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A Discrete Trial Choice Procedure for Assessing the Periodic Equivalent of Aperiodic Ratio Schedules

Michael Joseph Boivin
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A DISCRETE TRIAL CHOICE PROCEDURE FOR ASSESSING THE PERIODIC EQUIVALENT OF APERIODIC RATIO SCHEDULES

by

Michael Joseph Boivin

A Dissertation Submitted to the Faculty of The Graduate College in partial fulfillment of the requirements for the Degree of Doctor of Philosophy Department of Psychology

Western Michigan University Kalamazoo, Michigan December 1980
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When looking back over my four years of graduate training at Western Michigan University, my most immediate impression is a recognition of the tremendous amount of work and endurance involved in completing my training here. Along with that impression, though, is the recollection of a number of individuals who have made this experience an endurable one, and indeed in some instances, one to be treasured. Kenny Stephens, Franz Van Haaren, Rob Cobez, and Tom Pritzel have been my closest laboratory associates throughout the bulk of my stay here at W. M. U. Their intellectual comradery and encouragement throughout the grind of day to day research will always be remembered. Tom's help in occasionally running the animals for me is especially appreciated, as was the expert repairmanship of both Rob and Tom, when they periodically kicked the computer interface in order to make it work correctly.

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gratitude to her that I can only begin to repay. That is why I am
dedicating this dissertation to her as well as to Him who forms the
basis of our relationship and gives meaning to life itself.

Michael Joseph Boivin
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A DISCRETE TRIAL CHOICE PROCEDURE FOR ASSESSING THE PERIODIC EQUIVALENT OF APERIODIC RATIO SCHEDULES

Western Michigan University

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CHAPTER I

INTRODUCTION

When observing the behavior of living organisms, it soon becomes apparent that at any particular point in time, they are usually engaging in one activity to the exclusion of others. This being the case, the factors determining an organism's "choice" of one activity over another in a particular instance have become of great interest to philosophers and scientists alike.

It is now generally recognized that the probable outcome of engaging in some behavior in terms of environmental changes, is an important variable in determining the future probability of that behavior. In addition to the environmental consequences following a particular behavior, other factors must be taken into account as well in predicting the likelihood of that behavior.

One important variable which is doubtless influential in this respect is the "cost" of the response in terms of topographical feasibility and energy requirements. For example, given a number of responses which are functionally identical, the response with the least stringent physical requirement on the organism will in all likelihood become the most frequent, all else being equal.
While this characteristic of behavior is readily apparent, the measurement of this process has not been. Various procedures have been employed in an attempt to elucidate the relationship between the "response cost" of an activity and the organism's choice for that activity. These procedures have by and large resulted in some consistencies with regards to the nature of choice between various response requirements, but there have been numerous inconsistencies as well (Hendry, 1969). One of the most glaring inconsistencies has been with respect to the optimal means of procedurally determining an organism's preference between response requirements which differ in terms of their variability.

Procedures utilizing choice between fixed- and variable-ratio schedules of reinforcement (FR and VR) as their major dependent variable have generally been the most popular in the study of this particular topic. A review of these procedures and the results which they have produced is presented below.

Concurrent Ratio Schedules of Reinforcement

Herrnstein (1958) conducted one of the earliest studies using a concurrent schedule of reinforcement in order to measure choice between various response requirements. In his procedure, two independent FR schedules of reinforcement were concurrently available to the pigeons on separate keys. The FR values for the two keys were varied across conditions, while at the same time maintaining a constant sum of 40 for the total response requirement for both keys. The response requirements were FR 20 - FR 20, FR 10 - FR 30, FR 30 - FR 10, FR 35 - FR 5, and FR 2 - FR 38. Herrnstein noted that for each condition in which
there was a discrepancy between the ratio requirements for the two keys, the pigeons would respond exclusively on the key with the lower ratio requirement. Even in that condition where the response requirements were equal, FR 20 - FR 20, the birds nevertheless demonstrated predispositions towards either one side or the other.

These results supported Herrnstein's later formulation with respect to how organisms distribute their time and responses among concurrent schedule options (Herrnstein, 1970). According to his analysis, when given a choice between different ratio schedules, subjects should maximize their overall reinforcement rates by responding only to the reinforcement schedule with the shorter ratio. Likewise, given equal response requirements, organisms will nevertheless maximize by exclusively responding on that lever which might be more favorable in other respects, such as force requirements.

Schroeder (1975) substantiated Herrnstein's prediction with developmentally retarded humans who responded on concurrent ratio schedules for monetary reinforcement. When subjects were given a choice between concurrent VR schedules of reinforcement, they worked for and received reinforcement almost exclusively on the lever on which the smaller of the two ratios was available. The same was also true when concurrent FR schedules were presented.

