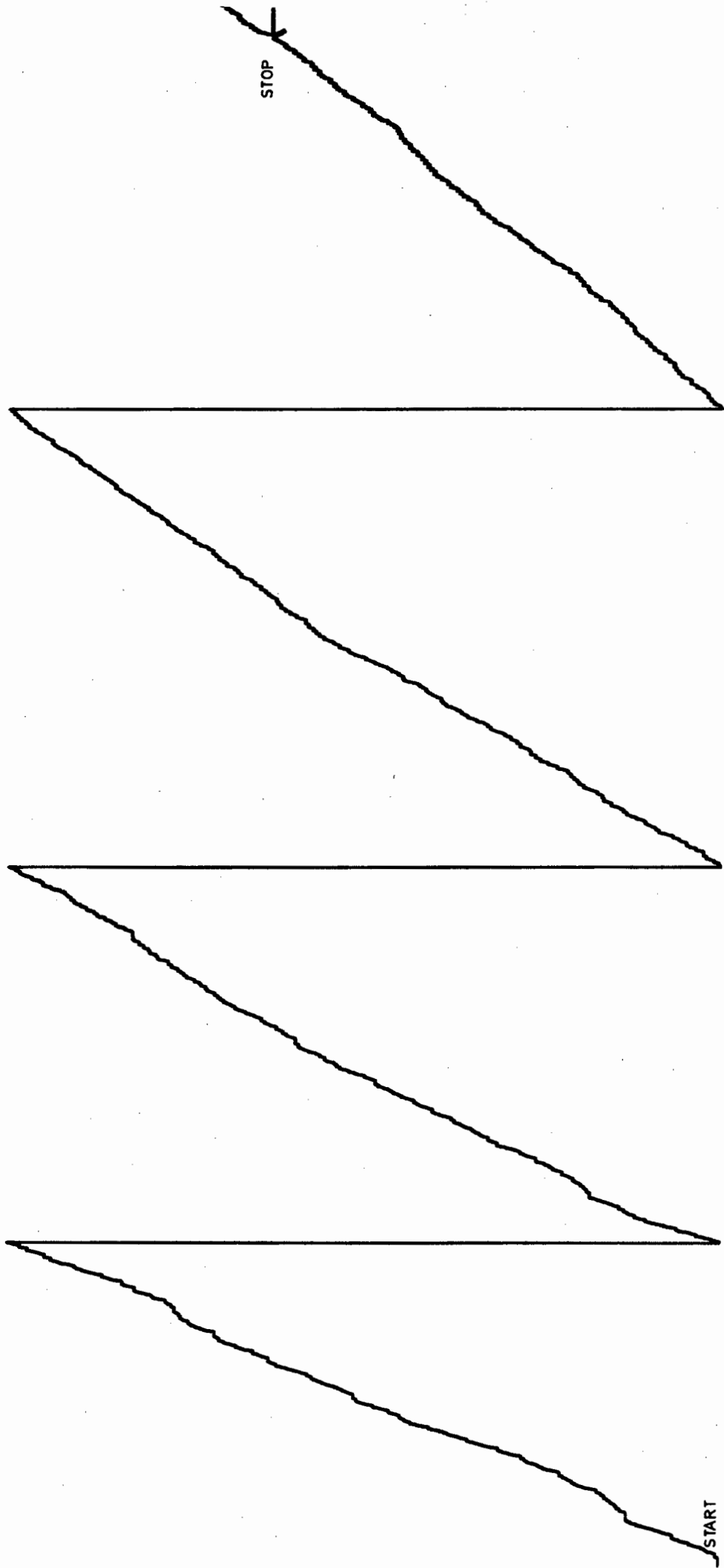
Experiment II, Bird 19, 22/1/75

TYPICAL ACQUISITION RESPONDING ON A VI SCHEDULE.



FIG(37)

TYPICAL EXTINCTION PERFORMANCE AFTER VI SCHEDULE RESPONDING. Experiment II, Bird L9, 29/1/75



The results of the present experiment, then, rule out the possibility that the fixed interval schedule itself could be the prime cause of the lack of any linear relationship between rate of responding and interval length, and hence of any lack of relationship between rate of responding and resistance to extinction.

The unique characteristic of the fixed interval schedule - the direct proportionality between elapsed time and probability of reinforcement which produces the idiosyncratic "scallop" effects during acquisition and extinction - was eliminated in the present experiment using variable interval schedules, in which no such direct proportionality was purposefully programmed (see FIGS. (36) and (37). Further, the relationship between sequence of preceding intervals and probability of reinforcement found by Anger in 1956, was eliminated using the constant probability variable interval schedule developed by Fleshler and Hoffman (1962).

It was thus found necessary to refocus attention back on the problem of individual differences which are inherent in any different subjects design. This then sets the scene for the third experiment in this series in which any confounding results attributable to individual differences were eliminated by the use of a single subjects design. In operant methodology this is achieved by using a multiple (MULT) schedule of reinforcement. With the results and discussion of the present experiment in mind, fixed interval components were utilized in the multiple schedules. These were used in preference to variable interval components, for their ease of programming, especially in multiple schedule situations.

viii) Summary and Conclusions.

Three different pigeons were put onto three different valued variable interval schedules. Rate of responding and resistance to extinction (for each value of the VI) were found not to be linearly related. A reason for this was probably

the lack of a consistent relationship between rate of responding and interval length. No great differences were found between the results of this experiment with VI schedules, and the results of the previous experiment with FI schedules, indicating that with regard the variables under study in the present series of experiments, the idiosyncratic effects on behaviour of the FI schedule have little influence. Again individual differences were blamed for the lack of any consistent relationship between these two fundamental measures of response strength.

EXPERIMENT III - An investigation of the relationship between rate of responding and resistance to extinction utilizing a single subjects design and Multiple Fixed Interval Schedules of Reinforcement.

i) Introduction.

"The complex system we call an organism has an elaborate and largely unknown history which endows it with a certain individuality. No two organisms embark upon an experiment in precisely the same condition nor are they affected in the same way by the contingencies in an experimental space" Skinner in Honig (1966; p.20). Here Skinner notes that even if the reinforcement history of the experimental organism is precisely controlled, there are many other factors (one obviously being genetic inheritance) which affect the organism's performance under specified operant contingencies. It was thus thought necessary to obtain average or group data in order to establish a functional relationship between certain environmental events (independent variables) and the behaviour of the organism (dependent variable). This led to the development of widescale interest in learning curves, and in curve-fitting experiments.

However, various problems exist when one wishes to draw inferences about individual behaviour functions from data gathered in experiments where groups of subjects are exposed to the different levels of the independent variable. Sidman (1952; p.263) pointed out that often the mean curve is not the same shape as the individual curves which go to form it. This problem becomes even more acute in situations where it is impossible to obtain individual curves directly. Estes (1956; pps.134-135), on the other hand, argued that individual inferences from group data are quite acceptable, "if we regard the mean curve solely as a source of inductive generalizations" (p.134). Thus the problem is not one of whether individual inferences from group data are valid or not, but one of the actual interpretation of the group data itself.

Schrier (1958) conducted an experiment to compare, under controlled conditions, the effects of amount of reward on performance using group data and data averaged from single subjects (pps.725-726). He found that the data obtained from presenting all the levels of the independent variable to each subject were more in agreement with previous findings than data obtained from presenting different levels of the independent variable to different groups of subjects.

The results of the classic experiment performed by Williams (1938) relating resistance to extinction and the number of reinforcements can be used to show the sort of individual variation that is submerged by the use of grouped or averaged results at each level of the independent variable.

Generally, Williams found that resistance to extinction increased with increases in the number of reinforcements presented (p.520). However, two of the animals in the lowest reinforcement group produced the highest number of responses in extinction (p.512). This variation was hidden when mean data was collected for all the 35 rats in this particular group. Also significant was the fact that the range of extinction scores for three of the four groups of rats were very nearly the same (p.512), even though the mean of each of these groups showed a consistent increase with increases in the number of reinforcements.

The position in summary then, is that "one of the most intractable methodological problems in traditional psychology has been inter-subject variability, which often results in between-group differences caused by factors other than the independent variable whose effects are being studied" Honig (1966; p.3).

Due mainly to the ability of pigeons to discriminate colour effectively, operant methodologists have been able to develop a means of presenting different values of the independent variable to the same subject. In this way the

subject serves as its own control against individual differences. This is achieved using a multiple schedule of reinforcement, (see Ferster and Skinner (1957; pps.503-579) where "reinforcement is programmed by two or more schedules alternating, usually at random, each schedule being accompanied by an appropriate stimulus as long as the schedule is in force" Ferster and Skinner (1957; pps.729-730).

As with any single subjects design practice or sequence effects often confound the real effect of the independent variable. This is controlled in the present experiment by randomizing the sequence in which the schedule S^0 's were presented. With colour discrimination a further problem arises - that of colour preference. In the present experiment this was controlled by representing each FI schedule with a different colour to each different bird (see under "design" below).

With multiple schedules of reinforcement a further confounding variable often plays an important role. This is called schedule interaction, and behavioural contrast (mentioned in Chapter 1) is an example of such an effect. Schedule interaction occurs when performance on one component of a multiple schedule affects the performance in the other component. This particular variable should not have any great influence in the present experiment as no manipulations to the component performances took place. A possible effect of this variable might be the existence of differences in performance under each component as compared to the performance on that schedule if it was programmed independently.

ii) Design.

A single subjects design was utilized, in which each level of the independent variable was presented to each subject.

The independent variable was again rate of responding obtained in the same way as in experiment I, except that it was

calculated for each component. The dependent variable was resistance to extinction measured over 4 days of non-reinforced responding (approximately 50 mins. per day).

Each level of the independent variable was represented by its own S^D , and for each subject each level was represented by a different S^D as Table (16) below shows;

TABLE (16). Design of the experiment.

SUBJECT	SCHEDULE			EXTINCTION
	FI 40	FI 60	FI 80	
C1	GREEN	RED	WHITE	3hrs.20mins.
C2	RED	WHITE	GREEN	3hrs.20mins.
C3	WHITE	GREEN	RED	3hrs.20mins.

The three component multiple fixed interval schedule (MULT FI) presented blocks of 6 intervals in one colour, followed by the presentation of a 10sec.time-out period (all lights switched off), which was then followed by the presentation of another block of 6 intervals of one of the two other colours in a random order. Each block of 6 intervals was presented three times, the pigeon thus received 54 reinforcements per day (55 counting the reinforcement given to the pigeon on entering the chamber).

Extinction consisted of presenting three periods of 5min.27secs. of each of the three colours, separated by a 10sec. time-out period for 4 days. This meant a total extinction time of 50mins.30secs. each day.

iii) Subjects.

Three experimentally naive male homing pigeons -

numbers C1, C2 and C3 were used. (For more details see section (ii) of chapter 2). During the running of the experiment they were kept at 80% of their ad libitum weights (± 15 grams) according to the following schedule;

TABLE (17). Schedule of body weight reductions (grams).

SUBJECT	<u>AD LIBITUM</u> <u>WEIGHT</u>	80% TARGET WEIGHT
C1	392	314
C2	368	294
C3	395	316

iv) Apparatus.

All the apparatus used in this experiment has been described above (section (iii) chapter 2). No additional equipment, except for the computer was required for the present experiment.

The R.A.T. timer was not utilized in the present experiment as the computer itself recorded this time.

The Computer

Hardware - see section (iv) of experiment II on page (97) for a full description of the hardware used.

Software - see Appendix IB for program listings and documentation.

The software for this multiple fixed interval schedule was of the same general format as the one used in experiment II - a FORTRAN main program, a FORTRAN subroutine for generating random sequences and an ASSEMBLER subroutine for input/output control.

As the computer controlled all the contingencies in this experiment, the establishment of the relevant parameters took up much of the first half of the main program. The program first called for the number of components and then requested, for each component, its length (in seconds), its input switch and its output switch. In this case the output switches were used to control the SD's associated with each of the components. The program then requested information about the number of intervals within each component, and how many components were to be presented during the experimental session. Lastly, the program called for the random generator start integer, the specification of the length of the reinforcement presentation, the length of the time-out period, the output channel for the reinforcement presentation and the output channel for the time-out period.

When parameter specification was completed program operation was temporarily halted. Its operation was restarted manually by the experimenter after the subject had been placed in the experimental chamber. The main program called in the input/output subroutine to check that all the channels were clear. The random generator subroutine then randomly selected one of the components and the time base generator began timing the first of its specified number of intervals. At the same time, via the ASSEMBLER subroutine, the output switch corresponding to the component selected was closed, thereby projecting the appropriate SD onto the pecking key.

When the computer clock had timed a period of time equal to the randomly selected interval length, the input channel was cleared so that the first input arriving through the channel was transferred to the main program via the input/output subroutine. In the meantime the computer clock timed the period of time between the end of the specified interval and the arrival of the input. When an input arrived the timing function continued, but was now outputted through the reinforcement switch to activate the food hopper in the operant chamber. At the same time the computer printed out (in 100ths of a

second) the length of the period timed from the end of the specified interval until the arrival of an input-reinforcement availability time.

After the specified number of intervals of the same component were presented, a time-out period was timed and outputted through the time-out channel. After the completion of this period control was again transferred to the random generator subroutine which then chose a different component SD. If this second component chosen was the same as the first, control was passed back to the random generator subroutine so that it could select another component.

After the presentation of the last interval in a certain component, the program cumulated the individual R.A.T.'s and printed out the result as a total R.A.T. for each component.

v) Procedure.

After the initial training period described in section (iv) chapter 2, four days of FR1 or continuous reinforcement were presented. Each day 60 reinforcements were given to each bird in two blocks of 10 reinforcements under each of the three SD's.

MULT FI training began when each of the components was raised to FI 10secs. An increase in the interval length of 10secs. per day was achieved until each of the birds was on its target schedule of MULT FI 40, 60, 80secs.

No attempt was made to control for inequality in the number of trials on the target schedule which arose from the fact that, say, the target of FI 40 was reached 4 days before the target of FI 80. To control for this would have meant disrupting the multiple schedule during the last few trials. Further it was believed that this inequality in number of trials in each component was small relative to the number of trials overall (4 to 41).

TABLE (18)	MEAN NUMBER OF RESPONSES PER REINFORCEMENT UNDER EACH COMPONENT	
	COMPONENT	RESPONSES/REINF.
	FI 40	43,086
	FI 60	50,955
	FI 80	53,301

TABLE (19)	*TOTAL AMOUNT OF TIME SPENT IN EACH COMPONENT "TIME-IN-SCHEDULE"	
	COMPONENT	TOTAL TIME
	FI 40	*1 8,2 hours
	FI 60	12,3 hours
	FI 80	16,4 hours

* NOTE: This is based on theoretical interval length and does not include R.A.T.

*1 NOTE: This time is for each bird.

TABLE (20)			MEAN RATE OF RESPONDING OVER ALL ACQUISITION TRIALS (41) - INDIVIDUAL DATA		
BIRD NO.	COMPONENT	RESPONSES/MIN.			
C1	FI 40	62,50			
C1	FI 60	52,93			
C1	FI 80	36,87			
C2	FI 40	59,28			
C2	FI 60	46,48			
C2	FI 80	39,34			
C3	FI 40	68,60			
C3	FI 60	50,77			
C3	FI 80	42,02			

TABLE (21)		MEAN RATE OF RESPONDING OVER ALL ACQUISITION TRIALS (41) - MEAN DATA	
COMPONENT	MEAN RESPONSES/MIN.		
FI 40	63,46		
FI 60	50,06		
FI 80	39,39		

TABLE (22)	MEAN RATE OF RESPONDING OVER LAST 10 ACQUISITION TRIALS - INDIVIDUAL DATA	
BIRD NO.	COMPONENT	RESPONSES/MIN.
C1	FI 40	84,24
C1	FI 60	68,58
C1	FI 80	44,22
C2	FI 40	59,38
C2	FI 60	47,71
C2	FI 80	38,18
C3	FI 40	81,61
C3	FI 60	61,06
C3	FI 80	48,49

TABLE (23)	MEAN RATE OF RESPONDING OVER LAST 10 ACQUISITION TRIALS - MEAN DATA	
COMPONENT	MEAN RESPONSES/MIN.	
FI 40	75,07	
FI 60	59,11	
FI 80	43,63	

TABLE (24)	TOTAL NUMBER OF RESPONSES MADE IN EACH COMPONENT DURING EXTINCTION (4 DAYS - 50 MINS PER DAY) - INDIVIDUAL DATA	
BIRD NO.	COMPONENT	RESPONSES
C1	FI 40	1711
C1	FI 60	1694
C1	FI 80	872
C2	FI 40	1960
C2	FI 60	801
C2	FI 80	635
C3	FI 40	2876
C3	FI 60	1643
C3	FI 80	295

TABLE (25)	MEAN TOTAL NUMBER OF RESPONSES MADE IN EACH COMPONENT DURING EXTINCTION (4 DAYS - 50 MINS PER DAY) - MEAN DATA	
COMPONENT	RESPONSES	
FI 40	2182,30	
FI 60	1379,30	
FI 80	600,67	

Extinction, which began after the behavioural stability criterion mentioned in experiment I was reached, consisted of the disconnection of the reinforcement timer and the presentation of the SD's employed during acquisition according to the pattern described in section (ii) of this experiment.

After the extinction trials were completed the experimental pigeons were returned to their home cages and fed enough to bring their weights back to their ad libitum levels.

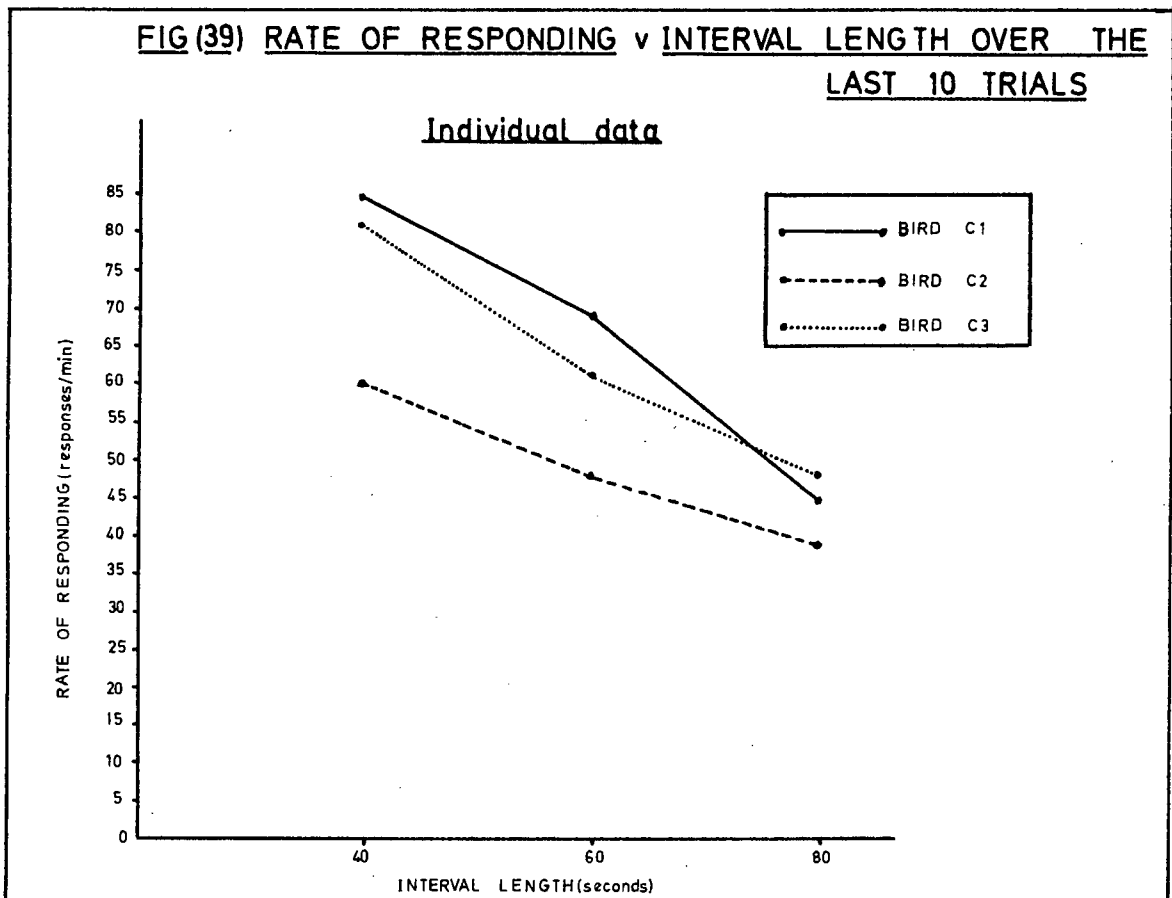
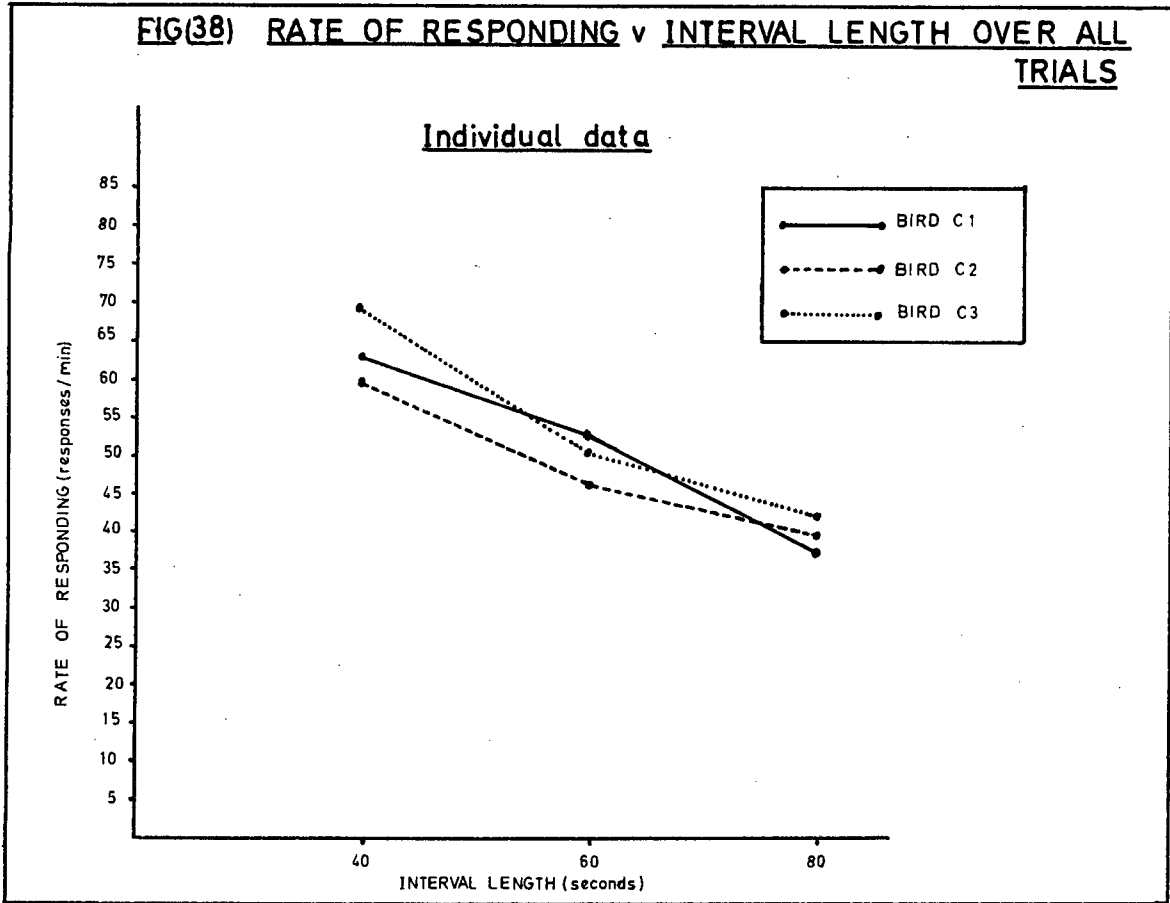
vi) Results.