As in the Schroeder study, Herrnstein and Loveland (1975) used a concurrent VR-VR schedule of reinforcement with pigeons and found similar results. Pigeons on concurrent VR schedules displayed maximizing with respect to the key upon which the majority of responding occurred, usually the key with the lower response requirement.
The studies described above all involved the simultaneous presentation of ratio schedules which were independent of one another in that responding on the ratio schedule on one key had no effect on the ratio schedule which was concurrently available on the other key. Shull and Pliskoff (1971) conducted a study which involved the presentation of concurrent non-independent ratio schedules of reinforcement as well as independent schedules. In their experiment, a Findley changeover key procedure was employed (Findley, 1958), in which two sets of concurrent VR 60 - VR 60 and FR 60 - FR 60 schedules were presented. In one set of each pair of schedules, the ratio components were non-independent of one another in that responses on one schedule counted towards meeting the response requirement on the absent schedule as well. For the other concurrent FR 60 - FR 60 and concurrent VR 60 - VR 60, the schedules were independent of one another. With the independent concurrent FR 60 - FR 60 and concurrent VR 60 - VR 60, as well as the non-independent FR 60 - FR 60 schedules, all three birds remained largely in either one component or the other, emitting few changeover responses. In the non-independent VR 60 - VR 60 condition however, changeover responses were fairly frequent (18-25 changeovers per minute) with a more equal distribution of obtained reinforcers in the two components.

These results led Shull and Pliskoff to suggest that changeover responding between components in a concurrent schedule was to a great extent dependent on the probability of reinforcement following a changeover response. Should the probability be minimal, few changeover responses are likely. The subject will therefore largely remain in one
of the components with the result being the "maximization" or exclusive preference often obtained with such procedures.

In concurrent ratio schedules of reinforcement, therefore, the commonly used preference measures are largely dependent on the form of the changeover responses. Given the sensitivity of changeover responses to the probability of reinforcement following their occurrence, the utility of concurrent schedules of reinforcement as a sensitive gauge for measuring preference between differing response costs is highly limited. Perhaps it is possible, however, to incorporate various procedural changes into the concurrent schedule which would encourage switching between components while at the same time insuring a low probability of reinforcement following a changeover. Such a procedure could insure the independence of the changeover response from other coincidental contingencies involved in reinforcement for responding in the separate components. At the same time, this procedure could prevent the preference measures from merely being secondary to the form of the changeover responding.

One such procedure was employed by Weiner (1966) in an attempt to measure preference between FR and VR schedules equal with respect to the arithmetic mean response requirement. Incidentally, this study was also one of the first direct tests of preference between FR and VR schedules. His procedure was similar to that of Findley (1958) in that subjects determined which component would be made available by responding on a "changeover" key. Meanwhile subjects worked to meet the response requirements for whatever schedule was being presented by responding on the "main" key. In addition to changeover responses resulting in
the presentation of the other independent component, components were automatically switched on a regular basis after each reinforcement as well, thereby insuring extensive exposure on the part of the subject to both available schedules.

No differential preference with respect to either response rate or changeover responses was apparent in those schedules which consisted of FR and VR schedules with similar means. Weiner also presented schedules which consisted of different valued FR components and found that subjects consistently switched to the lower FR.

The lack of differential preference in the equal valued VR-FR condition is in direct contradiction to those studies mentioned earlier in which equal valued independent ratio schedules resulted in definite preferences for one of the components (Herrnstein, 1958; Herrnstein and Loveland, 1975). The feature of Weiner's procedure which may have led to this discrepancy, however, was the fact that both components were regularly presented to the subject automatically. With such a procedure, subjects are assured of a fair amount of exposure to both components despite little changeover responding or little "preference" in terms of changeover responses to one component or the other. This procedure increases the subject's sampling of the available components while at the same time, not dramatically increasing the probability of reinforcement following a changeover response. At the same time, however, Weiner's procedure may have proved insensitive to schedule differences because it was far easier for a subject to simply respond on whatever schedule was currently available without going through "all the trouble"
of emitting changeover responses. This is because the components were alternated after every reinforcement regardless.

Repp and Deitz (1975) employed a procedure similar to that of Weiner in many respects. In their study, normal humans responded on a Findley changeover key procedure for token reinforcements. The FR 60 and VR 60 components of the schedule were regularly alternated on the main key, while the subject could change from the schedule which was currently in effect by simply responding on the changeover key. Though the response rates did not differ significantly between the two components, the majority of the switching responses occurred to the VR component. According to Repp and Deitz, this signified a definite preference for the VR. As the response requirement on the changeover key was systematically increased, changeover responses occurred more and more exclusively to the VR component.