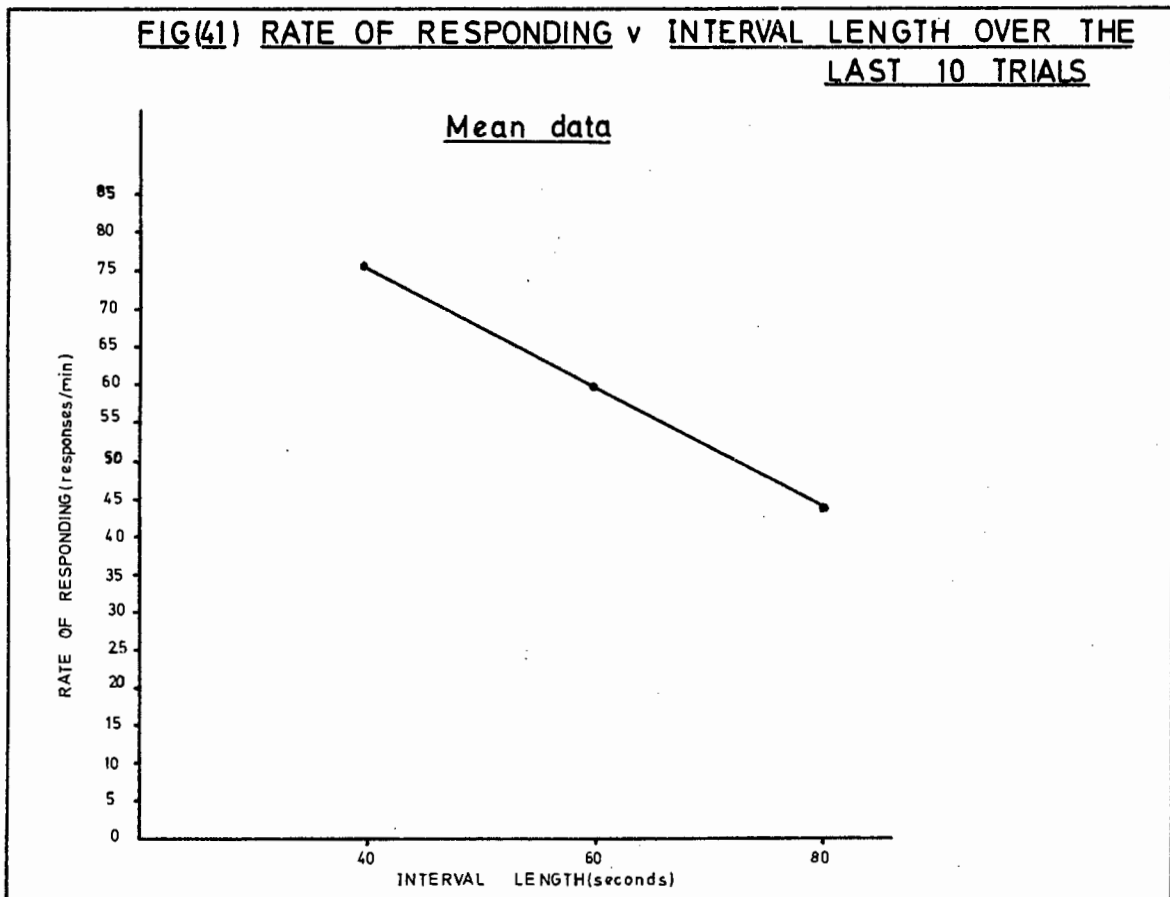
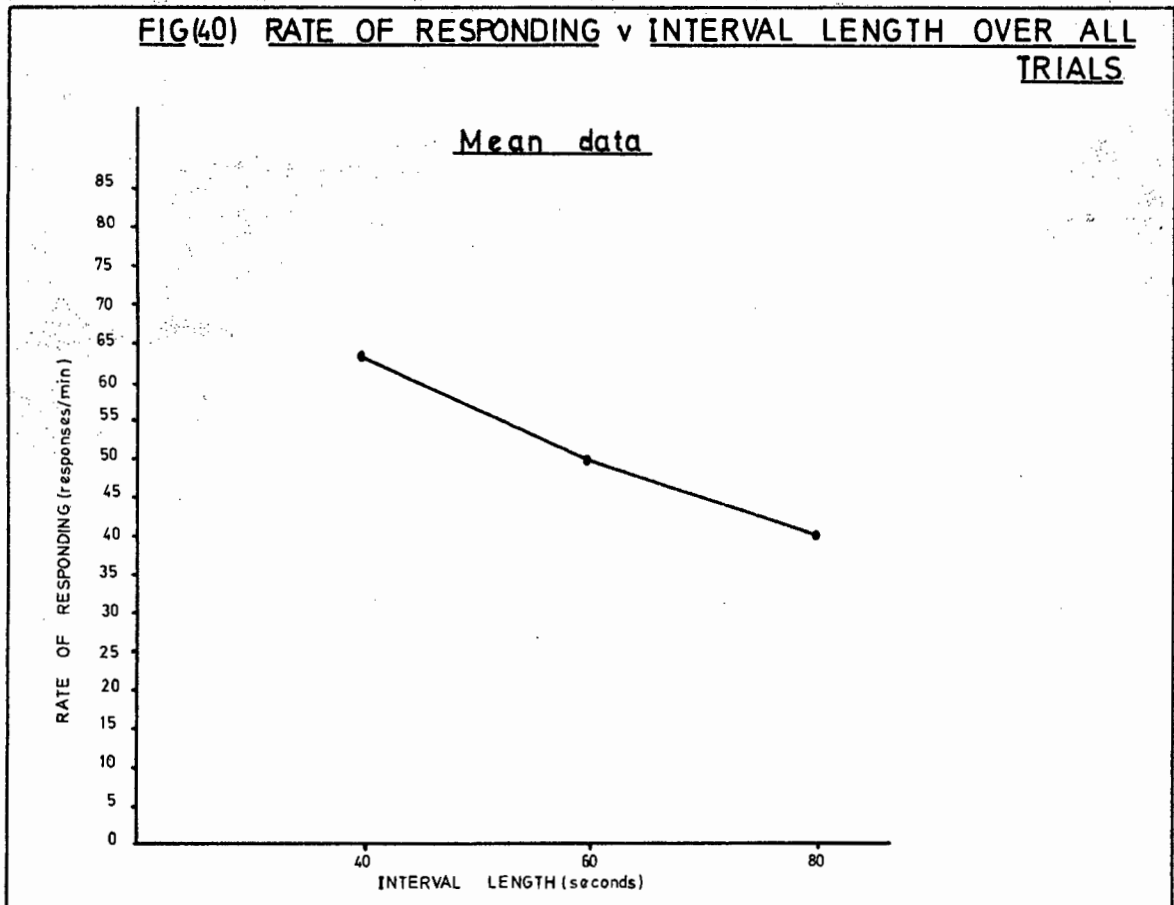
The results of this experiment are summarized in tables (18) to (25) and in FIGS.(38) to (45).

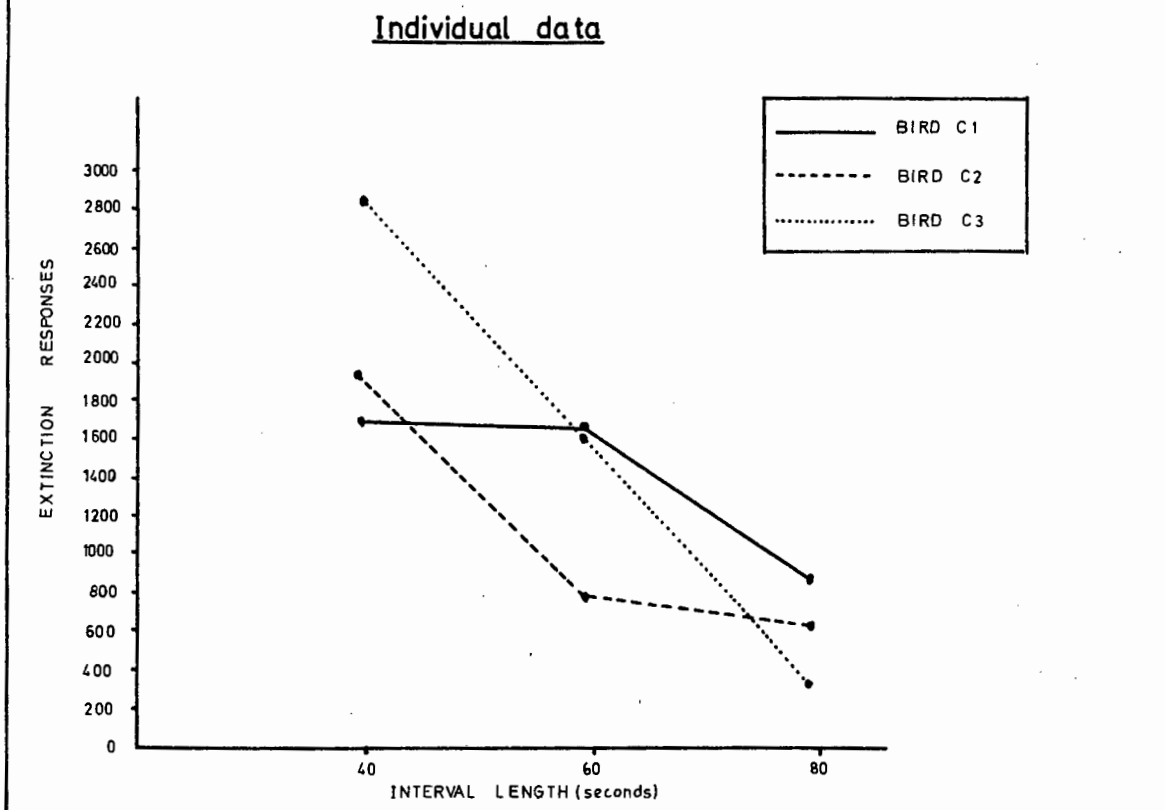
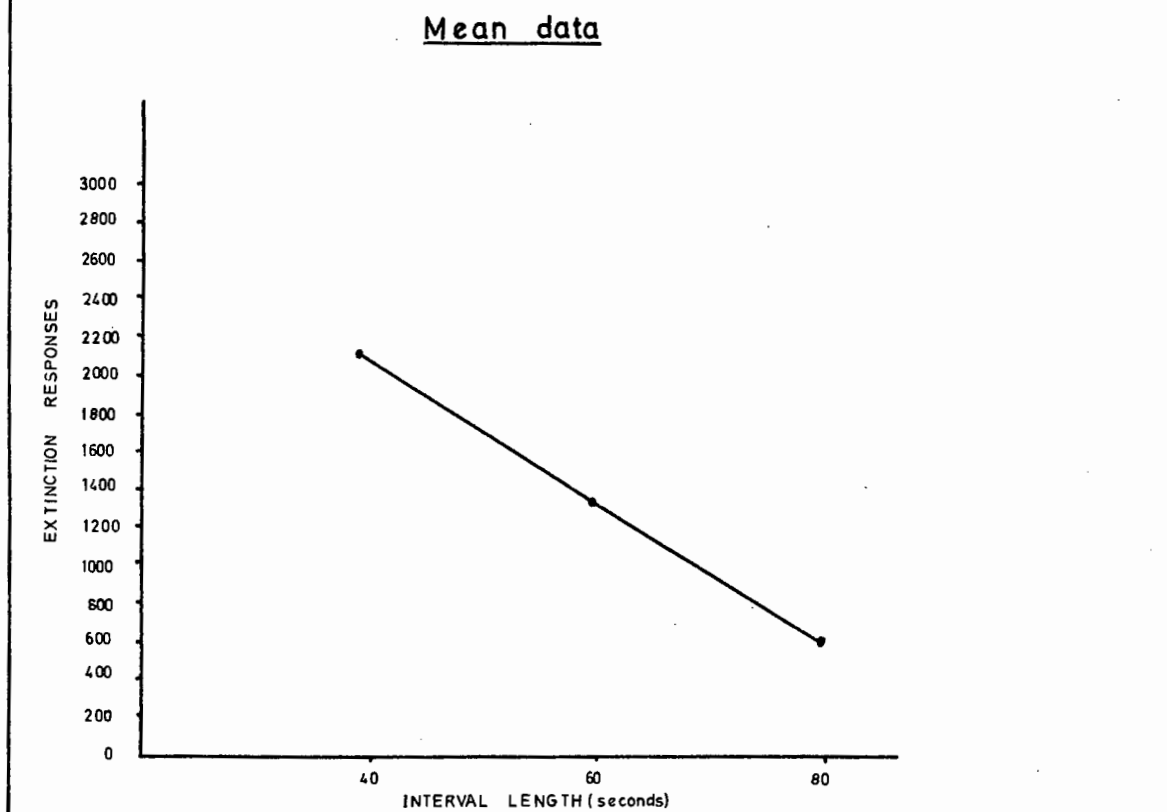
Tables (18) and (19) were again included in this results section for they show, firstly, that the extinction ratio does not remain constant with changes in interval length even during same subject performance; and secondly, that quite substantial differences exist in the amount of time each subject spent in each of the three component schedules. Further discussion of these differences can be found in the "Introduction" section of experiment IV below.

The more important results for the present study are contained in tables (20) and (22) for individual subjects and tables (21) and (23) for mean scores of the three subjects. FIGS.(38) and (39) for individual subjects and FIGS.(40) and (41) for mean data illustrate the relationship between rate of responding and interval length in multiple schedules, over both all the acquisition trials (41) and over the last 10 trials when the behavioural stability criterion was operating. The functions obtained were, in all cases, consistent, linear and downward sloping.

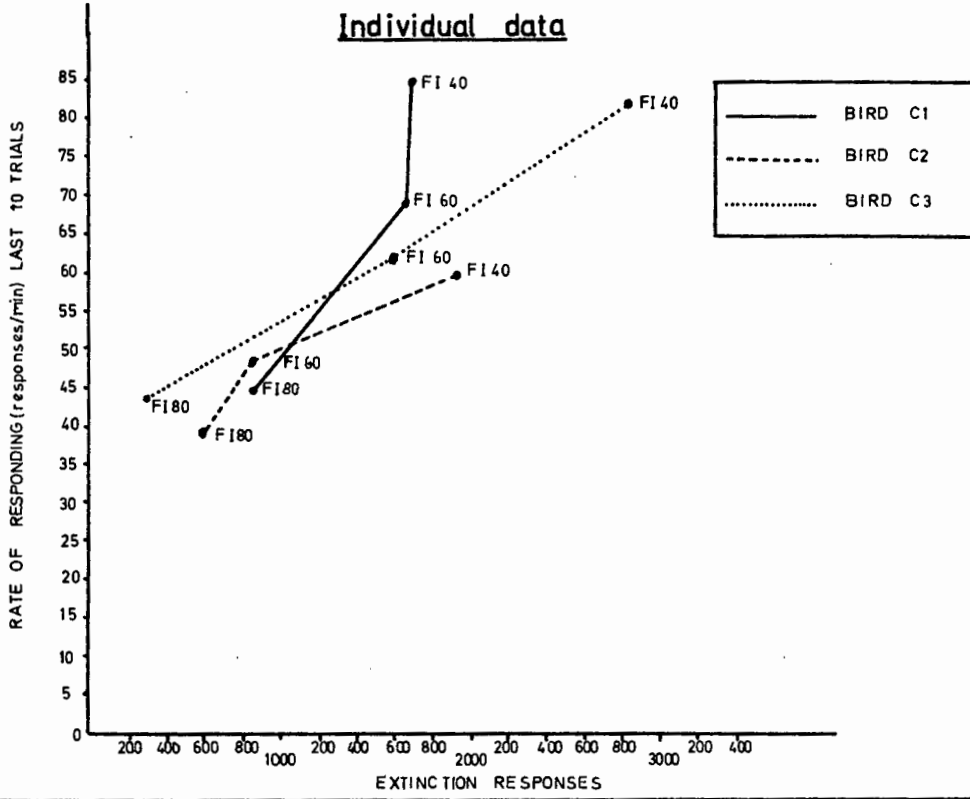
Table (24) for individual subjects and table (25) for mean data contain information obtained from the extinction



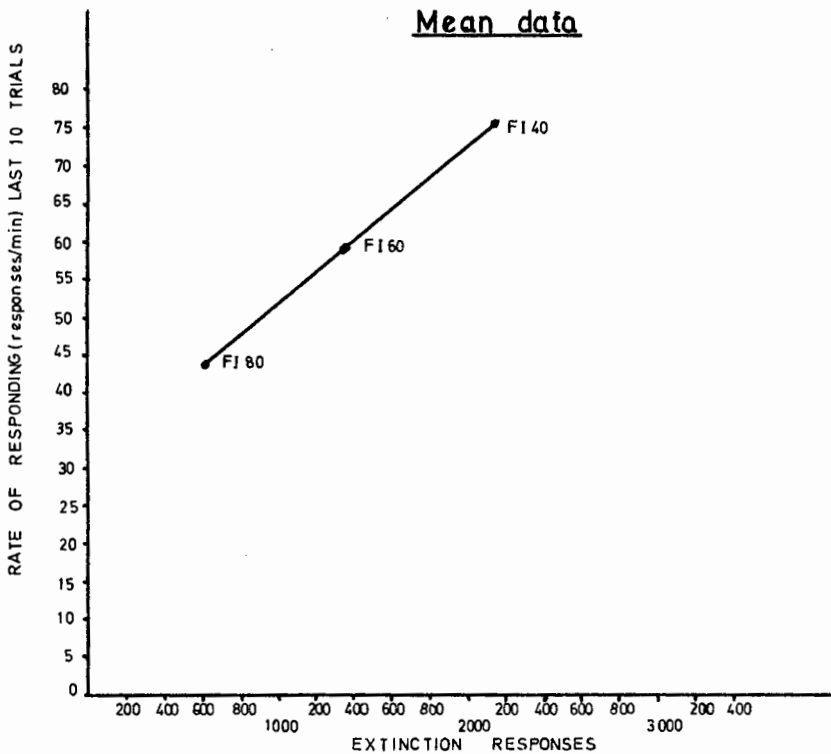


FIG(42) EXTINCTION RESPONSES v INTERVAL LENGTH**FIG(43) EXTINCTION RESPONSES v INTERVAL LENGTH**

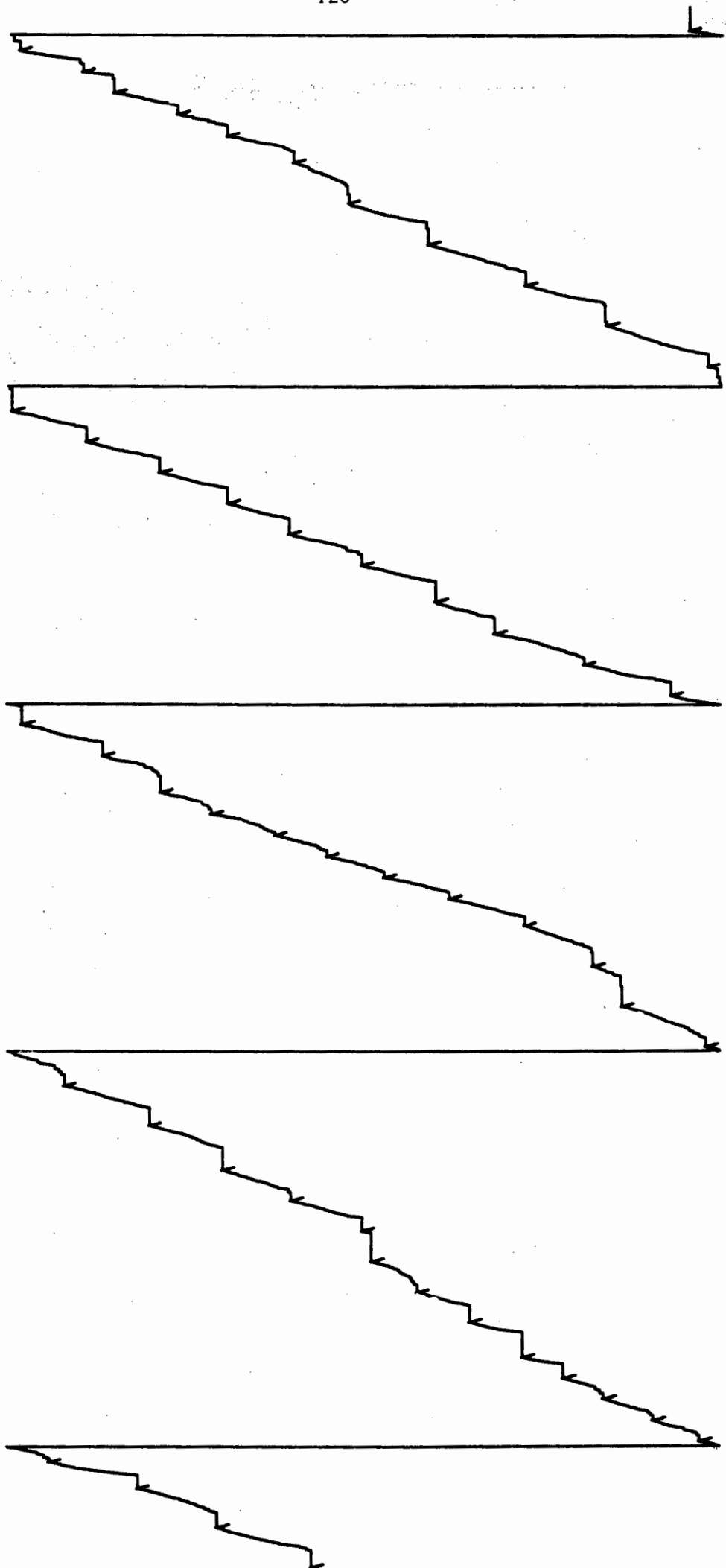
FIG(44) RESISTANCE TO EXTINCTION AS A FUNCTION OF RATE OF RESPONDING AT VARIOUS FIXED INTERVALS



FIG(45) RESISTANCE TO EXTINCTION AS A FUNCTION OF RATE OF RESPONDING AT VARIOUS FIXED INTERVALS



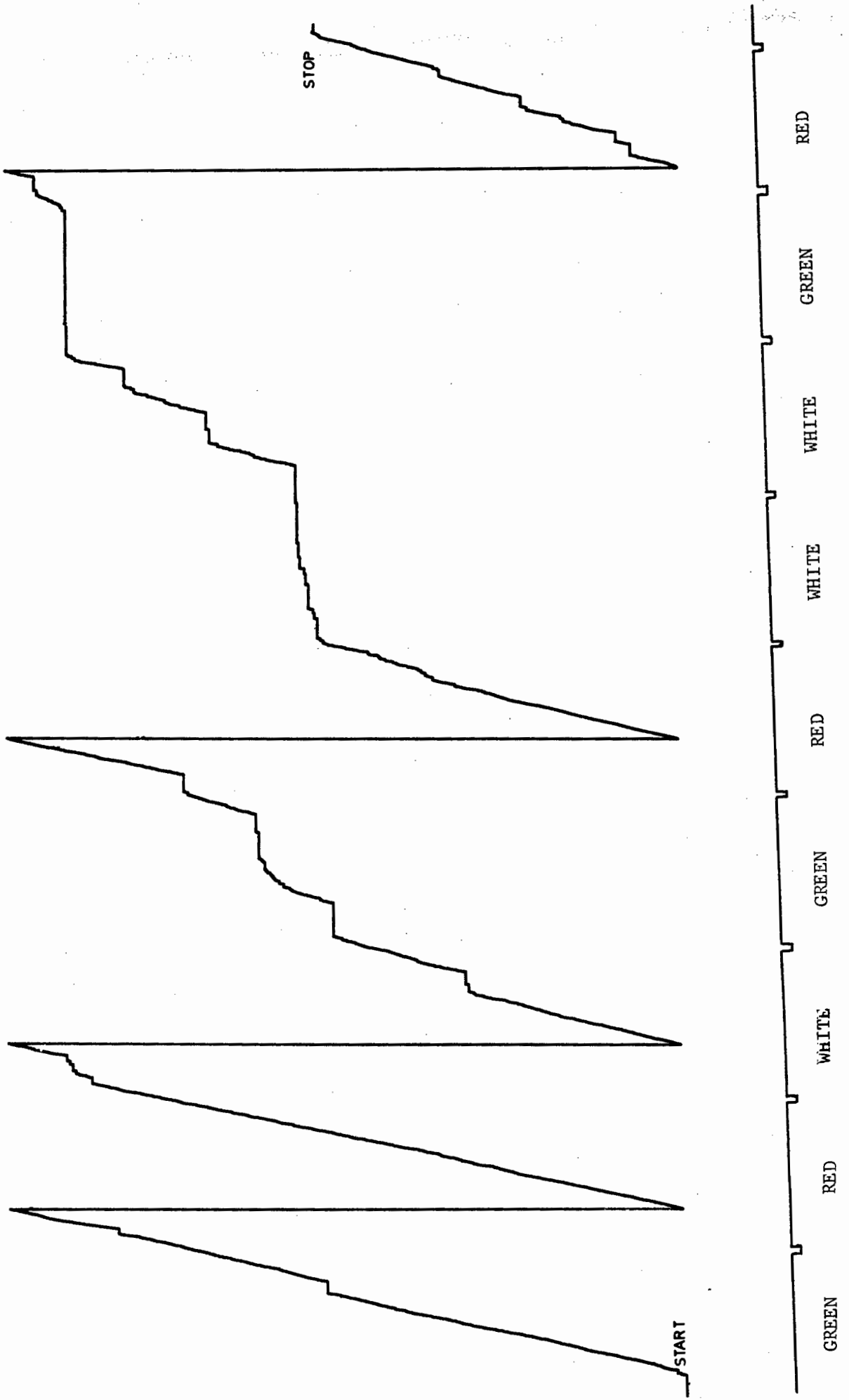
FIG(46)
TYPICAL ACQUISITION RESPONDING ON A MULT FI SCHEDULE.
Experiment III, Bird C2, 6/4/75



FIG(47)

Experiment III, Bird C2, 9/4/75

TYPICAL EXTINCTION PERFORMANCE AFTER MULT FI SCHEDULE RESPONDING.



trials. FIG.(42) for individual subjects and FIG.(43) for mean data illustrate the relationship between resistance to extinction and interval length. Here the function was generally linear and upward sloping. This is especially so for the mean data FIG.(43) where a straight line was drawn between the three points.