Such results are obviously in disagreement with Weiner's, in which little or no changeover responses occurred to either component in the FR 40 - VR 40 condition. One feature of the Repp and Deitz procedure which might account for this discrepancy is the fact that "a changeover from a component did not result in the ratio being reset for that component". While Weiner does not clearly specify whether or not a reset contingency was in effect for his procedure, it appears likely that each component was in fact reset after a changeover response to a subsequent reinforcement in the other component.

Whether or not such reset contingencies are in effect have been known to drastically alter the form of the preference function in for example, concurrent interval schedules of reinforcement (De la Garza,
In Boivin's study, rats were presented with a Findley changeover key procedure in which two components were available, each with different frequencies of free milk presentation. Components were occasionally alternated automatically as in the Weiner (1966) study. When a reset contingency was in effect in which changeover responses resulted in a resetting of the interrupted interval, changeover responses became few. When no reset contingency was in effect, however, changeover responses became much more frequent.

In procedures such as Weiner's, in which the contingencies favor few changeover responses, such a lack of changeovers might well be mistaken as simply indicating indifference between the two components. More frequent changeover response rates as evident in non-reset procedures such as Repp and Deitz, might well result in the clearer delineation of even minimal preferences.

Rider (1979) employed a procedure with a somewhat different method of providing the subject with a sufficient amount of exposure to the available components of a concurrent ratio schedule. Rats were given a choice between an FR schedule on one lever, and either a mixed-ratio (MR) or a VR schedule on the other, depending on the group. Both schedules were usually available simultaneously. When a subject had obtained nine consecutive reinforcements on the same lever, however, the signal lamp above that lever was turned off, signalling that the lever had become inoperative and that that particular schedule was no longer available. Once the animal had met the response requirement and had obtained reinforcement on the other lever, the previously preferred
lever and its corresponding schedule were once again reinstated. Rider found that for the most part, subjects displayed a slight overall preference for the MR or VR schedules over their equal valued FR counterparts. This meant that the majority of the animal's responses occurred on the lever with the variable response requirement when compared to an FR schedule with an "equal response" requirement. Given two concurrent ratio schedules with different response requirements, subjects generally responded to the schedule with the smaller ratio of the two, although the preference was by no means exclusive.

The fact that Rider's subjects did display some preference for the variable response requirements whereas Weiner's subjects did not is not surprising in light of their procedural differences. In Weiner's experiment, the indifference between the VR and the FR was characterized by a complete absence of changeover responses to either component. Despite the absence of changeover responses, subjects continued responding in both components due to the automatic switching of the components on a regular basis. As discussed earlier, with such a procedure it is likely that changeover responding would be maintained only in such cases where there was a sharp discrepancy between the ratio requirements of the components. Rider's procedure on the other hand allowed for the appearance of some definite preferences in equal valued conditions by allowing the subject to perseverate on one particular schedule for nine reinforcements at most, while requiring the subject to sample the less preferred schedule only once. By allowing such perseverations, more definite preferences would be likely to form in even those schedules whose response requirements were only minimally different. At the same
time, exclusive response preferences of the sort noted in Herrnstein (1958) and Herrnstein and Loveland (1975) were actively discouraged by requiring that the subject periodically sample, and be reinforced in, the less preferred component.

One final variation of the Findley changeover key procedure should also be discussed. Sherman and Thomas (1968) maintained pigeons responding on a nine component multiple schedule of reinforcement, each component consisting of a different valued FR schedule. At the beginning of each component, subjects had an opportunity to respond on a changeover key which simply served to discontinue the presentation of the discriminative stimuli for those same nine components. This served to turn the multiple schedule into a mixed one until the currently available component had been completed. By noting those FR schedules which the pigeons "changed-over" on, Sherman and Thomas could evaluate the extent to which the arithmetic average of the MR approximated the point at which the multiple schedule was changed into a mixed schedule.

In all, subjects demonstrated more preference for the MR than would be predicted on the basis of a comparison between the mean rates of reinforcement. When, for example, nine FR components were presented which averaged to 120 (FR 1, 30, 60, 90, 120, 150, 180, 210, 240), subjects would usually peck the changeover key at the start of those components whose FR value was 60 or higher, instead of 120.

These very clear-cut and yet non-exclusive preferences for the variable response requirement were generally in agreement with other concurrent procedures which have limited the favorability of changeover.
responding while at the same time insuring adequate exposure to the available schedules (Rider, 1979; Repp and Deitz, 1975).

In summary, the experiments using concurrent schedules of reinforcement in measuring preference between ratio schedules have yielded conflicting results. The discrepancies of these results are better understood in light of some of the procedural peculiarities of the various concurrent schedules employed. Such procedural considerations, while allowing one to possibly account for the apparent discrepancies, also testify to the limited utility of the concurrent schedule in such preference measures. Perhaps another schedule whose dependent measures are less sensitive to procedural variation affecting changover responding would allow more consistent and representative measures of preference. One likely candidate which has been occasionally employed is the concurrent chain schedule of reinforcement.

Concurrent Chain Schedules of Reinforcement

Fantino (1967) reported the first study in which such a schedule had been used to measure preference between an FR and an MR schedule of reinforcement. In Fantino's procedure, the initial link of each chain consisted of an independently operated VI schedule, which determined the availability of the terminal link. The terminal link in one chain consisted of an FR schedule. The terminal link in the other concurrent chain consisted of an MR schedule which was comprised of two or three equiprobable FR components. Fantino based his measure of preference for either of the terminal link schedules on the relative rate of responding which had occurred in the initial link of that particular chain.
Given an MR terminal link whose arithmetic average equaled the value of the FR terminal link, significantly larger rates of responding occurred on the MR initial link. Furthermore, the degree of preference for the MR chain increased as the MR became more variable; in other words, as the FR values making up the MR schedule became more extreme. For example, higher relative rates of responding were maintained on the MR chain consisting of FR 1, 99 than on that MR chain whose components were FR 25, 75. Such preferences point out an additional feature which must be considered when evaluating choice for varying ratio requirements.

In a similar type of study with concurrent chain schedules, Duncan and Fantino (1970) presented FR schedules in both terminal links. As might well be expected, the relative reinforcement rates were higher on those initial links associated with the smaller ratio value. As the values of each of the terminal links increased by a constant amount, however, choice proportions for the smaller of the two FR values increased. Such findings, according to Duncan and Fantino, discourage one from attempting to arrive at a simple transformation formula for translating aperiodic schedules into their periodic equivalents (Killeen, 1968).

Navarick and Fantino (1972), for example, found that simply because two particular terminal link alternatives may result in equal relative rates of reinforcement when compared directly, they may not give rise to the same degree of preference when presented separately in other choice situations. Such intransitivities are troubling given the intuitive appeal of arriving at a formulation of choice which can easily give periodic and aperiodic equivalents for the whole range of absolute
ratio values. What is troubling as well are the results of those cases in the Navarick and Fantino study, in which equal valued FR and VR terminal links were compared directly. The choice proportions for these instances were only slightly above indifference in favor of the VR schedules. The preferences for the variable response requirement in the Navarick and Fantino study (1972) were not nearly as great as in the Fantino study (1967). Perhaps a VR schedule proper is not as "variable" as the MR schedule of the sort employed by Fantino (1967), with the resulting discrepancies in preference for the VR and MR.

Hendry (1969), though, provided an alternative explanation for the apparent greater preference for MR as opposed to VR schedules. In Hendry's procedure, one chain consisted of an FR schedule in its terminal link, while the other consisted in either a multiple-, mixed-, or variable-ratio schedule. The multiple terminal link component consisted of two equiprobable FR components, each with their respective discriminative stimulus. The mixed link consisted of two equiprobable unsignalled components, and the VR of numerous unsignalled components. Overall, the birds preferred the multiple- more than the mixed-, which in turn was preferred more than the variable-ratio schedule. Such preferences, according to Hendry, coincided with the extent to which each of the schedules was "informative" with respect to the signalling of currently available components. What may be puzzling to some is the fact that the simple FR terminal link option is the least preferred when compared to equal valued multiple-, mixed-, or variable-ratio links, even though the FR is by far the most predictable and thus the most informative. In Hendry's opinion, however, in order for a schedule
to have "informative" value, it must provide information with respect
to the occurrence of one of a number of possibilities.

While such considerations may be speculative, the above discussion
does serve to point out all the more the apparent relativity of concurrent preference measures with regards to procedural specifications. Another example of this characteristic of concurrent chain preference measures is apparent when examining the manner in which the initial links of the schedules are programmed. The concurrent chain schedules discussed thus far have consisted of VI initial link components. Since the terminal link timers for such components are in operation simultaneously, prolonged responding to one side results in a greater likelihood of terminal link onset of the other chain with a changeover in responding to the other side. This occasional conditioned reinforcement of such changeovers by means of the onset of the terminal links is similar to what happens in simple concurrent VI schedules (Boivin, 1978). Here reinforcement timers to both components are oftentimes also simultaneously in operation. In both types of schedules, high rates of changeover responding are encouraged since reinforcement (either conditioned or primary) is frequently made available by the timer elapsing for one component while the subject is in the other.