Lastly, FIG.(44) for individual data and FIG.(45) for mean data show the relationship between rate of responding and resistance to extinction at different interval lengths. With the individual data FIG.(44) an upward sloping trend is apparent, whereas with the mean data FIG.(45) another straight line was drawn between the three points.

FIGS.(46) and (47) show typical performance during acquisition and performance on the MULT FI schedule.

vii) Discussion.

With individual differences controlled for using multiple schedules, the results of the present experiment are very different from those of the previous experiments in which different subjects designs were utilized. In all cases the curves are much smoother, more consistent and show clear-cut linearity. Individual differences in rates of responding and extinction responses were evident in many cases, but with the single subjects design they had no effect on the shape of the functions produced.

The function relating mean rate of responding to interval length, both over all trials FIG.(40) and over the last 10 trials FIG.(41) can be compared with those obtained in various different subjects designs. For example, Skinner's (1938; p.128) graph relating rate of responding to interval lengths ranging from 3mins. to 9mins., is remarkably similar to the present one - FIG.(1), especially with regard the slope of the function produced.

The data of the present experiment also compare

favourably with those obtained by Wilson (1954; p.53) (see FIG.(8) above), even though Wilson's function was curvilinear in shape as a result of including very short intervals.

The present data are also very much in agreement with those found by Catania and Reynolds (1968; p.357) who also utilized a single subjects design. Over equivalent rates of responding, the function relating rate of responding to interval length for mean data in the present experiment FIG.(41) is slightly steeper than that obtained by Catania and Reynolds.

In contrast, the function relating these two variables produced in this experiment differs markedly from the function obtained in experiment I with different subjects - FIG.(26). No minimum at 60secs. was found in the present study, and the slope obtained with mean data was orderly, linear and monotonically decreasing, rather than U shaped as in experiment I.

Also important in the light of the discussion in experiment II and the introduction to this experiment, were the functions relating rate of responding to interval length for individual subjects FIGS.(38) and (39). Although individual differences played no confounding role on the effect of the independent variable, their influences are worth noting. Especially interesting is the way the function obtained from Bird C1 seems to symmetrically oppose the function obtained from Bird C3 in FIGS.(38) and (39). At the same time the remaining subject - Bird C2 produced a function very similar to the one obtained when all three functions were averaged FIGS.(40) and (41).

A further interesting result, also attributable to individual differences, and especially those mentioned by Skinner (1966; p.20) to occur whilst the contingencies are in operation, is the fact that the functions were more widely separated during the last 10 trials - FIG.(39) than they were

during the whole 41 trials - FIG.(38). This would indicate that the same contingencies had different effects on the performances of each of the subjects during the progress of the experiment.

For the present experiment the direct relationship (straight line function) between rate of responding and interval length is of foremost importance. This is especially so as it has been concluded in the previous two experiments that the relationship between interval length and rate of responding is probably a major contributing factor in any function relating the two fundamental measures of response strength - rate of responding and resistance to extinction.

The function relating resistance to extinction and interval length obtained in the present study FIG.(43) differs quite considerably from that obtained by Wilson (1954; p.54).

The maximum resistance to extinction at FI 60 found by Wilson does not appear in the present study, where the curve produced was linear and monotonically decreasing. This result provides an interesting contrast with the data produced by Boren (1961; p.306) who related resistance to extinction and the value of the fixed ratio. He found the resulting function to be linear and monotonically increasing.

The results of the present experiment utilizing single subjects were in opposition to those found in experiments I and II which utilized different subjects. In experiment I, for example, the function relating resistance to extinction and interval length was linear and monotonically increasing (like Boren's), whilst the same function in the present experiment was downward sloping. Possible reasons for this discrepancy will be dealt with in chapter 4, and include individual differences and essential differences between single FI schedules and multiple FI schedules.

With regard the individual functions relating resistance to extinction and interval length - FIG.(42) a similar symmetry as to the one in FIG.(39) was found to exist

between the performances of two of the subjects. This time Birds C1 and C2 produced symmetrically opposed functions about the point of FI 60 - Bird C1 produced a slightly convex function about FI 60, whilst Bird C2 produced a similarly concave function about the same point. Bird C3, on the other hand, produced a function which directly related these two variables. Thus, in the production of the mean curve, the functions of Birds C1 and C2 cancelled each other out to produce the straight line function shown in FIG.(43).

For mean data then, the function relating extinction responses to interval length formed an orderly, linear and monotonically decreasing relationship.

FIG.(45) shows the relationship between rate of responding and resistance to extinction, and, as expected from the discussion of the previous two functions, the result is a straight line function. For mean data a linear regression correlation coefficient of 1,0 for the last 10 days, and 0,998405 over all acquisition trials, was obtained. Thus with mean data the two measures of response strength investigated in this experiment were found to be directly related in the form of an orderly, linear and monotonically upward sloping function.

With the individual curves relating resistance to extinction and rate of responding, two of the three subjects again showed functions which were almost symmetrically opposed. FIG.(44) shows that Bird C1 produced a slightly concave function about FI 60 whilst Bird C2 produced a curve of convex shape at the same point. Quite unaffected by these deviations Bird C3 produced a function almost identical to the one produced with mean data.

To reiterate, then, it would seem from FIG.(45), that with individual differences controlled for, rate of responding and resistance to extinction are directly related. Further, it must be concluded that to gauge accurately the

effect of the schedule of reinforcement on the strength of behaviour, measured by its rate of responding and resistance to extinction, single subjects designs utilizing multiple schedules of reinforcement have to be employed.

Although the results of the present experiment were conclusive, it was decided to investigate the effects of "Time-in-schedule" on the relationship between rate of responding and resistance to extinction in a further experiment.

This experiment utilized DRL (differential reinforcement of low rate) and DRH (differential reinforcement of high rate) requirements in two components of a multiple fixed interval schedule. In this way "Time-in-schedule" in each of the two components was equated, but the rates of responding in each of the components was made to vary considerably.

Viii) Summary and Conclusions.

A single subjects design, employing three component multiple fixed interval schedules was used to investigate the relationship between rate of responding during acquisition and resistance to extinction. The results were conclusive: that rate of responding and resistance to extinction, the fundamental measures of response strength were found to be directly related. This leads to the summary statement: When the number of reinforcements is equated, a schedule which produces a higher rate of responding will be the more resistance to experimental extinction.

EXPERIMENT IV - An investigation of the relationship between rate of responding and resistance to extinction utilizing a single subjects design and multiple conjunctive fixed interval - fixed ratio (Differential reinforcement of low rate) (Differential reinforcement of high rate) reinforcement schedules.

i) Introduction.

In studies relating some aspect of intermittent reinforcement to resistance to extinction it has proved virtually impossible to control both the number of reinforcements and the time the organism spends either in the experimental chamber or exposed to the discriminative stimulus. This particular problem led Wilson (1954) to state "If the independent variable is length of the PR (fixed) interval, it is impossible to control both number of reinforcements and time in the experiment. Lacking experimental evidence, we felt that the number of reinforcements was the more important variable and this was held constant" p.52.

Jenkins and Rigby (1950) did, however, provide experimental evidence which, in retrospect, would have given Wilson's statement some validity. Four groups of rats were presented with 90 2min. periodic intervals, 90 1min. periodic intervals, 2400 continuous reinforcements or 90 continuous reinforcements respectively. Important for the present discussion was that groups I and III were matched on time in the experimental chamber and groups I, II and IV were matched on number of reinforcements, but not time in the experimental chamber. The important results were that, of the two groups matched for time in the experimental chamber, the group on a periodic interval of 2mins. produced far more responses in extinction than the group on continuous reinforcement, even though in terms of the number of reinforcements presented the crf group received over 25 times as many reinforcements as the periodic interval group. The results show that the number of reinforcements per se was not an important determinant of resistance to extinction, as was also the case with time in

the experimental chamber.

This led Jenkins and Rigby to conclude "Time in the experimental situation during conditioning could hardly have been playing more than a minor role as a concomitant of the method of partial reinforcement employed" p.38.

However, the actual differences in 'time-in-schedule' between intervals of 40secs., 60secs. and 80secs. used in the present series of experiments are quite large as table (26) below illustrates;

Table (26). Comparison of the amount of "time-in-schedule" for each of the preceding experiments.

EXPERIMENT NO.	SCHEDULE	INTERVALS		
		40secs.	60secs.	80secs.
I	Fixed Interval	24hrs30m	36hrs45m	49hrs 0m
II	Variable Interval	22hrs13m	33hrs20m	44hrs26m
III	Multiple Fixed Interval	8hrs12m	12hrs18m	16hrs24m*

* (Each bird).

The differences in total "time-in-schedule" were in direct proportion to the differences in the interval length - a multiple of $\frac{1}{2}$. This means that "time-in-schedule" for an interval length of 60secs. was $\frac{1}{2}$ times greater than for an interval length of 40secs., and for an interval length of 80secs. - twice as great.

Thus even though these large differences seemed to have no effect on the relationship between rate of responding and resistance to extinction (Experiment III), it was decided in this experiment to control for both number of reinforcements

and "time-in-schedule". At the same time it was believed that rate of responding could still be made to vary in a partial reinforcement situation.

This was achieved by combining the DRL and DRH schedules developed by Fantino (1968) into a multiple schedule. Although Fantino called these schedules DRL and DRH (p.16), they differed somewhat from the differential reinforcement of rate schedules outlined by Ferster and Skinner (1957; Chapter 9). Thus in order to avoid confusion between the Fantino DRL and DRH schedules and traditional differential reinforcement schedules, it was attempted, in the present experiment, to fit the Fantino schedules into the framework of traditional reinforcement schedule terminology. Even then, the uniqueness of these schedules made it difficult to subsume all their properties under traditional terminology. The result of this exercise was a schedule called a multiple conjunctive fixed interval - fixed ratio (DRL)(DRH) schedule of reinforcement.

The schedule programmed two components each represented by its own S^D , and reinforcement was available after the requirements of each had been met - multiple schedule. Under one of the components two contingencies had to be met in order to achieve reinforcement - conjunctive schedule. The contingencies were (a) a fixed interval of 20 seconds and (b) a fixed ratio (DRL) requirement of less than 15 responses. Thus the organism was reinforced for the first response emitted after 20 seconds, provided less than 15 responses had been emitted during that 20 second period.

This differential reinforcement of low rate schedule based on Fantino's (1968) DRL schedule does exactly what its title suggests - it differentially reinforces low rates of responding, by specifying a maximum number of responses which can be emitted during a set period of time. This can be contrasted with traditional DRL schedules (eg. Wilson and Keller (1953); Staddon (1965); and summarized by Kramer and Rilling (1970), in which interresponse times of greater than a

specified length are selectively reinforced. This type of schedule can lead to the situation, after extended training, in which the animal only produces IRT's greater than the required length, and hence the schedule becomes one of continuous reinforcement.

The second component also consisted of a conjunctive schedule. The contingencies operating in this component were (a) a fixed interval of 20secs., and (b) a fixed ratio (DRH) requirement of more than 30 responses. Thus the organism was reinforced for the first response emitted after 20 seconds, provided more than 30 responses had been emitted during that 20 second period.

This DRH requirement also differed from that traditionally used in operant research (Ferster and Skinner (1957; pps.493-502), in that the traditional DRH requirements are normally added to another schedule (usually a variable interval schedule). Further, if the DRH schedule reinforces only single short IRT's unusual response topographies occur (Ferster and Skinner (1957; p.33). It is more common to differentially reinforce sequences of short IRT's (Anger; 1956). In the present experiment no effort was made to specify exactly how short each of the IRT's must be, but obviously in order to obtain reinforcement the mean length of the IRT's must be short. Also the present DRH schedule required the organism to emit short IRT's over a specified, constant period of time - the FI contingency.

Thus with this multiple conjunctive FI-FR (DRL-DRH) schedule it was possible to control both rate of reinforcement (absolute and relative) and "time-in-schedule". Theoretically, then, the above schedule should produce a situation in which the rate of responding in one component (the DRH component) is at least twice the rate of responding in the other component (the DRL component) with both number of reinforcements and "time-in-schedule" equated across both components.

ii) Design.

A single subjects design was used in the present experiment, in which each level of the independent variable was presented to each subject.

The independent variable was rate of responding, which in this experiment was manipulated directly using rate based schedules. It was obtained by dividing the total number of responses in each component by the theoretical interval length, multiplied by the number of intervals, to which was added total reinforcement availability time.

$$\text{Rate of responding} = \frac{\text{TR}}{(\text{I} \times \text{N}) + \text{T.R.A.T.}}$$

where;

- TR = total number of responses in one component per session.
- I = interval length of component (minutes).
- N = number of components in each session.
- T.R.A.T. = total reinforcement availability time.

The dependent variable was resistance to extinction measured over 4 days of non-reinforced responding (approximately 45mins. per day). Two levels of the independent variable, corresponding to the two components of the multiple conjunctive FI-FR (DRL-DRH) schedule were utilized.

1) FI20 FR15 (DRL) - the pigeon had to emit less than 15 responses in 20 seconds in order to obtain reinforcement for the first response after 20 seconds.

2) FI20 FR30 (DRH) - the pigeon had to emit more than 30 responses in 20 seconds to obtain reinforcement for the first response after 20 seconds.

Thus the maximum rate of responding which could be achieved under DRL was 45 responses/minute, and the minimum under DRH

was 90 responses/minute, whilst the rate of reinforcement was held constant at 90 reinforcements per hour.

Each level of the independent variable was represented by its own S^D , and for each subject each level was represented by a different S^D as table (27) below shows:

Table (27). Design of the experiment.

SUBJECT	SCHEDULE		EXTINCTION
	DRL FI20 FR15	DRH FI20 FR30	
B14	GREEN	RED	3 hours
B15	RED	GREEN	3 hours
B16	WHITE	GREEN	3 hours

The two component multiple schedule presented blocks of 6 intervals of one colour, followed by a 10 second time-out period, followed by another block of 6 intervals. This second block of 6 intervals, in this experiment, could have been the same colour as the first block, although not more than two presentations of the same colour was programmed. The sequence with which one block followed the other was randomized by the computer. Each of the component blocks was presented 4 times. Thus, a session consisted of 48 presentations of the 20sec. intervals, 24 of them with DRL requirements and 24 of them with DRH requirements. (A reinforcement was also given for the pigeon's first peck upon entering the chamber - the daily total number of reinforcements was 49).

Extinction consisted of four presentations of each of the component S^D 's for 5min.27secs. in a random sequence. A 10sec. time-out period intervened between changes in the S^D . This procedure lasted for nearly 45mins. per day, and

was continued for four days, giving a total extinction time of 3 hours.

iii) Subjects.

Three experimentally naive male homing pigeons - numbers B14, B15 and B16 were used. They were maintained at 80% of their ad libitum body weights (± 15 grams) throughout the experiment according to the following schedule;

Table (28). Schedule of body-weight reductions (grams).

SUBJECT	<u>AD LIBITUM</u> WEIGHT	80% TARGET WEIGHT
B14	480	384
B15	350	280
B16	486	388

iv) Apparatus.

All the apparatus used in this experiment has been described in section (iii) of chapter 2 above. In addition the Hewlett-Packard computer was utilized, which apart from programming the schedules also recorded R.A.T.

The computer:

Hardware - see section (iv) Experiment II (page 97) for a full description of the hardware used.

Software - see Appendix IC for program listings and documentation.

The program used in this experiment was the same as that used in experiment III, except that only two components could be

specified and that each of these components contained different response rate requirements.

The program thus requested additional parameters in the form of the DRL and DRH requirements. When parameter specification was completed program operation was halted temporarily. When restarted the random generator subroutine randomly selected one of the two components and presented the appropriate S^D via the input/output subroutine. At the same time a count facility was added to the main program to count the number of inputs (responses). The program then made a decision whether to reinforce or to punish the organism in the chamber through the operation of an IF statement in the main program. Under the DRL contingency, as soon as the input count exceeded the specified DRL requirement within the time period specified by the component length, punishment (a 4 second time-out) was administered, via the specified time-out output channel. If the specified time period ended and the count had not exceeded the DRL requirement then reinforcement was presented in the way described in experiment III.

If a DRH component was randomly scheduled then its appropriate S^D was presented via the ASSEMBLER subroutine. Again via the IF statement operation, reinforcement was presented for the first input after the end of the timing of the interval, providing the number of inputs received prior to this equalled or exceeded the specified DRH requirement. If the requirement was not met by the end of the interval, then the first input arriving after this period produced a punishment.

Specifications included in the main program allowed not more than two components of the same requirement, selected by the random generator, to be presented one after the other.

This program also recorded R.A.T. in the same way as the program in the previous experiment and printed out the cumulative R.A.T. after each block of intervals comprising a component was completed.

v) Procedure.

After initial training (section (iv) chapter 2), four days of continuous reinforcement were presented, during which the subjects were exposed to their respective SD's. Each day of this continuous reinforcement training contained 60 reinforcements, presented in blocks of 10.

DRL and DRH training began on the fifth day, with the presentation of the multiple conjunctive schedule. The following sequence of values were used during training to criterion;

FI 10	FR 10	in both components.	
FI 15	FR 15	in both components.	
FI 20	FR 20	in both components.	
FI 20	FR 19	FI 20	FR 21
FI 20	FR 18	FI 20	FR 24
FI 20	FR 17	FI 20	FR 26
FI 20	FR 16	FI 20	FR 28
FI 20	FR 15	FI 20	FR 30

It was often necessary to remain on a particular value if the pigeon had difficulty in fulfilling the requirements. In fact, this experiment lasted 65 days, of which only the last 20 (where criterion performances occurred) were recorded in the results section below.

Performance on these last 20 trials fulfilled a criterion of maximum allowable error. This was defined in the present experiment as a maximum ratio of 20% between punishments and reinforcements. Punishment (a four second time out) was administered immediately the pigeon emitted more than the FR requirement (15) in the DRL component, or if it emitted less than the FR requirement (30) by the time the fixed interval was completed in the DRH component.

After extended training punished performances were almost non-existent in the DRH component. However, the

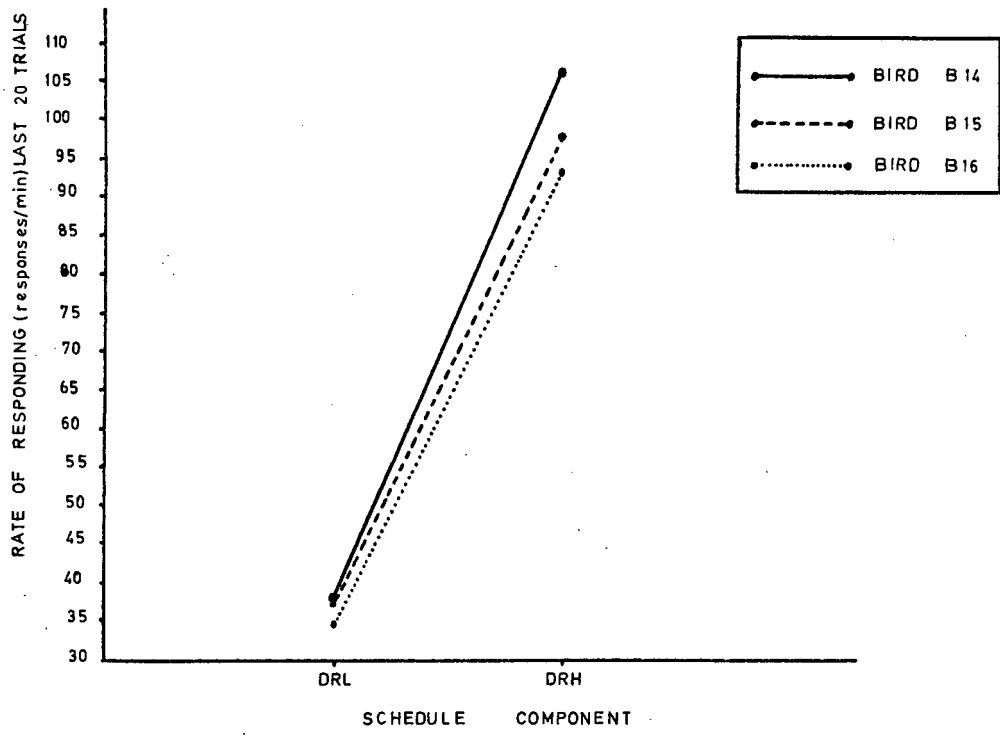
TABLE (29)	MEAN RATE OF RESPONDING OVER LAST 20 ACQUISITION TRIALS - INDIVIDUAL DATA	
BIRD NO.	COMPONENT	RESPONSES/MIN.
B14	DRL	37,066
B14	DRH	105,073
B15	DRL	36,909
B15	DRH	97,240
B16	DRL	34,455
B16	DRH	93,400

TABLE (30)	MEAN RATE OF RESPONDING OVER LAST 20 ACQUISITION TRIALS - MEAN DATA	
COMPONENT	MEAN RESPONSES/MIN.	
DRL	36,143	
DRH	98,571	

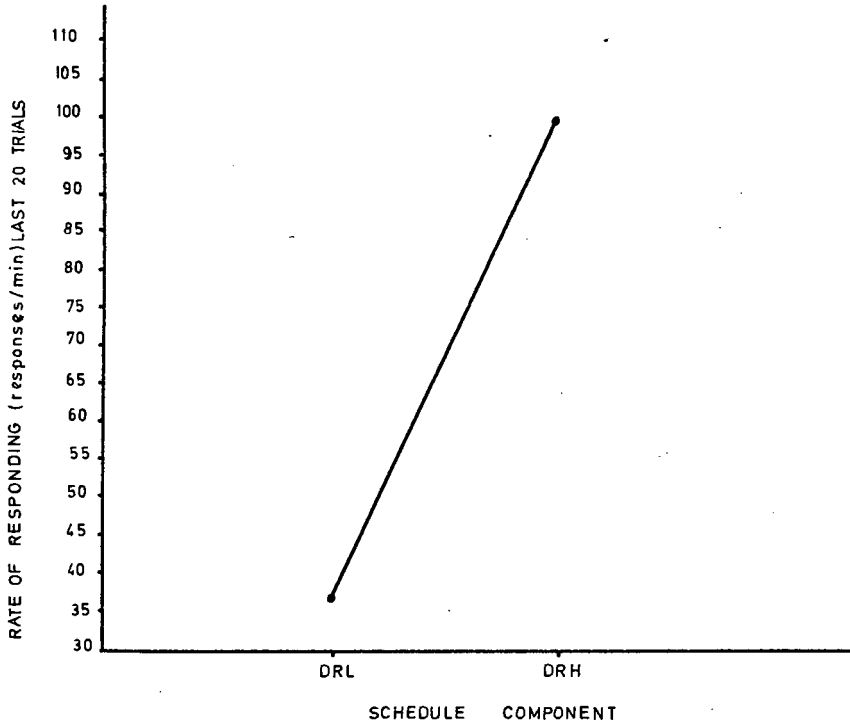
TABLE (31)	TOTAL NUMBER OF RESPONSES MADE IN EACH COMPONENT DURING EXTINCTION (4 DAYS - 45 MINS PER DAY) - INDIVIDUAL DATA	
BIRD NO.	COMPONENT	RESPONSES
B14	DRL	879
B14	DRH	1659
B15	DRL	1486
B15	DRH	3077
B16	DRL	2564
B16	DRH	3562

TABLE (32)	MEAN TOTAL NUMBER OF RESPONSES MADE IN EACH COMPONENT DURING EXTINCTION (4 DAYS - 45 MINS PER DAY) - MEAN DATA	
COMPONENT	RESPONSES	
DRL	1643	
DRH	2766	

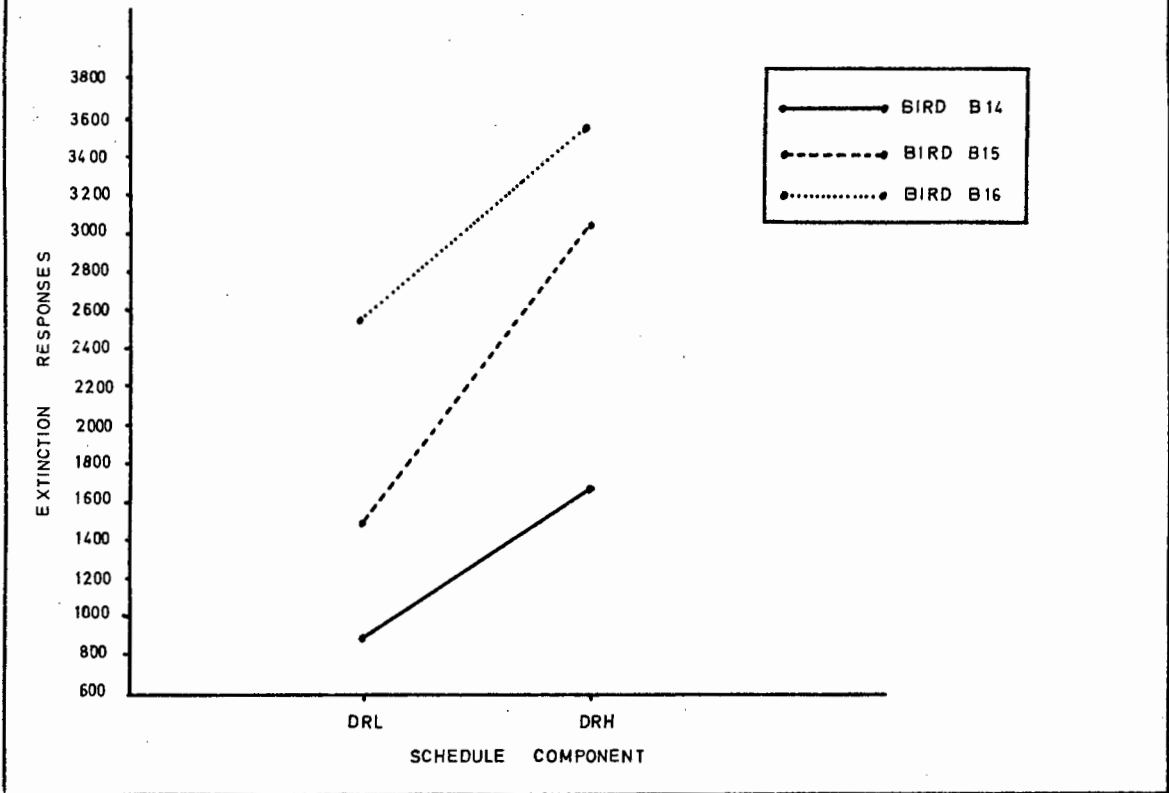
**FIG (48) RATE OF RESPONDING v SCHEDULE COMPONENT
OVER LAST 20 TRIALS - INDIVIDUAL DATA**



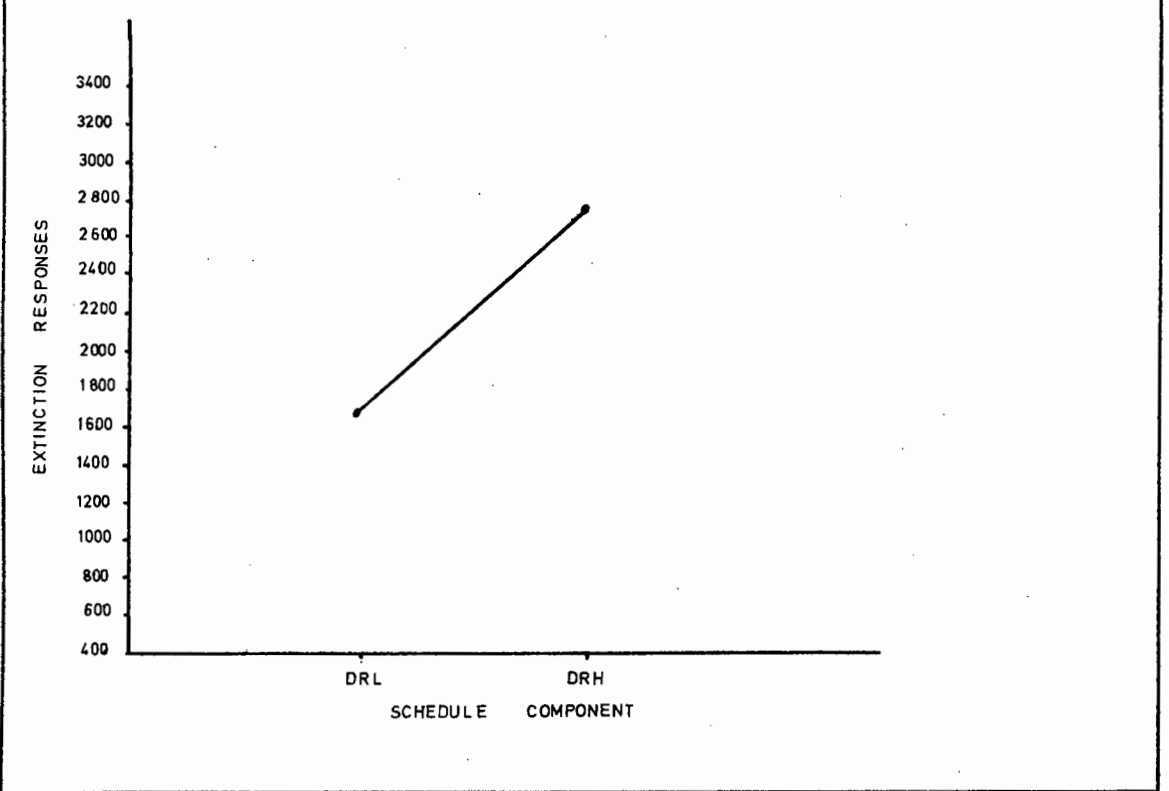
**FIG (49) RATE OF RESPONDING v SCHEDULE COMPONENT
OVER LAST 20 TRIALS - MEAN DATA**



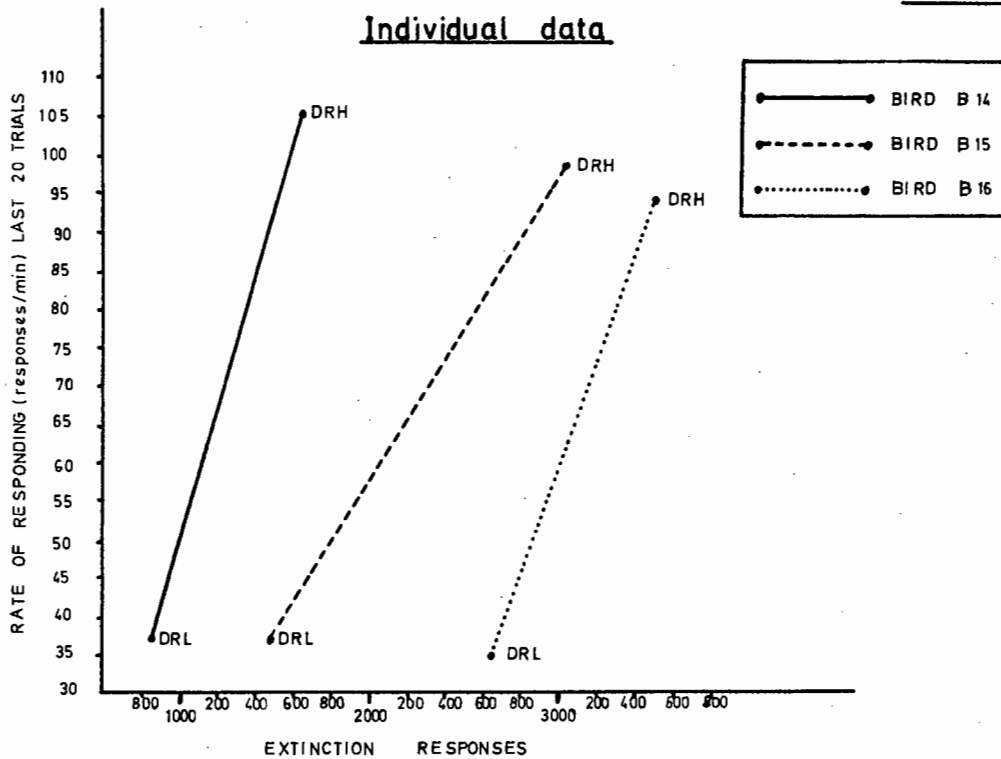
FIG(50) EXTINCTION RESPONSES v SCHEDULE COMPONENT
INDIVIDUAL DATA



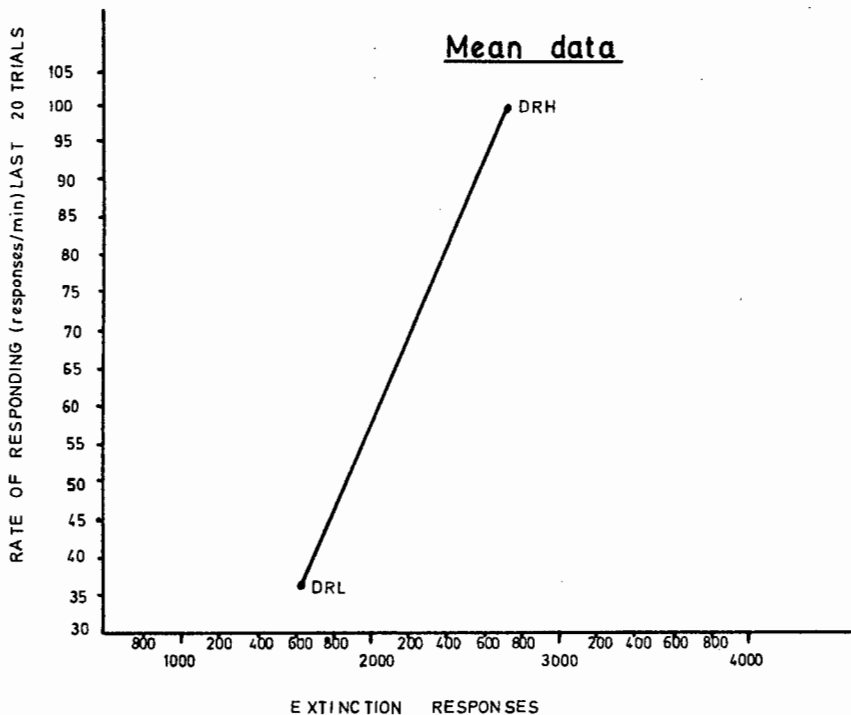
FIG(51) EXTINCTION RESPONSES v SCHEDULE COMPONENT
MEAN DATA



FIG(52) RESISTANCE TO EXTINCTION AS A FUNCTION OF RATE OF RESPONDING FOR VARIOUS COMPONENT REQUIREMENTS



FIG(53) RESISTANCE TO EXTINCTION AS A FUNCTION OF RATE OF RESPONDING FOR VARIOUS COMPONENT REQUIREMENTS



FIG(54)

TYPICAL ACQUISITION RESPONDING ON A MULT CONJ

FI-FR(DRL-DRH) SCHEDULE. Experiment IV, Bird B16,

8/6/75

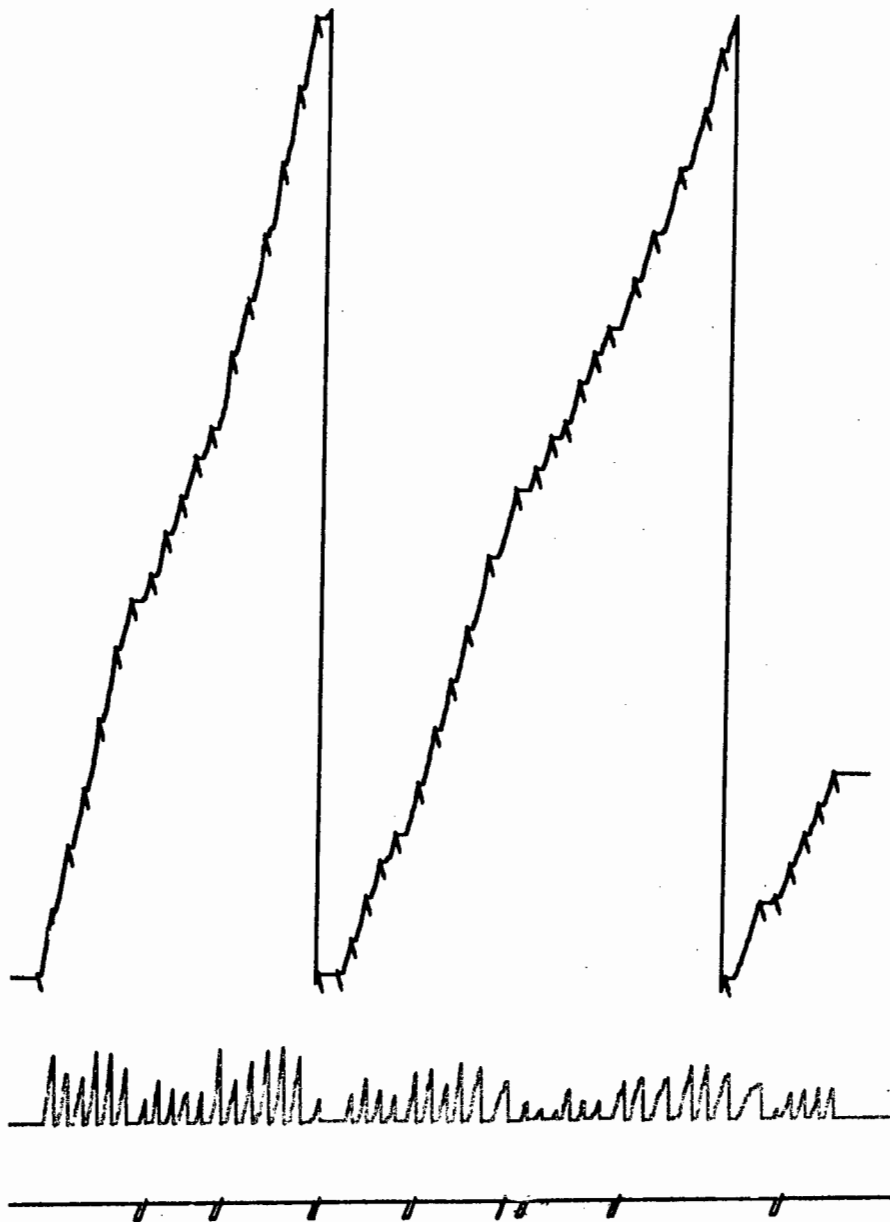
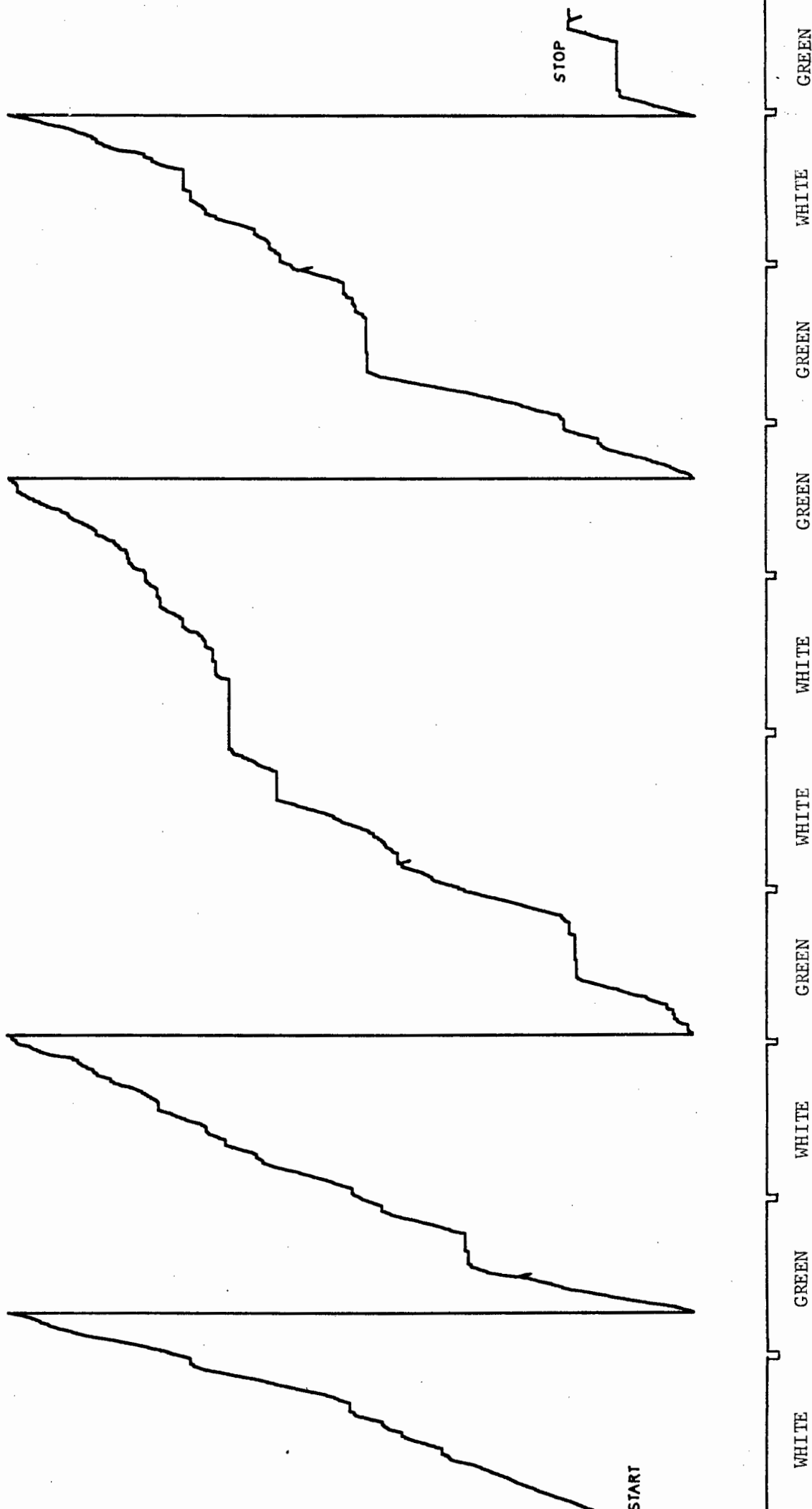


FIG (55)

TYPICAL EXTINCTION PERFORMANCE AFTER MULT CONJ FI-FR(DRL-DRH) SCHEDULE RESPONDING. Experiment IV, Bird B16, 22/6/75



criterion was applied strictly to DRL performance. The total number of responses which resulted in a punishment were subtracted from the response total in the DRL component. (Punishments were recorded by an event pen on the cumulative recorder).

When the response rates had reached a stable level (see section (v) of experiment I) and the percentage of punishments was less than 20%, extinction was begun. This consisted of the disconnection of the reinforcement timer and the presentation of the S^D's employed during acquisition according to the pattern described in section (ii) of this experiment.

After the completion of the extinction trials the pigeons were returned to their home cages and fed enough to return them to their ad libitum weights.

vi) Results.

The results obtained during this experiment were recorded in tables (29) to (32), and FIGS. (48) to (53).

Table (29) and FIG.(48) show, for individual subjects, the mean rate of responding in each component over the last 20 trials during which the error criterion and response rate stability criterion were in operation. Table (30) and FIG.(49) show the same data but averaged across the three subjects.

Table (31) shows the number of responses emitted in extinction in each of the components for individual subjects. Table (32) shows the same data averaged across the three subjects.

FIGS. (50) and (51) relate the number of responses emitted during extinction to the component requirements. Again the trend is upward sloping - meaning that more responses were produced in extinction to the DRH component than to the DRL component.

Lastly FIG.(52) for individual data and FIG.(53) for mean data show the relationship between rate of responding and resistance to extinction resulting from performance under the two component multiple conjunctive FI-FR (DRL-DRH) schedule. The trend, in both graphs is upward sloping. FIGS.(54) and (55) show typical acquisition and extinction performance under this schedule.

vii) Discussion.