It is not difficult to see how procedures which favor responding back and forth between components can result in unusually high indifference for certain terminal link options which other procedures have found to be very much preferred. This may especially be the case when one's measures of preference for a terminal link option are dependent upon the relative amount of responding for its respective initial link,
as is usually the case in concurrent chain procedures. This may therefore explain why experiments which have employed procedures and dependent variable measures similar to those described above have found indifference for the VR option in cases where other studies have revealed definite preferences over the FR schedule (Navarick and Fantino, 1972).

One means of discouraging frequent changeovers between the initial links is to employ independent ratio schedules as opposed to VI schedules. Hendry (1969) conducted a preference study using such a schedule. In his procedure pigeons were given a choice between two chain schedules consisting of a chain FR 10 - VR 50 on one side, and a chain FR 10 - FR X on the other. "X" was varied until Hendry arrived at that FR terminal link which was equally preferred to the VR 50 terminal link.

The form of the initial link responding differed markedly from that normally observed in concurrent chains with VI initial link components. Hendry found that at the onset of an initial link, the pigeons usually began responding to one side or the other and continued doing so without any changeovers until the terminal link for that side had been acquired. As one might suspect, this type of responding resulted in some very clear-cut preferences for either one chain or the other in most of the chains tested, in terms of which terminal link was acquired most often. When comparing equal valued FR and VR terminal links, Hendry found almost exclusive preference for the VR link. In fact, the pigeons did not respond to acquire the FR terminal link as often as the VR one until the FR option was as low as 30 (FR 30).

It would appear then, that in concurrent chain schedules as well as simple concurrent schedules, procedural considerations are of vital
importance in determining the outcome of one's preference measures. With respect to the studies discussed above, such considerations would include the favorability of changeover responding, the variability of the variable-ratio schedule, and whether or not the fixed and variable schedules are compared directly or to some third schedule (intransitivity). Although these characteristics of preference with concurrent chains are fairly evident, what makes them so troublesome is that sometimes they are arbitrarily decided upon and not taken into consideration when comparing the results of different concurrent chain procedures. Even if such procedural considerations were taken into account, the relationship between them and preference in general is still so poorly understood, that the simultaneous variation of a number of these parameters makes one's results nonetheless uninterpretable.

What would be optimal is a choice procedure whose specifications can be varied with little effect on one's resulting preference functions. Intuitively, it would seem that such a procedure might allow for a direct study of the nature of choice. Of the two choice procedures discussed thus far, simple concurrent and concurrent chain schedules, neither meet this requirement.

Response Weakening Operations and Ratio Schedules

At this point, it may prove worthwhile to consider an entirely different approach to the problem of response preference. Some researchers prefer not to conceptualize response strength as the likelihood of one choice over another given concurrently available options. They would rather consider response strength from the standpoint of the
resistance of the probability of a particular response to response weakening operations (Smith, 1974).

Powell (1970) conducted one such study in which an attempt was made to compare FR and VR schedules with respect to their resiliency in the face of punishment. Pigeons were maintained on multiple schedules of reinforcement in this procedure. The components consisted of equal valued FR and VR schedules as well as a VI schedule in several of the conditions. After responding had stabilized in each condition, shock punishment was presented in both components of the multiple schedule. The VI schedule for the most part proved to be more resistant to punishment than either the VR or FR schedules, both of which were suppressed to approximately the same extent.

Powell hypothesized that the difference between the interval and ratio schedules was most likely due to the drastic reduction in reinforcement rate which accompanied any initial reduction in ratio responding caused by the shock punishment. Romanczyk (1976) in fact considered VR schedules to be entirely inappropriate for studying various forms of ratio punishment due to the great susceptibility of the VR to disruption. Interval schedules remain a better choice for such procedures because initial suppressions in interval responding would not necessarily affect the ongoing rate of reinforcement.

A major consideration then becomes apparent when employing response weakening operations with ratio schedules. Are the differential decreases between, for example, FR and VR responding, when punished, due to the different "strengths" of the two; or do they reflect instead decreases in the rate of reinforcement?
In concurrent choice procedures, one can at least equate the ongoing rates of reinforcement as in the case of Weiner (1966). With the response weakening operations though, one's major dependent variables, such as decreases in response rate, are inextricably wound up with those factors influential in determining the strength of the response, such as rate of reinforcement.