Before this particular experiment began, a pilot study was initiated in which a three component multiple schedule with DRL and DRH requirements on two of the components was utilized. The third component was a simple fixed interval with no rate requirements. It was found that this no rate requirement component confused the pigeon, and often resulted in high rates of responding under the DRL SD and low rates of responding under the DRH SD.

However, with further training and some procedural modifications a three component multiple schedule could be developed in which two of the three components would have rate requirements, whilst the rate of responding in the third component would be left to stabilize at its own rate.

As a result of the above, only two values of the independent variable were measured in the present experiment, thus allowing only trends in the data to be examined.

The relationship between rate of responding and the component requirement in FIGS.(48) and (49) is of a generally steep upward sloping nature. In all cases the rate of responding was well below the maximum allowed under the DRL contingency. This maximum was 45 responses per min., and the rates of responding under the DRL component were as follows; BIRD B14 37,066, BIRD B15 36,909 and BIRD B16 34,455 resp/min., giving a mean rate of responding of 36,143 resps/min., for all three birds.

The rate of responding under the DRH contingency was in all cases above the minimum allowed (90 resps/min.) - BIRD B14 achieved 105,073 resps/min., whilst BIRDS B15 and B16 achieved 97,240 and 93,4 respectively. The mean rate of responding under this contingency was just over 8 resps/min. higher than the minimum - 98,571 responses/min.

Some differences in slope amongst the three functions in FIG.(48) were apparent. More important, however, was that, in all cases, the bird which responded at the lowest rate under DRL also responded at the lowest rate under DRH.

Individual differences in resistance to extinction resulting from the different rate requirements were apparent in FIG.(50). An interesting result was that the slope of the functions for BIRDS 14 and 16 were almost parallel, whilst that for BIRD 15 was much steeper. For all birds many more responses were emitted in extinction after acquisition training under DRH contingencies than under DRL contingencies, even though the number of reinforcements and "time-in-schedule" were controlled for. FIG.(51) shows an upward sloping function between the mean number of responses in extinction and the component requirement.

The important results for the present series of experiments were contained in FIGS.(52) and (53). In FIG.(52) all the functions were upward sloping, with those of BIRDS B14 and B16 almost parallel, whilst that of BIRD B15 was slightly less steep.

As only two values of the independent variable were used no conclusions as to the direct relationship between rate of responding and resistance to extinction can be made. However, the following general statement summarizes the results of this experiment - with the number of reinforcements (and rate) and "time-in-schedule" equated, the schedule which produced the lowest rate of responding also produced the least responses in extinction. Further the schedule which required a high rate of responding produced a far greater resistance

to extinction. This occurred in all three cases investigated.

To this conclusion must be added the fact that the relationship described in the general statement above, was found not to be direct, in that the mean rate of responding produced in the DRL component was 36,143 resps/min. - which produced 1643 responses in extinction. In contrast, the DRH component produced a rate of responding almost 3 times greater than the DRL component (98,571), but a resistance to extinction not even twice as great (2766).

The importance of this experiment was not so much in the results obtained, but in the method used to obtain them. It has thus proved possible, with the schedule developed here, to control both "time-in-schedule" and number of reinforcements, and yet produce a large difference in rate of responding, without having to resort to methods such as the withdrawal of the operant manipulanda or the yoked-control experiment.

viii) Summary and Conclusions.

A single subjects design utilizing two component multiple fixed interval - fixed ratio (DRL) (DRH) schedules to produce markedly different rates of responding, was used in a partial reinforcement situation where both "time-in-schedule" and number of reinforcements were equated. Although only two values of the independent variable were measured the results were in agreement with those of the previous experiments - that a low rate of responding (DRL component) produced a low resistance to extinction and a high rate of responding (DRH component) produced a high resistance to extinction. Thus "time-in-schedule" was found not to be an important influence on the relationship between the two fundamental measures of response strength - rate of responding and resistance to extinction.

CHAPTER IVGENERAL DISCUSSION(i) The concept of response strength and the results of the present series of experiments.

"The concept of strength is not, perhaps, a logical necessity. Agreements in the effects of diverse operations can be noted without invoking a common variable. However, the identification of a common variable such as response strength provides an economical summary of a large number of findings" Nevin (1974) p.403. The concept 'response strength', then, has adequately summarized the results of a number of studies ranging from early experiments on the P.R.E. effect, Skinner (1938), Jenkins and Stanley (1950); through early experiments with intermittent schedules of reinforcement, Skinner (1938) and (1946), Wilson (1954); through the more recent systematic research with interval schedules, Catania and Reynolds (1968), Dews (1970); to the contemporary research of Nevin (1974), and to some extent the present series of experiments.

The concept of 'response strength' is nevertheless a valid one, and one that is still widely used (e.g. Nevin (1974), Morse (1966), Thomas and Konick (1966) and Nevin and Reynolds (1973). Although the concept has changed somewhat from the hypothetical entity 'reflex reserve' of Skinner (1938) to the recent notion that it is nothing more than the measures used in determining it (Herrnstein, 1970), there still remains the fact that, whichever concept is used, the relationship amongst the various measures of response strength is of fundamental importance. It is for this reason that the present series of experiments was undertaken to determine the nature of the relationship between two of the more widely used measures of response strength in the operant paradigm - rate of responding and resistance to extinction.

It was the overall aim of the present study to show

that such a relationship between these two measures benefits both the original 'reflex reserve' concept of response strength, and the notion that strength is nothing more than the measures used to determine it. In this way, both the old and the new can be combined within the confines of the Laws of Parsimony (Occam's Razor).

The initial view was of reflex (or response) strength existing as a hypothetical entity, whose structure could be inferred from various static properties. These static properties change as the operations of reinforcement and extinction, add to and subtract from them. The presence of this hypothetical entity, however, can be determined by the known measures of response strength - rate of responding and resistance to extinction.

Reflex strength in the form Skinner (1938) developed was composed of two components - (1) 'the reflex reserve', a sort of hypothetical "store", which in turn, was composed of an immediate reserve and a total reserve - in Skinner's system rate of responding was proportional to the immediate reserve, which in turn drew its strength from the total reserve; and (2) the extinction ratio - the ratio of reinforced to unreinforced responses, which has special importance in interval schedules where reinforcement does not depend directly on the number of unreinforced responses.

With a known, constant rate of reinforcement, rate of responding and the extinction ratio are directly related - for rate of responding is simply the extinction ratio divided by the interval length, when interval length is held constant (p.131). Further, the rate of responding was stated by Skinner to be proportional to the existing reserve (pps.83-84), and the extinction ratio was found to be directly related to resistance to extinction (p.138). Thus, the production of a higher rate of responding will result in a higher extinction ratio, and hence a greater resistance to extinction, providing number of reinforcements are equated.

The results of experiments III and IV of the present study, where individual differences and number of reinforcements were controlled, are in direct agreement with the predictions generated from the original Skinnerian hypothesis outlined above.

The more recent approach to the analysis of response strength has been to equate it with the measures used to determine it. If this is the case, and response strength is nothing more than the measures used to gauge it, then the measures themselves must be well related. If they are not, then either the concept of response strength is something more than the measures used to gauge it, as Nevin (1974) argued, or the measures themselves are faulty.

Following the suggestions of Morse (1966; p.78) and Herrnstein (1970; p.246) - that more research should be undertaken to determine the relationship between the measures of response strength - the experiments reported above show that, with proper control exercised over the relevant variables, two of the more important measures of response strength - rate of responding and resistance to extinction are in fact well related (experiments III and IV).

Evidence both from the present study and from the studies reviewed in Chapter I, which show that these two measures are well related, lends much support to the argument that response strength is rate of responding and/or resistance to extinction, and that nothing further need be added to determine its nature, as Nevin (1974) and Kling (1971) suggest.

Theoretically, then, the results of this study have served a two-fold purpose. They have realized the predictions made by Skinner's early account of the nature of response strength, and they have provided some direct evidence for those recent theorists who believe that the measures used to gauge response strength, themselves constitute that strength.

(ii) Evaluation of the present study.

The series of experiments reported above have

contributed in a modest way, both methodologically and technologically, to the study of response strength within the operant paradigm. However, they are not without criticism, much of which is of a procedural nature. These contributions and criticisms will be discussed below.

a) Contributions.

In any research where resistance to extinction is used as a dependent variable, careful control over all the relevant confounding variables is of utmost importance. Chapter 2 (section 1) contains a summary of the known variables which differentially affect resistance to extinction. In experiments I, II and III all of these variables with the exception of "time-in-schedule" and number of responses were carefully controlled. In the discussion of these variables in Chapter 2 it was noted that the role which the gross number of responses plays in resistance to extinction is somewhat limited. Of much more importance, however, is the extinction ratio - the ratio of reinforced to non-reinforced responses. In the present study the extinction ratio itself was a concomitant of the independent variable, as rate of responding is directly dependent on the extinction ratio when rate of reinforcement is equated.

As with any other study utilizing intermittent reinforcement both "time-in-schedule" and number of reinforcements could not be controlled simultaneously in experiments I, II and III, but were controlled, however, in experiment IV.

No great differences were found between the results of experiments III and IV where individual differences were controlled for. Thus, with the contingencies used in the present series of experiments it was concluded that 'time-in-schedule' did not confound the effects of the rate of responding during acquisition on resistance to extinction.

The constant probability variable interval schedule

employed in experiment II has contributed towards solving the problem of sequential dependency. The computer program which timed the intervals was designed in such a way that the random generator subroutine which sampled the interval lengths from the progression of intervals could have, as its starting point, any integer between 1 and 16001. In this way an entirely different sequence of intervals could be produced every day for over forty years.

The conclusions drawn from experiment III emphasized the fact that in studies of response strength single subjects or repeated measures designs are essential. The multiple schedule of reinforcement adequately serves this purpose in the operant paradigm, by presenting two or more levels of the independent variable to the same subject.

The multiple conjunctive FI-FR(DRL-DRH) schedule used in experiment IV could have a number of uses as it enables control to be exercised over both 'time-in-schedule' and number of reinforcements. It could be used effectively in the study of behavioural contrast, where, for example, the DRH component could be manipulated to see its effects on the unchanged DRL component, or vice versa. It could also be used in a three component situation, in which two of the components would have DRL requirements and the third DRH or vice versa.

The recording of reinforcement availability time was also an important feature of the present series of experiments, for it increased the accuracy of the measure of rate of responding. Many researchers tend to disregard the measurement of R.A.T. for it is normally very small in comparison to the interval length. However, with the relatively short intervals employed in the present study (40, 60 and 80 seconds) the addition of R.A.T. did play a significant role. For example, during an interval of 40 seconds a pigeon might respond 50 times, thus producing a response rate of 75 responses per min. If, say, the recorded R.A.T. was only 2 seconds, then the response rate would drop to 71,4 responses per min.

This study featured a number of technological innovations. The timer used in experiments I and II recorded reinforcement availability time to an accuracy of 1/10 second. This particular timer with start, stop and cumulative functions, proved to be extremely useful in those experiments in which electro-mechanical programming and recording equipment was used.

Although the on-line control of operant experiments by computer is quite common in the U.S.A., this series of experiments was the first time that such control of operant experiments has been attempted in this country. In experiments III and IV the computer controlled all the contingencies such as the key light, reinforcement presentation, reinforcement timing, interval timing, houselight control, time-out control and time-out timing. It also recorded reinforcement availability time and made this data available in the form of printout.

Due to some technical difficulties experienced the computer did not count responses (except in the DRL-DRH schedules) - rather this was done by standard electro-mechanical counters. However, the computer did count the number of reinforcements and then brought the experimental session to an end when this number reached a specified parameter.

Possibly the most important contribution of computer technology to operant behaviour is the remarkable flexibility it offers in reinforcement schedule development. Almost any schedule of reinforcement, together with many combinations of schedules can quite easily be presented by the computer.

The simplicity of the interfacing between the computer and the experimental chamber was also a feature of experiments III and IV. Circuits for key lights, reinforcement relay, etc. were simply wired through switches on the interface, which when closed by the computer operated the particular device wired to that switch. The only limitation to this system is the fact that the computer can only switch a current of up to 2amps. However, with operant technology this is not a serious problem

as most of the equipment associated with the operant chamber requires a current of only about 1 amp.

The double-box technique, although not a new innovation, did allow much easier access to the operant chamber, than if the chamber was situated in an adjoining room. Further, the use of closed circuit television to visually monitor the bird's performance and to check the operation of the reinforcement light, proved more beneficial than more direct observation techniques such as one-way mirrors, in terms of any possible disruptive influences on the pigeon's behaviour.

b) Criticisms.

Perhaps most criticism can be levelled at the use of different subjects for the various levels of the independent variable in experiments I and II. Further only one subject was assigned to each of these values. Thus the idiosyncratic performances of the particular bird assigned to each level of the independent variable overwhelmed the effect of the independent variable itself. These individual differences could have been partially controlled by using more than one subject at each level of the independent variable.

However the lesson learned from this experience contributed to the design of experiment III and to the results obtained in that experiment. Thus the problem of individual differences highlighted in experiments I and II has emphasized the need for single subjects designs in any experiment in which resistance to extinction is used as the dependent variable. Further these sort of problems have led directly to the development of different measures of response strength, such as relative rate of responding (Herrnstein; 1961) and relative resistance to change (Nevin; 1974).

This series of experiments was designed primarily to show that a direct relationship does exist between the two fundamental measures of response strength. If the present

study itself was simply an analysis of response strength then it would contain an important flaw. This is because the title of the present study contains the word "acquisition", and in order to assess response strength adequately more than just behaviour acquisition would have to be studied. Rather the 'maintenance' of behaviour by the schedules of reinforcement in operation would have to be continued until asymptotic conditions were attained.

In this respect, then, one could possibly argue that the schedules used in the present experiment were too short, and that not enough daily sessions were given to the subjects.

To counter these possible shortcomings it must be emphasized that the schedule lengths were chosen in such a way that they would straddle an interval length of 60 seconds, where Wilson (1954) found a maximum resistance to extinction.

In reply to the possible shortcoming that not enough daily sessions of training were given to the birds, it must be stated that as this was a study of the acquisition (the acquiring of or improvement upon) of behaviour, experimentation was terminated when stable performance was achieved. Thus, when stable performance occurred the process involved in the development of behaviour changed from one of acquisition to one of maintenance, and therefore to an area outside the scope of the present study.

A real criticism along these lines was that not enough levels of the independent variable were utilized. In this way any construction of a curve relating the two variables under study was of a slightly tenuous nature. Three points (the number used in experiments I, II and III) are the minimum number that can be used to form a functional relationship. With more points the graph becomes more accurate, and the conclusions drawn from such a function more generalizable.

However, the results of the present series of

experiments show that individual differences severely confounded the effect of the independent variable in those experiments where different subjects were assigned to each level of the IV. As a result a different subjects design with more than three levels of the IV would suffer from the same confounding effects of individual differences that were found in experiments I and II.

The use of multiple schedules to control for individual differences could prove difficult if more than three component schedules are utilized. In this case it is possible that individual performances resulting from each of the component SD's might prove more difficult to determine as the number of component SD's increases.

A number of methodological problems experienced during this series of experiments could be cause for criticism. For example, the standard 80% level of deprivation used in most operant studies as an operational definition of drive level, was shown to have a serious shortcoming, in that it had different effects on performance depending upon the ad libitum weight of the bird. It was thus necessary, in order to equate initial training performances, to maintain those birds with a large ad libitum weight at sometimes up to 30 grams under their 80% target weight. At other times small birds were kept at weights over their 80% level. This problem was to some extent aggravated by a short supply of birds which necessitated using birds whose weight varied considerably even though they were aged between 1 and 3 years.

The above, then, are some criticisms of the present study which have arisen during the period of experimentation and analysis of the results. Many of them, will to some extent, be answered below.

(iii) Other measures of response strength.

In order to avoid the sort of problems encountered

with traditional measures of response strength, recent advances in operant theory have made possible the development of new measures of response strength. Two such measures will be dealt with here (a) Nevin's (1974) analysis and (b) concurrent schedule analysis.

a) The relative resistance to change hypothesis of Nevin (1974).

In this system the strength of an operant is identified with its relative resistance to change. "A strong operant may be identified in relation to a second operant by the higher rate of occurrence of its response, relative to its baseline rate, when a single operation is applied uniformly to reduce both rates" Nevin (1974; p.403). In this way response strength is unaffected by individual differences in rate of responding, as the change is measured from a baseline rate obtained from the same subject. A further interesting feature of this measure of response strength is that it can be obtained even though reinforcement conditions are not held constant.

In the series of experiments reported by Nevin, the reinforcement conditions in each of the components of a MULT VI schedule differed in various ways - frequency of reinforcement per unit time, magnitude of reinforcement, delay of reinforcement and contingencies on response rate at the time of reinforcement (DRL-DRH). The single operation used to reduce the response rates in each of these components was either extinction or response-independent-reinforcement (R.I.R.) applied during the intercomponent interval.

Thus by applying either of these two measures to both component response rates, the stronger operant would be the one whose rate was reduced least by this operation.

In experiment I (p.391), for example, the number of food presentations per hour during dark key periods was varied from 20 per hour to 360 per hour. The two schedule components

represented by their own SD 's were VI 1min. and VI 3min. The results obtained by Nevin during pre RIR training were as expected - the rate of responding was higher for VI 1min. than for VI 3min. When RIR was presented both rates of responding decreased. If the rate of responding in each of the schedule components during the first hour of FIR was expressed as a proportion of the baseline response rate in each component averaged during 3 hours of pre RIR responding, then interesting differences between VI 1min. and VI 3min. schedules appeared. In all cases Nevin (p.392) found that the response rate relative to baseline performance was less in the VI 3min. schedule than in the VI 1min. From this it was apparent that responding maintained by the more frequent reinforcement (VI 1min.) was less affected by response rate reduction and hence stronger than the less frequent reinforcement schedule (VI 3min.). In experiment II of the same study it was also found that a more frequently reinforced schedule (VI 2min.) was more resistant to extinction than a schedule generating less frequent reinforcement (VI 6min.). These results were found to be consistent with those of a number of recent researchers including; Gollub and Urban (1958), Carlton (1961) and Blackman (1968).

Perhaps the most interesting results of the Nevin study were contained in experiment V (p.399), where DRL and DRH requirements were added to VI 1min. and VI 3min. schedules respectively. Again the effects of applying RIR and extinction to both components were measured in relative terms.

It was found that with reinforcement frequency equated the DRL contingency was stronger in terms of relative resistance to change than the DRH contingency. This result, then, is directly opposed to the results of experiment IV of the present study, if both rate of responding and resistance to extinction are taken as measures of response strength. For, in all cases, both rate of responding and resistance to extinction were higher during the DRH contingency than during the DRL contingency in the present study. Nevin (1974) p.402

does explain, however, that the results of his experiment were not expected, and that the experiment itself was not specifically designed to isolate the effects of the two response rate contingencies. "To do so, it would be best to arrange identical reinforcement frequencies in conjunction with different contingencies in the two components of a multiple schedule, so that comparisons could be made without the variability introduced by intervals of nearly three months between the conditions being compared". (p.402). This is exactly what was done in experiment IV of the present study, but with results somewhat different to those expected by Nevin.

Nevin also showed that response strength could be quantified if a relative resistance to change method was used to measure it. The reasoning is based on the fact that if a function between the rates of responding in a two component multiple schedule is less than 1,0, then changes in component rate represented on the abscissa are always greater than corresponding changes in component rate represented along the ordinate. According to Nevin this is exactly equivalent to the identification of strength with change in responding relative to baseline performance. "Thus, the relative strengths of two operants may be measured by the exponent of the function relating their response rates: the greater the departure of the exponent from 1,0 the greater the difference in strength" Nevin (1974; p.404).

The above, then, gives a brief overview of one recently developed method of measuring response strength. It does, however, have a number of shortcomings. Firstly, one can only measure relative response strength, a severe restriction if one wants to know the effect on behaviour strength of only one particular reinforcement schedule. Secondly, it seems that this particular measure can only be used with multiple schedules of reinforcement; and thirdly, as Nevin himself mentions, it can only be used with intermittent schedules of reinforcement (p.405).

Nevertheless, it does offer a new look at the concept

of response strength, and, more importantly, it questions the need for such a concept. However, more research with quantitative data is needed in order to explore further "relative resistance to change" as a measure of response strength.

b) The use of concurrent schedules of reinforcement.

Concurrent schedules of reinforcement are similar to multiple schedules, in that two or more different schedules can be presented to the same subject. With concurrent schedules, however, the two components are presented simultaneously and independently on two different manipulanda.

An important feature of the concurrent procedure in operant studies with pigeons is that the subject cannot respond to the two keys simultaneously, even though they are presented concurrently. Further, in concurrent procedures the pigeon can control the length of time spent responding in each schedule, whereas in multiple schedules this is controlled by the interval lengths programmed by the experimenter. Thus, concurrent procedures enable the researcher to study the behaviour resulting from two different schedules and the behaviour of choosing between these two schedules.

The development of a quantitative account of responding under concurrent schedules is mainly attributable to Herrnstein (1958, (1961), (1970) and (1974); Catania (1963 a and b), (1966), (1969) and (1972); and Killeen (1972). The major finding of these theorists which has relevance to the present discussion has been termed the Matching Law, and can be mathematically expressed as

$$\frac{P_L}{P_L + P_R} = \frac{R_L}{R_L + R_R}$$

where P_L = responses on left key.

P_R = responses on right key.

R_L = reinforcements delivered to left key.

R_R = reinforcements delivered to right key.

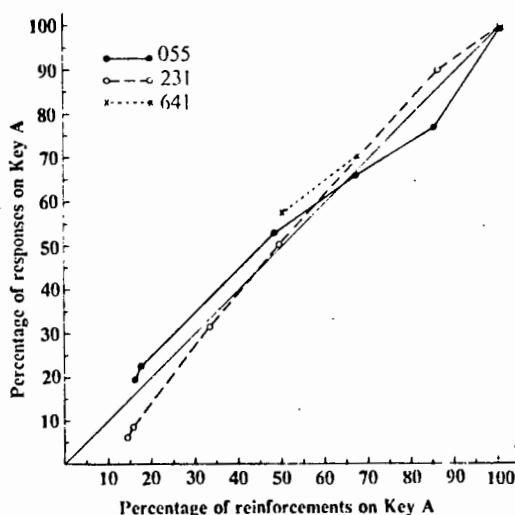
This Matching Law simply asserts; that in a situation where concurrently available schedules are programmed independently, the pigeon will distribute its responses according to the distribution of reinforcements. In other words, the pigeon matches its relative rate of responding (the left side of the equation above) to the relative rate of reinforcement (the right side of the equation above).

The importance of this relation for the present discussion is that although it is a relative measure it was stated by Herrnstein (1961; p.270) to be derived from evidence that the relation between absolute rates of responding and reinforcement was of a similar nature in a concurrent schedule situation. "Moreover, this relation between absolute rates of responding and reinforcement is one that is consonant with a plausible view of response strength: Rate of responding is a linear measure of response strength, which is itself a linear function of frequency of reinforcement" p.270. Thus the matching relation results ".... from the fact that the behaviour on each of the two keys obeys a simple linear rule governing strength of response" p.270.

As with the Nevin analysis, response strength measured by the degree of matching between relative rate of responding and relative rate of reinforcement in concurrent schedules, again only measures strength relative to another operant. In fact in single-key situations a linear relationship between absolute rate of responding and absolute rate of reinforcement has been shown to be inconclusive - Clark (1958), Catania and Reynolds (1968) and Findley (1958 - using a single key concurrent procedure).

This matching relation in concurrent procedures can be illustrated by results obtained from Herrnstein's (1961) experiment:

FIG.(56). Relative frequency of responding on key A as a function of relative frequency of reinforcement on key A: The Matching Function (Herrnstein 1961; p.268).