Obstruction Techniques

The durability of certain preferences can be tested, not only by attempting to weaken the response directly, but also by increasing the response cost of a particular option by imposing some sort of obstacle of obstruction (Snapper, 1979). In the case of ratio schedules where response requirements are already of primary concern, one can instead increase the response cost for an option by imposing a time-out (TO) period as a "penalty" for choosing that option. Striefel (1972) presented human subjects with ten different pairs of concurrent FR schedules. Under these conditions, preferences normally developed for the smaller of the two ratios. After such preferences developed, however, Striefel imposed a TO after each reinforcer in the preferred component, increasing the TO period until preference was reversed to the other schedule. In general, the larger the FR difference, the greater the TO required to shift the subject to the previously nonpreferred ratio. While such systematic relationships are impressive, this obstruction technique carries with it the same basic problem inherent in the response weakening operation described above. Was the attenuation of preference for the more favorable FR due to a decrease in the overall

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rate of reinforcement resulting from the imposition of time-out periods? On the other hand, do such attenuations reflect a weakening of the favorability of response option in some manner other than reinforcement rate? As mentioned earlier, the dependence of reinforcement rate on the form of ongoing ratio responding makes the resolution of such theoretical issues difficult. This characteristic, therefore, serves to limit the utility of response weakening and obstruction techniques with regards to arriving at a comprehensive model of preference in ratio responding.

Discrete Trial Choice Procedures

The schedules discussed thus far, such as the concurrent, concurrent chain, and multiple schedule, have all oftentimes led to a primarily molar analysis in terms of overall preference (Herrnstein, 1970). Herrnstein and Loveland (1975), for example, have expressed the opinion that choice is more sensibly viewed in terms of overall relative proportion of responding to one option as opposed to another, throughout the course of the session. Shimp (1966, 1969), on the other hand, prefers a more molecular analysis, in which preference is viewed as a function of individual choices, each being determined by the "momentary probability" of reinforcement for that response.

Keeping in line with a more molecular analysis, preference might best be studied by partitioning the subject's selection into discrete trials. Such a procedure might better reflect a subject's immediate preference, in addition to being less sensitive to other factors such as ongoing sequential dependencies of reinforcement; either of the choice

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or of the changeover response, Bitgood and Platt (1973), for example, found that discrete trial FR schedules proved more sensitive to different magnitudes of reinforcement and response requirements than did ongoing ones.

Though discrete trial procedures have long been employed in the study of sensory capacities within the area of psychophysics (Gescheider, 1976), they have been less popular when measuring the sensitivity of an organism to different behavioral outcomes. Campbell (1955) was one of the first who attempted such an application. He used a discrete trial psychophysics procedure to evaluate the subject's preference for one of two levels of white noise. His major dependent variable was the amount of time rats spent on either side of a shuttle-box.

Tarpy (1969 a, 1969 b) and Johanson (1971) have also employed a discrete trial procedure to assess response preference for differential outcomes with respect to free-operant responding. In the Johanson study, monkeys completed an FR 5 response requirement on either of two levers in order to receive an injection of cocaine. After repeated sampling of both alternatives in their respective single alternative phases, a 30-minute time-out period was instituted, followed by a free choice series of trials in which both options were simultaneously presented. Johanson found that the discrete trial procedure was useful in gauging the degree of preference between various dosages of cocaine. Other variables influencing preference in this procedure, such as delay of reinforcement, punishment, and response requirements were subsequently investigated (Johanson, 1976). While the Johanson discrete trial choice procedure was primarily used to evaluate choice with regards to drug
maintained responding, its applicability in the investigation of other variables influencing free operant preference are readily apparent. Perhaps the types of discrete trial procedures discussed above can prove useful in describing the sensitivity of a subject's behavior to differing response requirements of variable and ratio schedules as well. In the present study, therefore, a commonly used psychophysics discrete trial method, the method of limits (Fechner, 1860; Blough and Blough, 1977), was employed as a means of testing preference between periodic and aperiodic response requirements.

One of the parameters which was varied using this method was the length of time between the presentation of successive trials. This parameter was thought to be of possible importance in affecting preference outcomes within a discrete trial procedure based on a study by Fantino (1969). In this study, Fantino found that with concurrent chain schedules, the duration of the initial links was an important factor in determining the degree to which the subject will prefer one schedule over another. In general, the longer the initial links the more indifferent the subject becomes to differences between the two terminal links. Fantino (1977) suggests that this is due to the fact that as the initial links of each chain are both increased, the overall delays to reinforcement for both terminal and initial links together become less different between the two schedules. This would suggest that the overall delay to reinforcement, and not the specific features of the terminal links themselves, is what is important in determining preference, at least in a concurrent chain procedure. Whether or not the overall delay of reinforcement is an important consideration in
discrete trial procedures as well remains to be tested. Perhaps the period of time between successive trial presentations (inter-trial interval) does not so much serve to clearly demarcate successive trials, as to simply impose a delay of reinforcement in a manner similar to the initial interval links of Fantino's (1969) concurrent chains. If this were the case, then the overall length of the inter-trial interval (ITI) would be implicated as an important parametric consideration in discrete trial choice measurement in general.