From FIG.(56) above, perfect matching is represented by the 45° diagonal line originating at the intercept. Under this system a strong operant would be one whose matching function was to the left or above the hypothetical matching line, and a weak operant, one whose matching function was to the right or below the 45° line. The Matching Law would still hold as long as the functions produced paralleled the 45° line.

As a suggestion for future research in this area a concurrent VIDRH-VIDRL schedule could be programmed so that a situation such as the one described above be simulated. As a further check the degree of shift above or below the 45° line for each schedule could be related to the number of responses produced under each schedule S^D during extinction.

Thus concurrent scheduling procedures offer an alternative method of assessing response strength in the operant paradigm. Further, the results of the present series of experiments appear to be more compatible with the matching relation as a measure of response strength, than with the relative resistance to change hypothesis.

(iv) Suggestions for future research.

Future research, along the same lines as that conducted in the present series of experiments could take a number of different forms.

Firstly, an attempt could be made to replicate experiment III, using six, instead of three, levels of the independent variable. A multiple schedule of this complexity could raise a number of problems during initial training, but with extended exposure to the schedule, individual response characteristics arising from each of the schedule components should become apparent.

Secondly, the multiple conjunctive schedule used in experiment IV could be extended to embrace three components, thus enabling a functional relationship to be developed. This third component would have to have some sort of response rate requirement, as a pilot study to experiment IV of the present series, showed that the introduction of a free-rate FI schedule proved to have serious confounding effects on performance in the other two components.

Thirdly, the relationship between rate of responding and resistance to extinction could be investigated in a simultaneous, rather than successive discrimination procedure. In a three key concurrent schedule each key could represent either a different rate of reinforcement (interval length) or a different response rate requirement (DRL, DRH etc). Numbers of reinforcements delivered to each key would have to be equated. Response strength in this situation could be measured in a number of ways; rate of responding on each of the keys, resistance to extinction on each of the keys, preference (relative rate of responding) for one particular key and the matching function itself.

Lastly, experiment III which used a multiple FI schedule could be replicated in its entirety but with variable

interval instead of fixed interval components.

Many interesting possibilities for future research are afforded in the various other measures of response strength. For example, in the concurrent schedule procedure where the matching relation can be used as an indication of response strength, Rachlin (1971; p.249) has developed an alternative form of the matching function. This equation is of the form

$$\frac{T_L}{T_R} = \frac{R_L}{R_R}$$

where T_L = time spent responding on left key.
 T_R = time spent responding on right key.
 R_L = reinforcements delivered to left key.
 R_R = reinforcements delivered to right key.

Rachlin (1971), together with Premack (1959), (1965) and (1971) believe that time spent responding is a far more accurate measure of behaviour than frequency or number of responses emitted.

This is because response duration or time spent responding enables between-response comparison, an essential part of Premackian theory, to be carried out. "... time is extrinsic to all behaviours and thus can be applied universally" Premack (1965; p.134).

Further, Premack states that "... response duration will provide a strict estimate of probability insofar as the distribution of responding is random throughout the considered interval of time" (p.135). Thus, to Premack response strength would be equated with probability which in turn would be estimated from response duration.

Premack suggests a way in which the strength of topographically different responses could be measured. This

he called the "increment postulate" (1965; pps.146-148), which stated that "if we apply different more probable responses to a common base response, we may expect the increment to be proportional to the probability of the contingent response" (p.146). In other words, the strength of, say, a drinking response could be compared with an eating response, by making them both contingent upon a bar-press response. The greater increase in the bar press activity after each of the contingent responses would indicate a greater strength of that response.

This could be achieved in an operant situation where different rates of responding produced by different terminal link schedule lengths could be made contingent on an unchanged initial link in a chained schedule of reinforcement. This could be further extended to a concurrent chains procedure, where two different terminal link responses could be compared when made contingent upon two identical initial link responses (eg., Fantino (1969), Hursh and Fantino (1973), Squires and Fantino (1971) and Herrnstein (1964)).

Lastly, the schedule interactions of positive and negative behavioural contrast, which occur between components of a multiple schedule could be used to measure response strength in a way similar to that used by Nevin (1974). Most research so far, has investigated the phenomenon of positive behavioural contrast, which occurs when manipulation to reduce the rate of responding in the second component of a multiple schedule has the effect of increasing the rate of responding in the first component, even though no manipulations to this component occurred (eg. Reynolds and Limpo (1968), Bloomfield (1967) and Pliskoff, Shull and Gollub (1968)).

However, studies of negative behavioural contrast, where manipulations to the second component produce a decrease in the rate of responding in the first component, have received far less attention. Thus, in a multiple schedule where the rates of reinforcement in each of the components were equated, a procedure which would raise the rate of

responding could be introduced to the second component (a DRH requirement, for example). The corresponding decrease in the rate of responding in the first component would then be noted. This could then be compared to a different first component schedule to which the same procedure was applied, in order to analyse the degree of reduction in the response rate. The schedule which suffered the least reduction in rate compared to a baseline rate of responding would then be regarded as the "stronger" response.

In summary, then, it would prove an interesting exercise if, together with all the measures of response strength mentioned above, a measure of resistance to extinction was also obtained. Would, then, all the "strongest" responses found from the above procedures also be more resistant to extinction?

(v) Conclusions.

Operant theory is concerned with the way in which the environment changes or modifies the behaviour of living organisms. Reinforcement (or the presentation of a reinforcing stimulus) is one aspect of the environment which tends to increase the organism's potentiality to behave in a similar way in the future. Thus reinforcement strengthens behaviour as reflected in an increase in the known and widely used observable measures of response strength - rate of responding and resistance to extinction. It is therefore critical that these measures exhibit identical characteristics when a single operation is applied to both. Thus rate of responding and resistance to extinction must show equal increments when reinforcement is made contingent upon an operant response, in order that a parsimonious description of the state of that response at any particular moment (its strength) be achieved.

The present study showed that such a relationship was possible when the confounding effects of individual differences were controlled for. It can thus be concluded that rate of

responding and resistance to extinction adequately mirror response strength and that the development of further measures of this entity be deemed unnecessary.

APPENDIX I Computer programs and documentation

Appendix IA	The Flesher and Hoffman Constant Probability Variable Interval Schedule.....	174
Appendix IB	Multiple Fixed Interval Schedule.....	181
Appendix IC	Multiple Conjunctive FI-FR(DRL-DRH).....	189

```

0001 FTN,B
0002 PROGRAM ANDY2
0003 DIMENSION VAL(200)
0004 COMMON IBASE,ITIME,IOUT,INPUT
0005 WRITE(2,10)
0006 10 FORMAT(///,"MEAN INTERVAL: -")
0007 READ(1,*)AV
0008 WRITE(2,11)
0009 11 FORMAT("NO OF INTERVALS: -")
0010 READ(1,*)NTERM
0011 TERM=NTERM
0012 X=1.0+ALOG(TERM)
0013 WRITE(2,12)
0014 12 FORMAT("COMPUTING")
0015 DO 100 I=1,NTERM
0016 Z=I
0017 Y=TERM-Z
0018 IF(Y)110,110,120
0019 110 W=Y-(Y+1.0)*ALOG(Y+1.0)
0020 GO TO 130
0021 120 W=X+Y*ALOG(Y)-(Y+1.0)*ALOG(Y+1.0)
0022 130 VAL(I)=W*AV
0023 100 CONTINUE
0024 WRITE(2,13)
0025 13 FORMAT("OUTPUT PLUG: -")
0026 READ(1,*)IPLUG
0027 J=16001
0028 WRITE(2,18)
0029 18 FORMAT("RAND NO: -")
0030 READ(1,*)I
0031 DO 140 K=1,I
0032 CALL RAND(J,X)
0033 140 CONTINUE
0034 IBASE=2
0035 CALL TIMER
0036 200 ITIME=0
0037 IOUT=0
0038 CALL RAND(J,X)
0039 X=TERM*X+1.0
0040 WRITE(2,17)X
0041 17 FORMAT("RAND=",F8.1)
0042 I=X
0043 INTER=VAL(I)
0044 IF(INTER-600)200,200,205
0045 205 WRITE(2,14)INTER
0046 14 FORMAT(/,"INTER=",I8)
0047 210 CONTINUE
0048 IF(INPUT)210,210,300
0049 300 CONTINUE
0050 WRITE(2,15)
0051 15 FORMAT("INPUT")
0052 330 CONTINUE
0053 IF(ITIME-INTER)330,310,310
0054 310 IOUT=IPLUG
0055 ITIME=0
0056 WRITE(2,16)
0057 16 FORMAT("NOW")
0058 320 CONTINUE
0059 IF(ITIME-25)320,320,200

```

174

PROGRAM LISTING

FORTRAN Main Program

```

0060 END
0061 ENDS

```

PROGRAM LISTING

ASSEMBLER Subroutine 'Timer'

```

0001 ASMB,R,B
0002     NAM TIMER
0003     COM BASE,TIME,OUT,INPUT
0004     ENT TIMER
0005 TBG EQU 10B
0006 IN EQU 14B
0007 OUTR EQU 15B
0008 MASK OCT 10
0009 TIMER NOP
0010     LDA BASE
0011     OTA TBG
0012     LDA IJSB
0013     STA TBG
0014     STC TBG,C
0015     JMP TIMER,I
0016 IJSB JSB POINT,I
0017     ORB
0018 POINT DEF C ONT
0019     ORR
0020 C ONT NOP
0021     STC TBG,C
0022     STA SAVEA
0023     LDA TIME
0024     CPA 17777B
0025     CLA
0026     INA
0027     STA TIME
0028     LIA IN
0029     AND MASK
0030     STA INPUT
0031     LDA OUT
0032     OTA OUTR
0033     LDA SAVEA
0034     JMP C ONT,I
0035 SAVEA BSS 1
0036     END

```

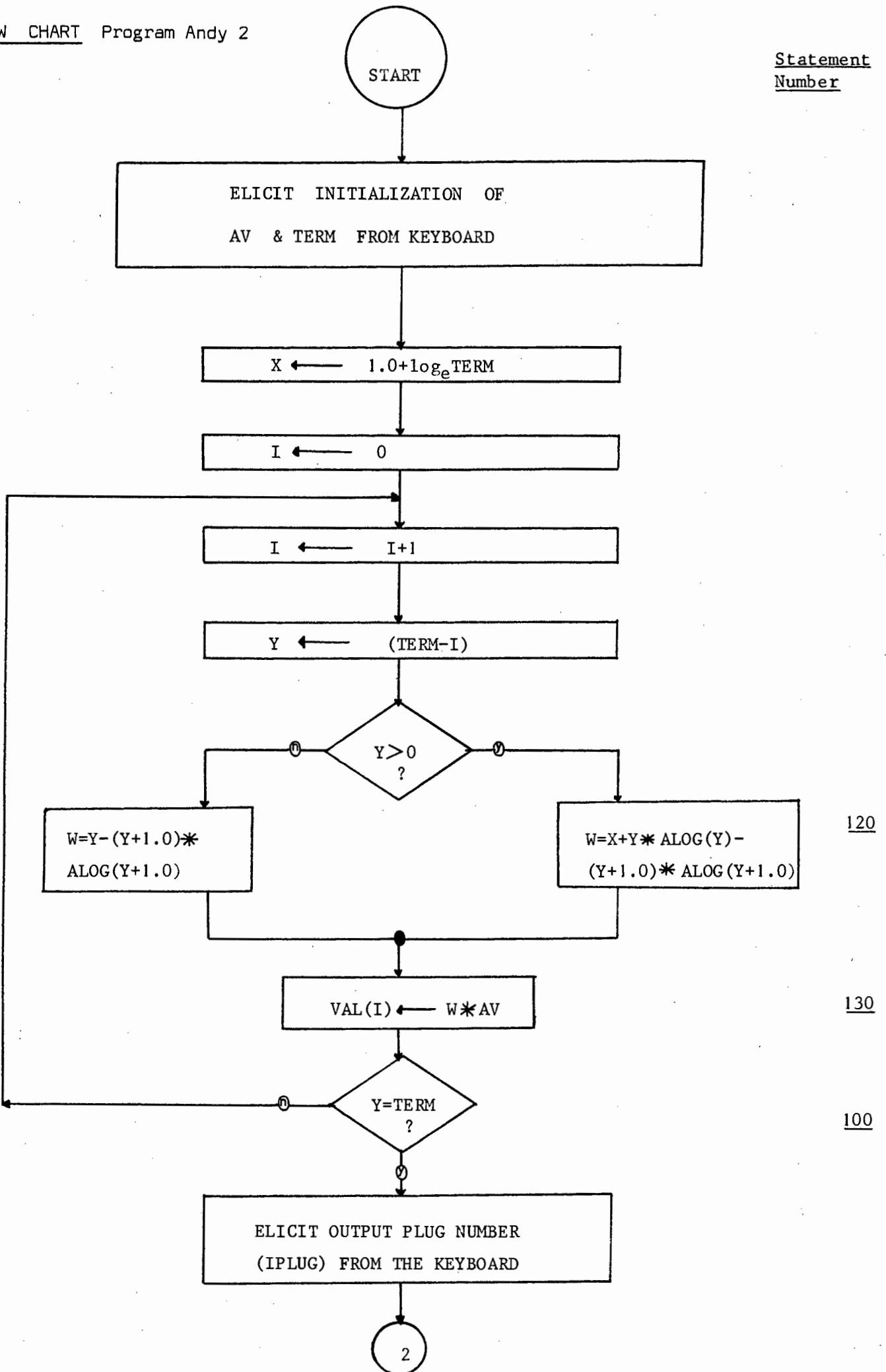
PROGRAM LISTING

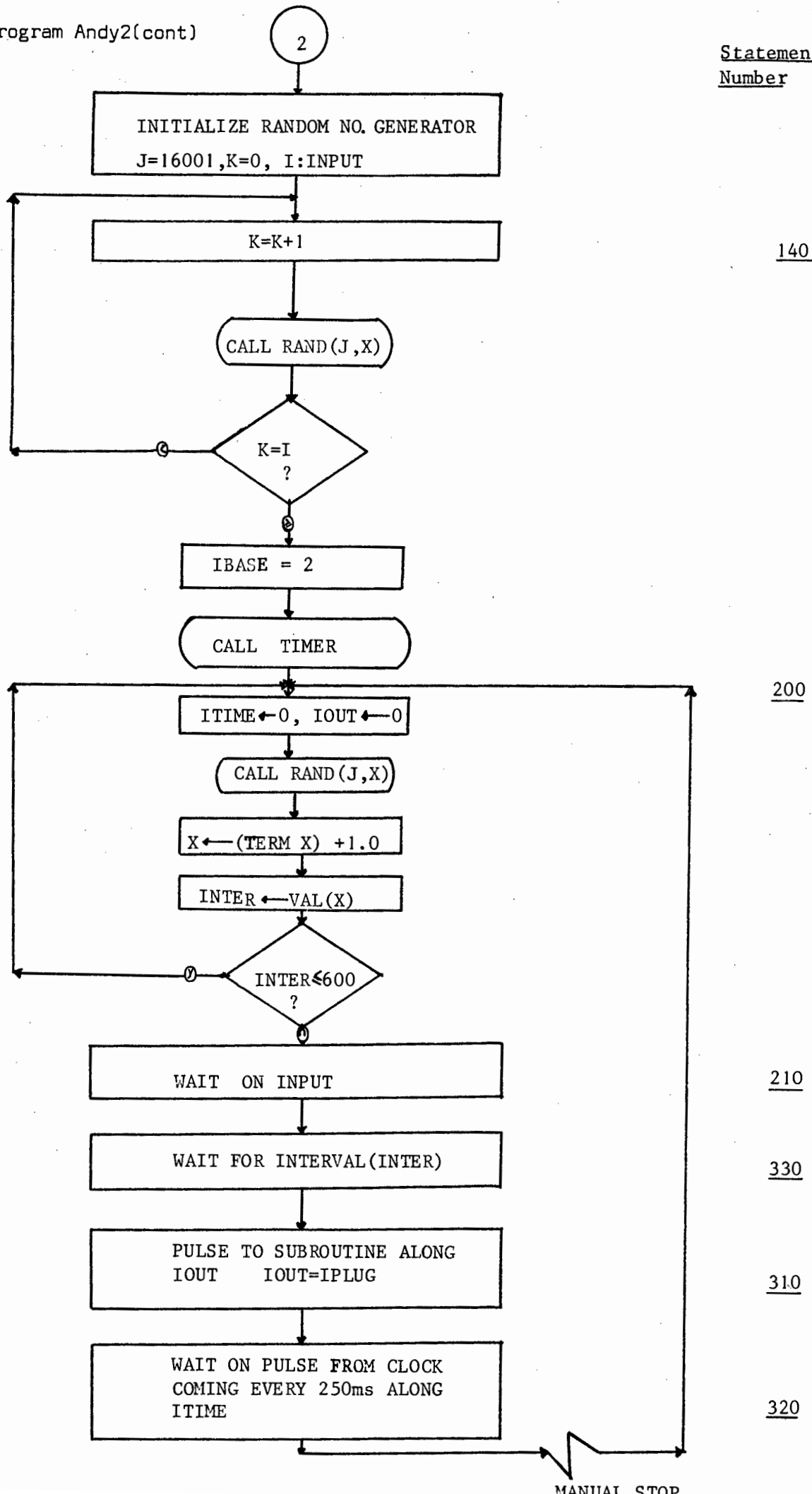
FORTRAN Subroutine 'Rand'

```

0001 FTN,B
0002     SUBROUTINE RAND(I,X)
0003     J=I*899
0004     IF(J)10,20,20
0005 10 J=J+32767+1
0006 20 X=J
0007     X=X/32768.0
0008     I=J
0009     RETURN
0010     END
0011     ENDS

```





140

200

210

330

310

320

MANUAL STOP

Appendix 1A : The Fleshler and Hoffman Constant
Probability Variable Interval Schedule.

i) Program name : Andy 2.

ii) Narrative.

This program is initialized by the user to the desired values for the average interval and the number of intervals. These then enable the program to yield specific values for a progression of intervals that are temporarily stored in an array. These intervals will later serve to monitor the issuing of output pulses.

For the purposes of this experiment, however, these intervals should not arise in any recognizable pattern. Thus it becomes necessary to retrieve the values held in the array concerned in a random manner. The values for the array index involved are therefore generated by a subroutine RAND.

A first call on RAND is needed to prime the action. A further call on RAND then yields a value which allows the retrieval of a specific interval, for which the program counts off unit periods from the computer clock.

Note that once initiated the program can be halted only through an outside intervention by the operator.

iii) Arrays and Constants.

```
DIMENSION VAL(200).
```

Array VAL is called on to hold the values for the N progression of intervals as computed from the relationship outlined on page (98).

The array is deliberately allocated a maximal size such that it will be in excess of any magnitude of N that might be expected to occur.

iv) Constants and Counters.

- AV : Mean Interval.
- TERM : Number of intervals - the specification of this by the user permits the setting of a desired limit to the number (N) of the progression of intervals. This must not exceed 200.
- X and Y : Registers to hold an intermediate value in computation of equation for progression of intervals.
- W : The contents of this register multiplied by the value of AV, will yield the interval which is then stored in a suitable entry of the array VAL, during the course of the program.
- X : This register is also used by the program to return to the main program at the place where the value is yielded by the subroutine RAND.
- INTER : A register which temporarily stores the values held in VAL(I), in a form more appropriate for the calculation of the interval. Only values in excess of 6 seconds are accepted.

v) Subroutines.

a) TIMER

This ASSEMBLER subroutine activates the computer clock and also channels the input and output. Once initiated it generates a steady output of pulses.

- IBASE (BASE) : used to instruct the timer subroutine as to the units of time to be used, e.g., IBASE = 2 - hundredths of a second.

- ITIME (TIME) : A clock generated pulse is passed along this word every 250 M.S.
- IOUT (OUT) : A pulse along this word causes the closure of the switch as specified by IPLUG, for some interval of time.
- INPUT (INPUT) : used to specify the desired input channel. It was redundant here as all 16 input channels could be used.
- IPLUG : used to accept from the user a specification of the output channel to be used.

b) RAND (I,X)

This FORTRAN subroutine is a contrivance, the implementation of which causes the computer to try and reach outside of the maximum allowable range for this configuration, and thereby comes up with a random sequence of numbers.

- J = 16001 : This value used in the first call upon the subroutine RAND, is needed for the "priming" of that subroutine.
- I : the specification of the value for I by the user, will provide the necessary start integer required by the subroutine RAND.

PROGRAM LISTING FORTRAN Main Program

```

0001  FTN,B
0002      PROGRAM ANDY3
0003      DIMENSION ISER(600),INTER(10),ISWT(10),ILITE(10)
0004      COMMON IBASE,ITIME,IOUT,INPUT,ISWNO
0005      WRITE(2,10)
0006  10   FORMAT(//,"NO OF COMPONENTS-")
0007      READ(1,*)COMP
0008      WRITE(2,11)
0009  11   FORMAT(/,"FOR EACH GIVE INTERVAL LENGTH","",/,
0010  1"INPUT SWITCH,"/, "OUTPUT SWITCH",/)
0011      NO=COMP
0012      DO 100 I=1,NO
0013      WRITE(2,12)I
0014  12   FORMAT(/,"INTERVAL",I2)
0015      READ(1,*)INTER(I),ISWT(I),ILITE(I)
0016  100  CONTINUE
0017      WRITE(2,13)
0018  13   FORMAT(/,"NO OF PRESENTATIONS OF EACH COMPONENT-")
0019      READ(1,*)ILOOP
0020      WRITE(2,22)
0021  22   FORMAT(/,"EACH?-")
0022      READ(1,*)NEACH
0023      WRITE(2,14)
0024  14   FORMAT("RANDOM GENERATOR START-")
0025      READ(1,*)NSKIP
0026      J=16001
0027      DO 110 I=1,NSKIP
0028      CALL RAND(J,X)
0029  110  CONTINUE
0030      WRITE(2,15)
0031  15   FORMAT("REINFORCEMENT TIME & TIME OUT-")
0032      READ(1,*)IREIN,ITO
0033      WRITE(2,17)
0034  17   FORMAT("REINF & TO PLUGS-")
0035      READ(1,*)IPR,IPT
0036      WRITE(2,16)
0037  16   FORMAT(//,"OK")
0038      PAUSE
0039      IBASE=2
0040      CALL TIMER
0041      IOUT=0
0042      DO 500 M=1,NEACH
0043      I1=(M-1)*NO+1
0044      I2=M*NO
0045      DO 500 I=I1,I2
0046      ISER(I)=0
0047  520  CALL RAND(J,X)
0048      Y=COMP*X+1.0
0049      K=Y
0050      DO 510 L=I1,I
0051      IF(ISER(L)-K)510,520,510
0052  510  CONTINUE
0053      ISER(I)=K
0054  500  CONTINUE
0055      DO 400 M=1,NEACH
0056      I1=(M-1)*NO+1
0057      I2=M*NO
0058      DO 400 K=I1,I2
0059      TOT=0.0

```

PROGRAM LISTING FORTRAN Main Program

```

0060      INEW=ISER(K)
0061  210  WRITE(2,19)INEW
0062  19   FORMAT(/,I2)
0063      IVAL=INTER(INEW)
0064      ISWNO=ISWT(INEW)
0065      ILIGT=ILITE(INEW)
0066      DO 300 I=1,IL00P
0067      ITIME=0
0068      IOJT=ILIGT
0069  220  CONTINUE
0070      IF(ITIME-IVAL)220,231,231
0071  231  ITIME=0
0072  230  CONTINUE
0073      IF(INPUT)230,230,240
0074  240  IOJT=IPR
0075      L=ITIME
0076      V=L
0077      WRITE(2,20)L
0078  20   FORMAT(I6,"-")
0079      TOT=T OT+V
0080      ITIME=0
0081  250  CONTINUE
0082      IF(ITIME-IREIN)250,260,260
0083  260  IOJT=0
0084  300  CONTINUE
0085      WRITE(2,21)TOT
0086  21   FORMAT(/,F8.0,/)
0087      ITIME=0
0088      IOJT=IPT
0089  310  CONTINUE
0090      IF(ITIME-ITO)310,320,320
0091  320  IOJT=0
0092  400  CONTINUE
0093      WRITE(2,18)
0094  18   FORMAT(/,"END OF EXPERIMENT!")
0095      PAUSE
0096      STOP
0097      END
0098      ENDS

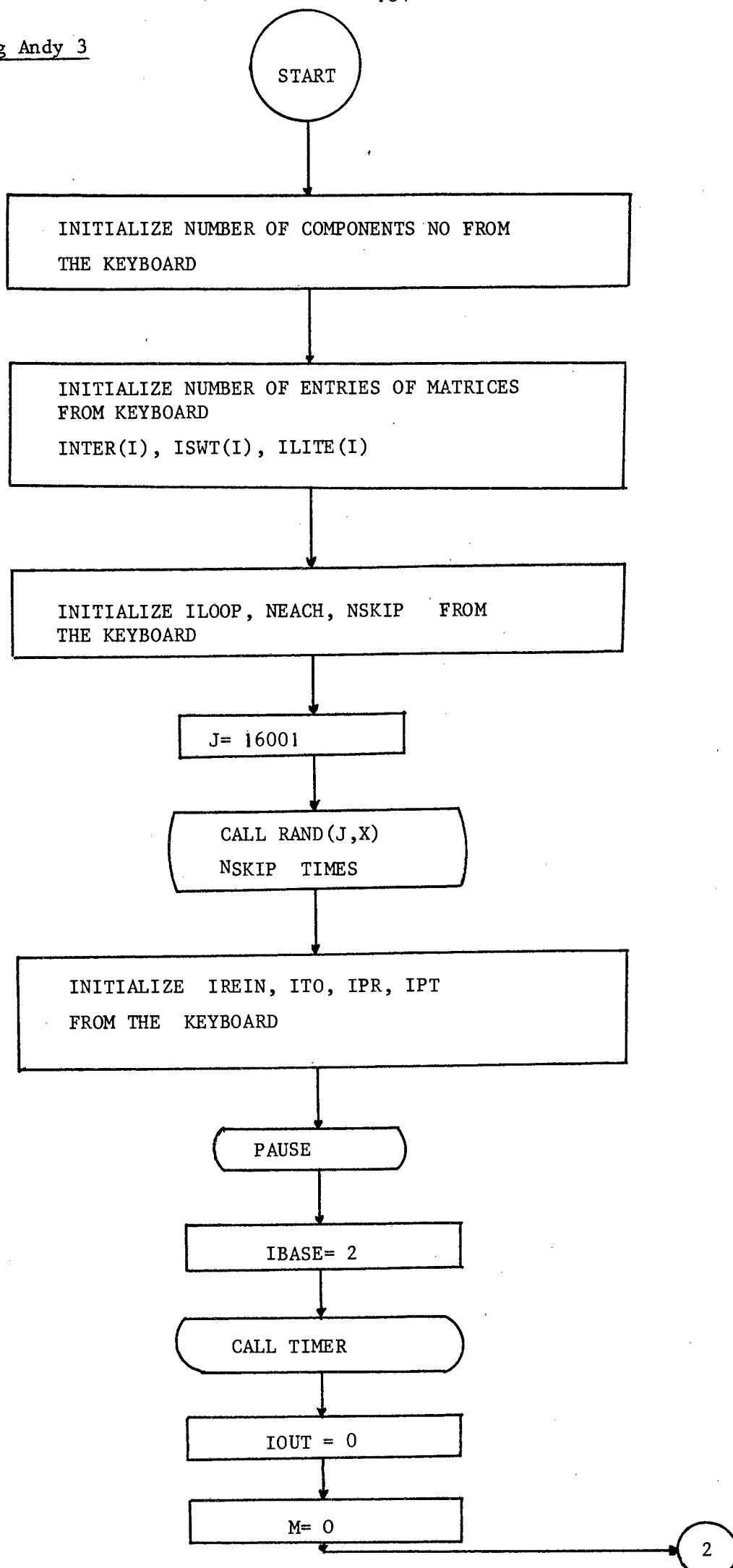
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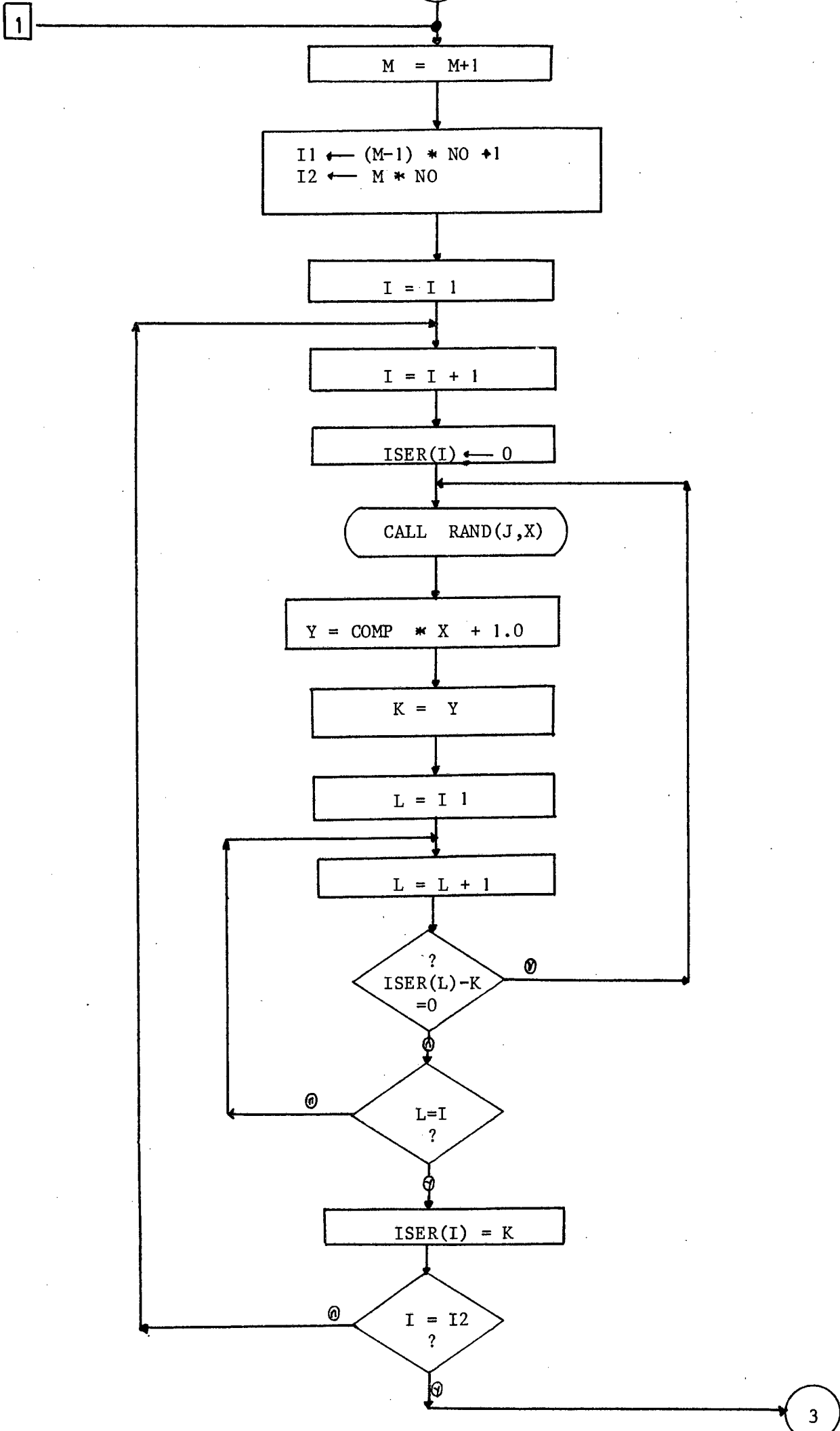
PROGRAM LISTING ASSEMBLER Subroutine 'Timer'

```

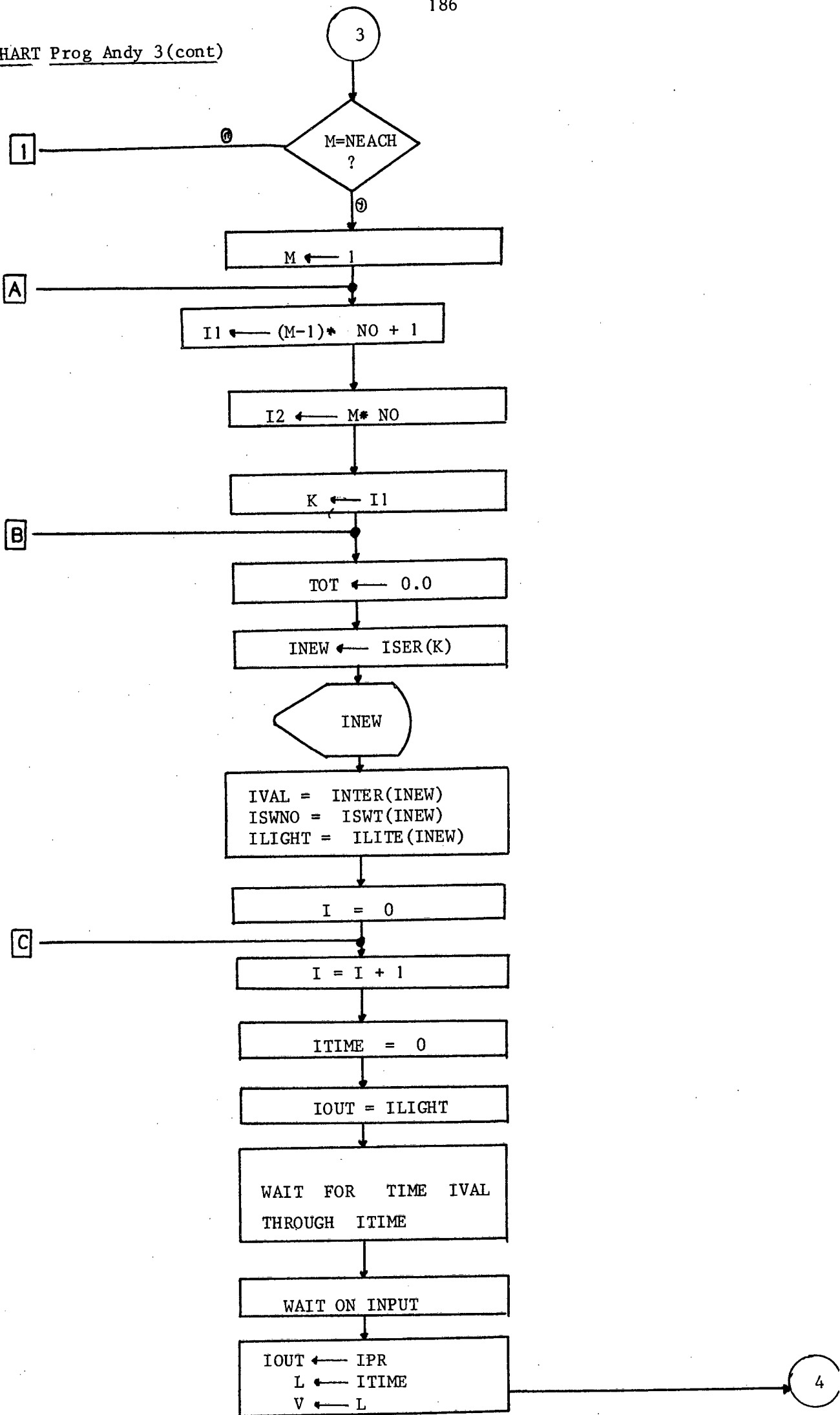
0001 ASMB,R,B
0002     NAM TIMER
0003     COM BASE,TIME,OUT,INPUT,ISW
0004     ENT TIMER
0005 TBG  EQU 10B
0006 IN   EQU 14B
0007 OUTR EQU 15B
0008 TIMER NOP
0009     LDA BASE
0010     OTA TBG
0011     LDA IJSB
0012     STA TBG
0013     STC TBG,C
0014     JMP TIMER,I
0015 IJSB JSB POINT,I
0016     ORB
0017 POINT DEF CONT
0018     ORR
0019 CONT  NOP
0020     STC TBG,C
0021     STA SAVEA
0022     LDA TIME
0023     CPA CONST
0024     CLA
0025     INA
0026     STA TIME
0027     LIA IN
0028     AND ISW
0029     STA INPUT
0030     LDA OUT
0031     OTA OUTR
0032     LDA SAVEA
0033     JMP CONT,I
0034 SAVEA BSS 1
0035 CONST OCT 177776
0036     END

```

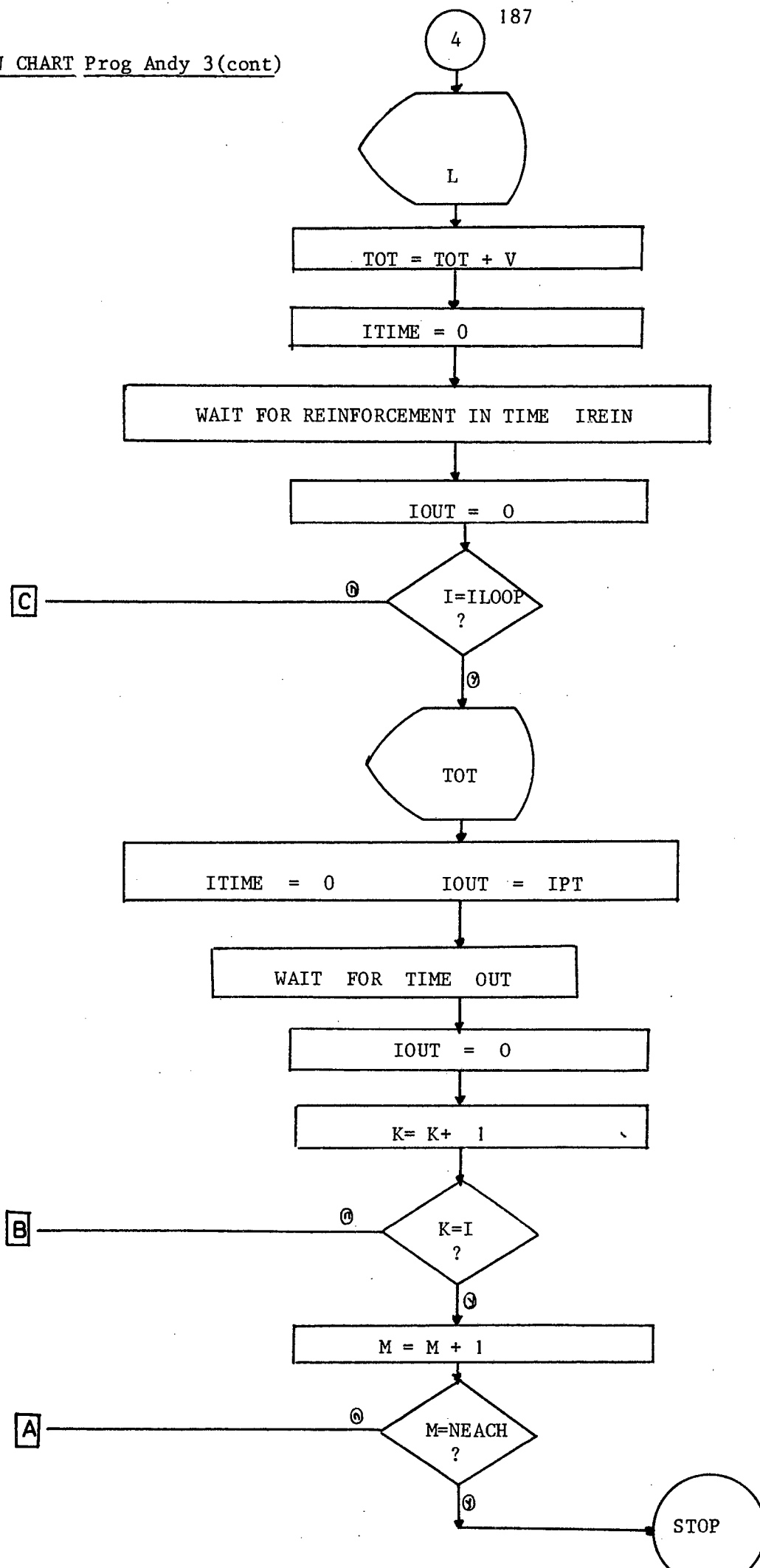
FLOW CHART Prog Andy 3



FLOW CHART Prog Andy 3(cont)



FLOW CHART Prog Andy 3(cont)



Appendix 1B : Multiple Fixed Interval Schedule

i) Program name : Andy 3.

ii) Narrative.

The main FORTRAN program has been designed with flexibility of application as one of its main features. Three main sections form the basic structure of this program. The first part has a housekeeping role, whereby the specific values which determine the constraints of the program are set. It also triggers the timer and initializes the random number generator. These constraints will determine the number of cycles being performed in the last section of the FORTRAN program. This last part consists of three FORTRAN DO-LOOPS nested within each other. The innermost DO-LOOP which monitors the input and issues a reinforcement thereon, is performed for as many times as there are intervals in one component (ILOOP times).

After each execution of this innermost loop, a halt is called for to correspond to the required time-out period. The contents of a register TOT, which has accumulated the values of the times spent waiting for input, is then displayed. Reinforcement Availability Time (R.A.T.).

The next DO-LOOP calls into play one of the members of the group of these components. Thus this cycle is performed for a certain number of times, as specified by the number of components. The outermost DO-LOOP oversees the presentation of the group of components, so that each component is performed NEACH times.

For the purposes of this program, however, it is important to have the components presented randomly. To achieve this, values which index these components are generated in a random sequence beforehand. They are stored in a matrix ISER. Zero values of this index are ignored by this routine. The values generated will lie within the limits set by the number of components in the experiment.

iii) Arrays and Constants.

ISER : Matrix of indeces.
 INTER : interval lengths.
 ISWT : input switches associated with each component.
 ILITE : output switches associated with each component.
 IBASE : used to instruct the timer subroutine as to the units of time to be used.
 ITIME : a clock generated pulse is passed along this word every 250 m.s.
 IOUT : a pulse along this word causes the closure of a switch as specified by ILITE, for some interval of time.
 INPUT : used to specify the desired input channel from ISWT.
 ISWNO : switch numbers.
 NO : number of components.
 ILOOP : number of presentations of each interval.
 NEACH : number of presentations of each component.
 NSKIP : number of calls on random generator.
 IREIN : reinforcement time.
 ITO : time out.
 IPR : output switch - reinforcement.
 IPT : output switch - time out.

iv) Subroutines

The basic components and subroutines used in this program were the same as those used in the previous program (Appendix 1A). A slight change was introduced to subroutine TIMER, to allow for the specification of separate input switches.

PROGRAM LISTING FORTRAN Main Program

```

0001  FTN,B
0002      PROGRAM ANDY3
0003      DIMENSION ISER(60),INTER(10),ISWT(10),ILITE(10),KNOC(10)
0004      COMMON IBASE,ITIME,IOUT,INPUT,ISWNO
0005      WRITE(2,10)
0006  10   FORMAT(//,"NO OF COMPONENTS~")
0007      READ(1,*)COMP
0008      WRITE(2,11)
0009  11   FORMAT(/,"FOR EACH GIVE INTERVAL LENGTH,"/,
0010 1"INPUT SWITCH,"/,"OUTPUT SWITCH",/,"D R REQ",/)
0011      NO=COMP
0012      DO 100 I=1,NO
0013      WRITE(2,12)I
0014  12   FORMAT(/,"INTERVAL",I2)
0015      READ(1,*)INTER(I),ISWT(I),ILITE(I),KNOC(I)
0016  100  CONTINUE
0017      WRITE(2,13)
0018  13   FORMAT(/,"NO OF PRESENTATIONS OF EACH COMPONENT~")
0019      READ(1,*)ILOOP
0020      WRITE(2,22)
0021  22   FORMAT(/,"EACH?~")
0022      READ(1,*)NEACH
0023      WRITE(2,14)
0024  14   FORMAT("RANDOM GENERATOR START~")
0025      READ(1,*)NSKIP
0026      J=16001
0027      DO 110 I=1,NSKIP
0028      CALL RAND(J,X)
0029  110  CONTINUE
0030      WRITE(2,15)
0031  15   FORMAT("REINFORCEMENT TIME,TIME OUT & PUNISH TO~")
0032      READ(1,*)IREIN,ITO,IPTO
0033      WRITE(2,17)
0034  17   FORMAT("REINF & TO PLUGS~")
0035      READ(1,*)IPR,IPT
0036      WRITE(2,16)
0037  16   FORMAT(//,"OK")
0038      PAUSE
0039      IBASE=2
0040      CALL TIMER
0041      IOUT=0
0042      DO 500 M=1,NEACH
0043      I1=(M-1)*NO+1
0044      I2=M*NO
0045      DO 500 I=I1,I2
0046      ISER(I)=0
0047  520  CALL RAND(J,X)
0048      Y=COMP*X+1.0
0049      K=Y
0050      DO 510 L=I1,I
0051      IF(ISER(L)-K)510,520,510
0052  510  CONTINUE
0053      ISER(I)=K
0054  500  CONTINUE
0055      DO 400 M=1,NEACH
0056      I1=(M-1)*NO+1
0057      I2=M*NO
0058      DO 400 K=I1,I2
0059      TOT=0.0

```

PROGRAM LISTING FORTRAN Main Program(cont.)