In the present study, therefore, several ITI values were employed within the method of limits procedure, and the resulting preference functions compared.
CHAPTER II

METHOD

Subjects

Twelve naive male albino rats were obtained from Spartan Laboratories (Haslett, Michigan) to serve as subjects. They were approximately 90 days of age when first acquired, and after being housed individually, were immediately provided with unlimited access to food and water for an additional 30 days. At this point, subjects were allowed access to water for only 15 minutes each day until their body weights were reduced to 85% of the pre-deprivation weights. Thereafter, the amount of time that subjects were allowed access to water was varied for individual subjects so as to maintain subjects consistently at 85% of their ad lib weights throughout the experiment. During this time, food was constantly available in the home cages. Multiple vitamins were also placed in the subjects' water on a weekly basis as a dietary supplement.

Apparatus

Six experimental chambers were used, all of which were similar in their design and dimensions. The floor of each chamber consisted of four tubular rods, 1.9 cm in diameter, which were spaced 3.8 cm apart.
The interior walls of these plexiglass chambers were coated with aluminum sheets. The interior dimensions of each of the chambers were 20 cm long, 13 cm wide, and 15 cm high. On the front wall of the chamber, two identical flat levers (Compound Rodent Lever Model 121-05 from BRS/LVE) could be inserted through two holes. The holes were located 9 cm above the grid floor, were spaced about 6 cm apart, and measured 2.54 cm in diameter. The levers used in each chamber were carefully matched so as to require the exact same amount of downward force in order to operate a microswitch. The amount of downward force required to operate each pair of levers was generally 20 grams.

A smaller hole measuring 1.85 cm in diameter was located above each of the two lever holes. These holes were bored through the aluminum plate only, thus leaving the plexiglass wall intact; and were fashioned so as to provide a view of an independently operated stimulus light located above and behind each lever. Each stimulus light was covered with an amber cap. Located 2.54 cm above the grid floor and centered directly between the two lever holes was another hole measuring 2.54 cm in diameter. This hole provided access to a drop of water on the end of a dipper arm when the external dipper device was occasionally operated. The chamber was dimly illuminated by means of a houselight which was mounted below and in back of a side wall of the chamber. A 2900 Hz tone could be presented at various intensities by means of a Sonalert Model SC 628 auditory stimulus source mounted behind the same side wall of the chamber. During each experimental session, white noise was presented by means of a speaker housed behind the experimental compartments. The chambers were also fan-ventilated during the session.
The control of the experimental equipment and the collection of data were accomplished by means of a Digital Equipment Corporation (DEC) PDP 8/e computer during the major portion of the experiment. Due to equipment failure, a DEC PDP 8/a computer was used for the last part of the experiment. The computers were located in a room adjacent to the one containing the experimental chambers, and were connected to the experimental chambers throughout the entirety of the experiment by means of a computer interface provided by State Systems, Incorporated, of Kalamazoo, Michigan. The SuperSKED software language (Snapper and Inglis, 1979) was used to program the experiment, and allowed for simultaneous process control and data analysis.

Procedure

Initial training

All subjects were initially presented with a one hour habituation session in which they were simply placed in the experimental chamber with the houselight on. The levers were withdrawn beforehand, and the lever holes covered with smooth metal plates. After the habituation session, the left hand lever was inserted and a three stage training program was implemented in order to facilitate the acquisition of lever pressing on the part of the subjects. When each session of a training stage was completed with the left hand lever, it was removed and the right hand lever was then inserted. Throughout the course of training, therefore, the insertion of the left and right hand levers was alternated across individual sessions.
During the first stage of training, the dipper arm remained in the up position throughout the session so that the animal had continual access to the indentation at the end of the arm which contained the water drop. Every 90 seconds or so, the dipper arm was lowered into the water tray and immediately raised again to provide free reinforcement to the animal. Reinforcement was also presented whenever the subject emitted a lever press. If at any time, the subject emitted 10 lever presses within the space of one minute, the free reinforcements were discontinued, and from that point on, the animal received water reinforcement only for the occurrence of a lever press. The second stage differed from the first only in that the dipper arm constantly remained in the down position and was raised to allow access to the water drop occasionally for only a 5 second reinforcement period in response to either lever presses or scheduled free reinforcers. The Third stage was similar to stage two except that free reinforcements were no longer provided.