```

0060      INEW=ISER(K)
0061 210  WRITE(2,19)INEW
0062 19   FORMAT(/,I2)
0063      IVAL=INTER(INEW)
0064      ISWNO=ISWT(INEW)
0065      ILIGT=ILITE(INEW)
0066      DO 300 I=1,ILOOP
0067 371  J1=0
0068      NON=0
0069 370  ITIME=0
0070      IOJT=ILIGT
0071 220  CONTINUE
0072      IF(INPUT)271,271,280
0073 280  IF(J1)290,290,270
0074 271  J1=0
0075      GO TO 270
0076 290  J1=1
0077      NON=NON+1
0078      IF(INEW-1)270,272,270
0079 272  IF(KNO(INEW)-NON)360,270,270
0080 270  IF(ITIME-IVAL)220,231,231
0081 231  ITIME=0
0082      IF(INEW-2)230,340,230
0083 340  IF(NON-KNO(INEW))360,230,230
0084 360  CONTINUE
0085      IF(INPUT)360,360,361
0086 361  IOJT=IPT
0087      ITIME=0
0088 365  CONTINUE
0089      IF(ITIME-IPT)365,371,371
0090 230  CONTINUE
0091      IF(INPUT)230,230,240
0092 240  IOJT=IPR
0093      L=ITIME
0094      V=L
0095      WRITE(2,20)L
0096 20   FORMAT(I6," -")
0097      TOT=TOT+V
0098      ITIME=0
0099 250  CONTINUE
0100      IF(ITIME-IREIN)250,260,260
0101 260  IOJT=0
0102 300  CONTINUE
0103      WRITE(2,21)TOT
0104 21   FORMAT(/,F8.0,/)
0105      ITIME=0
0106      IOJT=IPT
0107 310  CONTINUE
0108      IF(ITIME-IT0)310,320,320
0109 320  IOJT=0
0110 400  CONTINUE
0111      WRITE(2,18)
0112 18   FORMAT(/,"END OF EXPERIMENT!")
0113      PAUSE
0114      STOP
0115      END
0116      ENDS

```

Appendix 1C : Multiple Conjunctive FI-FR (DRL-DRH) Schedule.

i) Program name : Andy 3.

ii) Narrative.

This was a simple modification of the program described in Appendix 1B. Only two components could be specified - in one, the issuing of a reinforcement was dependent upon the prior receipt of less than a specified number of inputs, and in the other, more than a specified number of inputs, within a certain interval of time. A count facility was added to each of the components - KNO. To test for these conditions two appropriate FORTRAN IF statements have been included in the program to rechannel the flow of logic appropriately (see statement numbers 272 and 340 on page 190). If these conditions are not met the logic flow is channelled so as to call for a time-out (punishment) period.

iii) Arrays and constants.

NON - the input count requirement for DRL and DRH.

KNO - input count.

APPENDIX II Daily Response Rates

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EXPERIMENT IDAILY RESPONSE RATES

DAY	BIRD B6	BIRD B5	BIRD B7
	FI 40	FI 60	FI 80
1	34,2	33,5	58,7
2	36,3	24,7	48,7
3	28,5	28,7	52,0
4	35,7	24,7	75,7
5	32,4	16,0	65,22
6	35,5	29,9	72,2
7	26,1	27,2	76,8
8	27,0	25,2	59,9
9	28,1	44,1	72,0
10	24,1	43,6	67,1
11	25,3	37,9	41,3
12	17,1	16,7	51,1
13	26,0	32,4	39,5
14	29,0	26,6	63,1
15	16,0	22,0	38,1
16	33,7	22,3	37,6
17	33,7	38,3	41,5
18	21,4	19,6	43,6
19	32,4	22,4	53,3
20	25,0	30,9	56,9
21	30,0	21,7	45,7
22	26,2	36,1	46,8
23	27,4	24,0	51,5
24	32,0	16,0	43,9
25	34,8	27,7	47,3
26	33,9	18,8	52,4

DAY	BIRD B6	BIRD B5	BIRD B7
	FI 40	FI 60	FI 80
27	25,8	18,9	47,8
28	37,4	22,9	57,6
29	31,4	26,2	58,5
30	29,9	18,7	43,6
31	34,2	19,6	50,2
32	30,9	21,5	47,6
33	32,0	10,4	39,3
34	26,1	12,0	48,0
35	35,7	18,0	52,4
36	31,7	13,3	53,5
37	40,3	27,1	57,8
38	30,0	15,5	47,0
39	41,1	20,4	40,9
40	42,6	28,7	43,0
41	35,0	14,1	49,4
42	30,0	22,0	47,9
43	34,8	29,7	35,7
44	34,0	22,0	51,8
45	38,7	20,3	56,7

EXPERIMENT IIDAILY RESPONSE RATES

DAY	BIRD L10	BIRD L9	BIRD L4
	VI 40	VI 60	VI 80
1	32,6	20,2	26,5
2	33,4	21,7	33,4
3	24,53	27,81	32,93
4	31,5	25,1	33,5
5	27,0	28,1	41,8
6	22,8	24,0	38,7
7	18,9	24,1	35,7
8	29,1	23,8	46,4
9	31,2	26,4	53,9
10	30,1	18,5	57,9
11	30,2	24,9	64,6
12	34,6	31,4	73,4
13	35,6	25,7	59,4
14	30,0	20,4	32,2
15	28,0	31,8	34,9
16	35,6	31,3	59,3
17	38,3	32,2	40,0
18	36,5	32,3	39,7
19	41,8	35,7	60,0
20	39,2	35,2	44,4
21	40,9	35,3	60,5
22	38,3	22,3	40,0
23	42,7	26,3	55,3
24	41,0	38,9	62,7
25	39,3	28,5	58,7
26	41,0	27,6	85,0

DAY	BIRD L10	BIRD L9	BIRD L4
	VI 40	VI 60	VI 80
27	18,9	26,5	28,9
28	39,8	35,7	73,2
29	37,0	30,4	73,3
30	43,1	31,5	73,0
31	30,2	19,3	50,0
32	42,3	36,6	72,4
33	41,6	41,0	71,5
34	37,0	36,2	72,8
35	41,5	36,1	56,5
36	28,7	35,4	57,6
37	38,8	33,2	65,3
38	42,5	34,4	61,4
39	33,4	29,8	73,8
40	32,0	37,4	47,2

EXPERIMENT IIIDAILY RESPONSE RATES

DAY	BIRD NO.	COMPONENT		
		FI 40	FI 60	FI 80
1	C1	43,9	25,6	25,9
	C2	31,3	31,1	17,2
	C3	50,8	37,8	27,7
2	C1	52,9	58,4	31,0
	C2	50,0	34,5	34,7
	C3	42,2	35,9	29,0
3	C1	50,2	41,6	35,0
	C2	53,8	50,6	42,7
	C3	39,4	32,9	30,3
4	C1	43,4	34,4	31,4
	C2	91,5	38,5	33,5
	C3	43,9	26,2	24,0
5	C1	37,5	29,4	26,1
	C2	67,0	42,0	41,0
	C3	36,6	21,2	24,0
6	C1	54,1	44,4	29,3
	C2	64,3	47,9	37,6
	C3	48,2	37,0	32,3
7	C1	44,9	46,1	39,6
	C2	53,9	43,6	32,5
	C3	59,9	51,1	39,3
8	C1	38,5	39,5	29,9
	C2	55,3	42,0	37,1
	C3	66,9	70,7	52,8
9	C1	44,1	38,6	34,5
	C2	49,8	38,8	38,2
	C3	69,3	55,7	50,2

DAY	BIRD NO.	COMPONENT		
		FI 40	FI 60	FI 80
10	C1	47,6	41,2	33,2
	C2	54,6	25,9	34,1
	C3	57,2	50,5	51,9
11	C1	38,1	41,1	27,2
	C2	58,6	45,3	38,9
	C3	75,1	50,3	57,8
12	C1	42,5	35,8	27,6
	C2	31,7	32,0	31,8
	C3	76,6	66,7	40,2
13	C1	49,0	47,2	27,9
	C2	57,0	47,6	33,9
	C3	75,4	59,6	39,4
14	C1	44,3	41,4	28,7
	C2	47,5	47,0	37,1
	C3	70,0	56,1	46,4
15	C1	51,8	38,7	36,9
	C2	66,4	47,6	41,6
	C3	65,8	52,1	46,2
16	C1	54,2	42,6	34,1
	C2	64,0	44,3	39,0
	C3	57,5	43,8	37,3
17	C1	56,1	45,1	33,8
	C2	58,7	42,6	34,0
	C3	80,8	51,4	35,2
18	C1	62,6	45,9	15,6
	C2	42,2	34,0	24,0
	C3	92,9	51,2	46,1

DAY	BIRD NO.	COMPONENT		
		FI 40	FI 60	FI 80
19	C1	58,1	47,1	53,6
	C2	54,0	46,6	35,5
	C3	76,8	59,2	48,5
20	C1	55,1	46,6	32,2
	C2	53,1	41,5	30,2
	C3	88,0	56,6	43,5
21	C1	55,7	47,4	27,6
	C2	55,0	43,0	42,0
	C3	64,8	50,4	35,5
22	C1	68,0	54,6	25,8
	C2	48,9	42,0	34,4
	C3	54,4	44,6	35,6
23	C1	73,9	66,3	42,5
	C2	45,4	38,0	29,3
	C3	64,4	43,7	36,6
24	C1	64,7	53,0	26,3
	C2	53,4	48,5	42,2
	C3	59,0	51,3	37,5
25	C1	71,8	60,7	38,0
	C2	65,2	58,0	53,4
	C3	63,7	50,7	38,7
26	C1	57,8	52,9	38,1
	C2	73,6	56,0	53,3
	C3	58,7	45,8	33,9
27	C1	68,3	65,5	47,0
	C2	73,5	61,5	59,0
	C3	71,6	53,0	43,9

DAY	BIRD ND.	COMPONENT		
		FI 40	FI 60	FI 80
28	C1	72,0	60,1	46,8
	C2	94,7	70,2	54,4
	C3	75,2	52,9	42,5
29	C1	72,5	57,4	45,3
	C2	78,8	58,4	57,6
	C3	74,8	48,8	35,5
30	C1	74,3	65,0	53,8
	C2	78,8	74,0	56,4
	C3	77,6	54,0	46,5
31	61	71,4	69,1	42,9
	C2	69,9	54,7	47,1
	C3	77,8	58,0	48,6
32	C1	75,8	71,0	48,9
	C2	69,5	58,6	47,0
	C3	75,7	58,1	48,6
33	C1	85,9	73,9	56,0
	C2	65,6	59,3	50,3
	C3	78,7	56,6	50,6
34	C1	84,4	67,9	38,5
	C2	52,8	43,0	39,0
	C3	81,8	51,2	35,9
35	C1	76,2	65,1	44,2
	C2	49,3	42,7	32,8
	C3	109,7	81,5	58,7
36	C1	82,5	70,0	37,5
	C2	67,4	51,8	44,4
	C3	82,6	71,4	45,2

DAY	BIRD NO.	COMPONENT		
		FI 40	FI 60	FI 80
37	C1	96,9	88,9	55,6
	C2	64,2	53,0	38,2
	C3	79,9	61,8	41,4
38	C1	88,9	63,9	39,6
	C2	59,1	44,9	35,3
	C3	78,4	58,4	53,7
39	C1	92,0	61,5	44,0
	C2	53,3	40,5	37,1
	C3	80,4	63,7	48,7
40	C1	74,0	57,8	35,9
	C2	52,2	35,5	19,7
	C3	79,2	58,2	53,0
41	C1	85,7	65,5	41,7
	C2	60,0	47,5	37,5
	C3	69,5	50,7	54,0

EXPERIMENT IVDAILY RESPONSE RATES
(Criterion trials only).

DAY	BIRD NO.	COMPONENT	
		DRL	DRH
1	B14	36,5	100,5
	B15	40,2	92,2
	B16	34,8	96,8
2	B14	35,2	99,5
	B15	39,8	107,3
	B16	36,5	99,8
3	B14	42,2	95,5
	B15	37,5	93,7
	B16	44,3	100,2
4	B14	42,0	97,7
	B15	40,1	96,3
	B16	39,8	90,62
5	B14	45,1	100,6
	B15	42,5	97,5
	B16	41,1	105,5
6	B14	43,8	114,1
	B15	29,7	94,8
	B16	31,6	94,5
7	B14	45,0	102,1
	B15	40,6	90,32
	B16	40,8	92,5
8	B14	39,7	96,7
	B15	38,5	96,1
	B16	34,8	90,57
9	B14	36,5	116,3
	B15	34,2	104,7
	B16	33,9	97,0

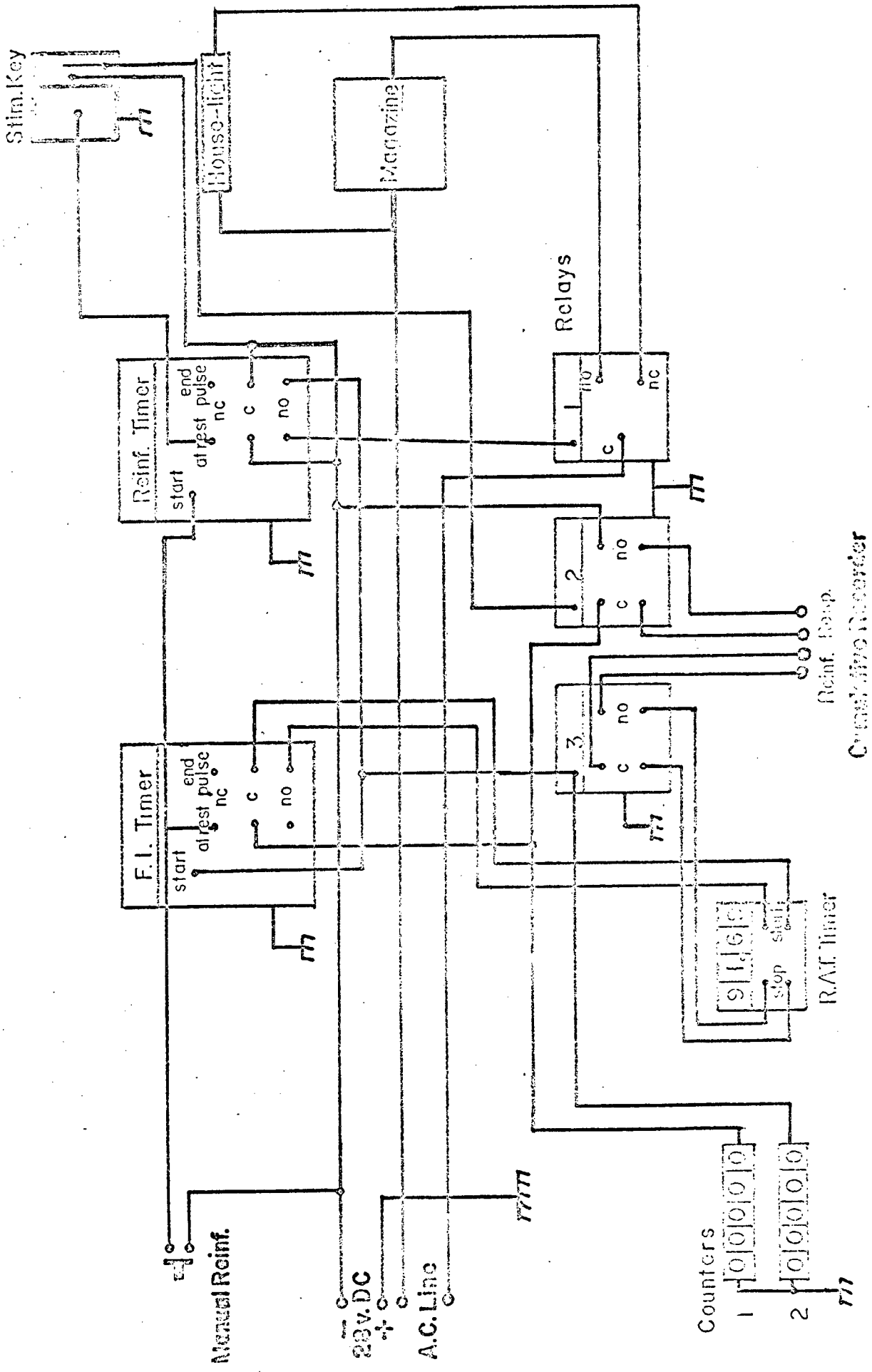
DAY	BIRD NO.	COMPONENT	
		DRL	DRH
10	B14	39,4	109,6
	B15	40,0	91,9
	B16	41,0	102,2
11	B14	29,9	121,4
	B15	40,2	110,4
	B16	30,4	99,7
12	B14	40,4	105,3
	B15	42,5	91,7
	B16	38,4	90,39
13	B14	35,7	114,8
	B15	22,2	98,7
	B16	30,5	96,7
14	B14	28,0	100,2
	B15	33,6	102,1
	B16	32,3	90,6
15	B14	25,8	95,5
	B15	37,3	90,4
	B16	30,7	90,5
16	B14	31,6	108,1
	B15	36,5	100,9
	B16	27,8	98,4
17	B14	37,0	111,8
	B15	36,9	98,7
	B16	35,0	100,6
18	B14	33,4	105,7
	B15	33,9	96,7
	B16	29,9	94,8

DAY	BIRD NO.	COMPONENT	
		DRL	DRH
19	B14	38,4	107,5
	B15	36,5	95,5
	B16	34,5	95,4
20	B14	35,8	97,9
	B15	34,9	99,1
	B16	24,7	94,6

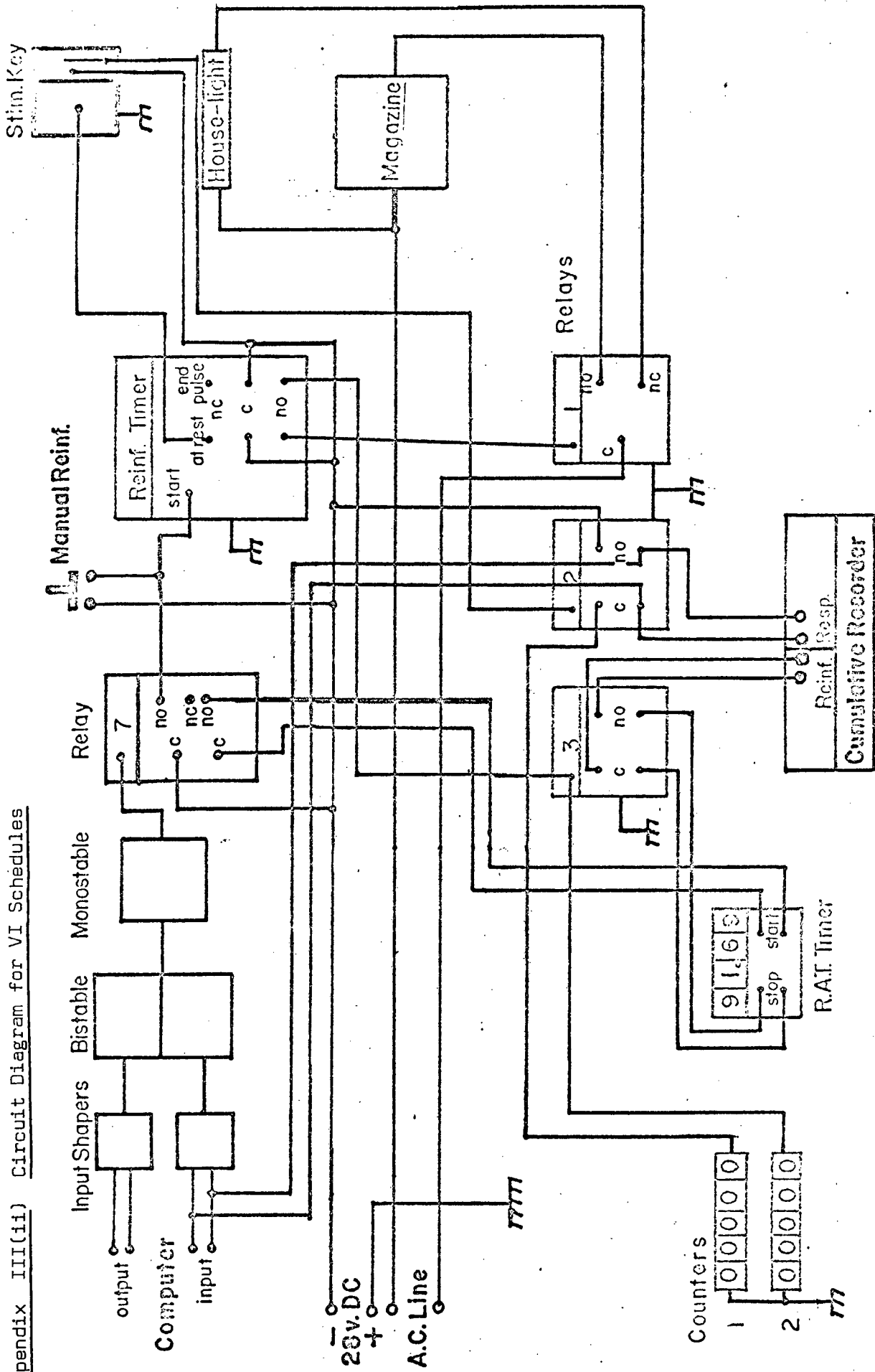
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iii) Computer controlled Multiple FI Schedules.....	208

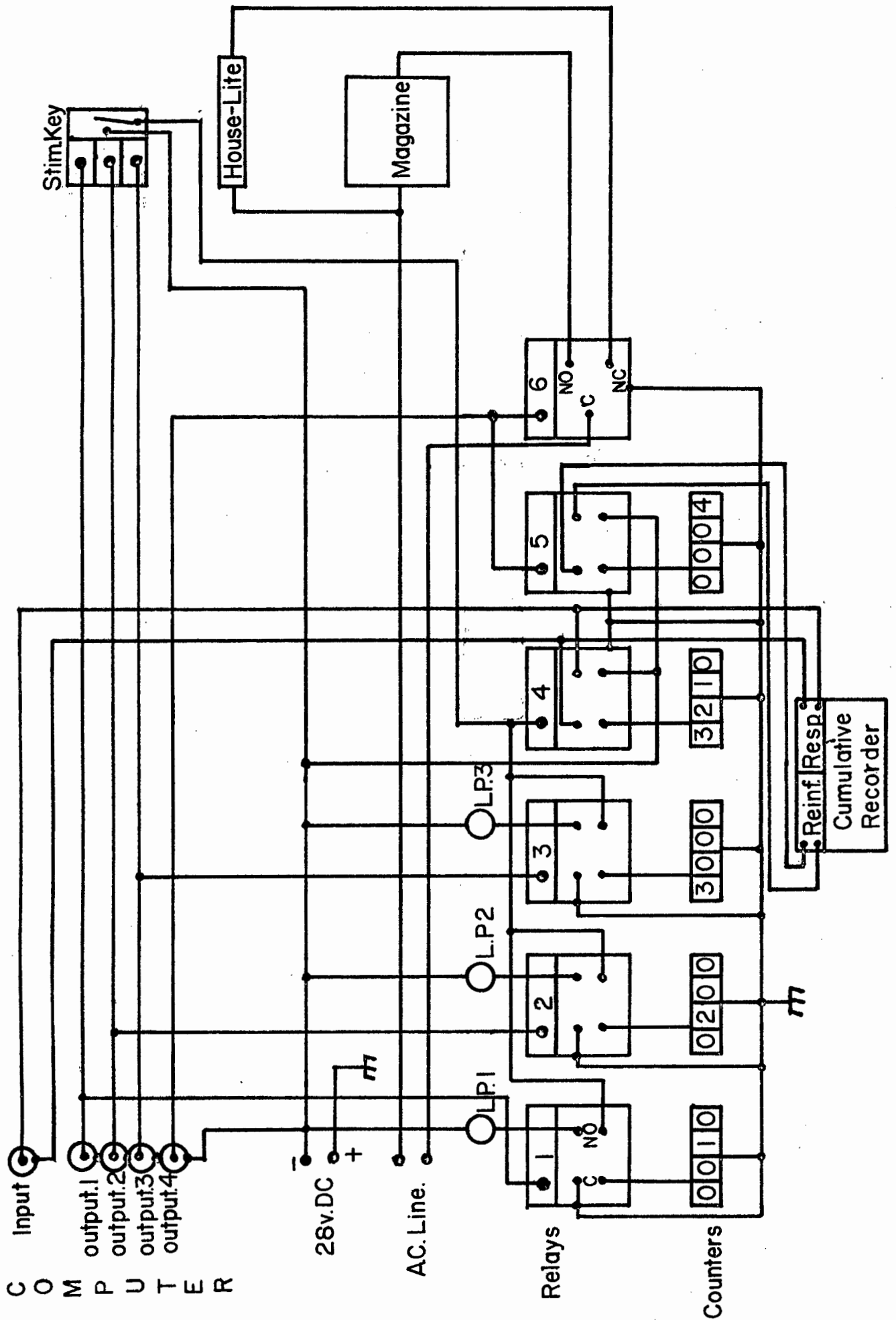
Appendix III(i) Circuit Diagram for FI Schedules



Appendix III(ii) Circuit Diagram for VI Schedules



APPENDIX III(iii) Circuit Diagram for MULT Schedules



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