Throughout these stages, the light above whichever lever happened to be inserted remained on throughout the session except during the reinforcement periods. For the entire experiment, every lever press which occurred to a lighted lever resulted in a very brief "blip" of the Sonalert. These "blips" served as a form of response feedback, signalling to the subject that the immediately preceding response was meeting part of the response requirement for reinforcement.

In all, ten of the twelve experimental animals acquired lever pressing during the course of these various stages. The remaining two animals were hand shaped to lever press. After an additional session in
which the schedule of reinforcement was gradually changed from an FR 1 to an FR 3, subjects were randomly assigned to two groups of six subjects each.

**Discrete trial training**

During the initial stages of discrete trial training, only one lever was inserted per session. The right and left levers were switched on successive sessions. For the early stages of discrete trial training, the general procedure was as follows. An inter-trial interval (ITI) would occur during which time the chamber was completely dark. After the ITI had elapsed, both the houselight and the light above the inserted lever would come on simultaneously. On about half of the trials, the light above the lever would flash on and off at a rate of five times per second. The rest of the time the light would remain on throughout the trial period. The houselight and lever light would remain on until either the FR 5 requirement had been met or else a 2 minute period had elapsed. If in fact, the subject met the FR 5 requirement, the houselight and lever light turned off, and a tone immediately came on along with the activation of the reinforcement dipper. If during that particular trial a flashing light had been presented, then the tone accompanying reinforcement was also turned on and off at the rate of five times per second throughout the five second reinforcement period. If that trial was a "steady-light" trial, however, the tone accompanying reinforcement remained continually on throughout the five second reinforcement period.
For those trials in which the houselight and lever light were presented for two minutes during which time the FR 5 requirement was not met, the lights were simply turned off, signifying the end of that trial and a return to the ITI. Unlike responding during the trial periods, responding during the ITIs did not result in a feedback "blip" or count towards the meeting of any FR reinforcement requirement. Although ITI responses were recorded, they had no effect on the programmed events.

During the initial sessions of the discrete trial training, the length of the ITI periods was gradually extended in increments of 10 seconds from an initial value of 10 seconds to 90 seconds for group one and 30 seconds for group two. The two groups, therefore, primarily differed with respect to the overall length of the ITI periods, both during this stage of training and throughout the rest of the experiment.

After responding had stabilized under this condition, all the subjects were exposed to the final phase of discrete trial training in which both the right and left levers were inserted simultaneously. During this phase, the occurrence of either a flashing or steady light trial was randomized as well as which lever the trial would be presented on. Although both levers were continually present in the chamber during this phase, trials were never presented on both levers simultaneously so as to encourage the subjects to track the trial presentations across both levers.

Other changes unique to this phase included the changing of the ITI periods from a constant value of 90 seconds and 30 seconds for group one and two, to variable ITI values of 90 seconds, and 30 seconds, respectively. ITI values were selected randomly from a Catania-Reynolds
(1968) series of 20 values on a trial by trial basis. An additional contingency was also added in that once a particular ITI period had timed out, a trial was not initiated unless the organism had not emitted any responses whatsoever for five seconds immediately prior to the scheduled trial onset. If the organism had in fact emitted any lever press responses during the final five second portion of the ITI, the onset of the trial was delayed until a five second period had elapsed with no lever presses whatsoever. This contingency was implemented so as to prevent any superstitious responding which might occur right up into the onset of the trial periods.

Throughout the discrete trial training portion of the experiment, sessions lasted until 100 trials had been presented.

Experimental Procedure

Condition one

Throughout the entire experiment, a flashing lever light signalled the availability of a VR schedule of reinforcement on that particular lever while a steady light signalled the availability of an FR schedule. Initially, a VR 5 and an FR 1 schedule were employed. The VR 5 schedule was made up of a Catania-Reynolds series of ten ratio values which were randomly selected on a trial by trial basis.

Trials where only one schedule was available were referred to as forced choice trials. This was because in order to obtain reinforcement, the subject had to respond to the side with the lighted lever. During such trials, responses to the inactive or dark lever had no
effect. Trials in which both the FR 1 and VR 5 schedule were available simultaneously were referred to as free choice trials, since the subject had the opportunity to respond to either schedule. At the start of such trials, both lever lights would come on, one flashing and one steady, signalling the availability of the VR and FR schedules on their respective levers. Once an initial response had occurred to either lever, the other lever was immediately made inactive and its lever light turned off. In order to obtain reinforcement, therefore, subjects were required to continue on the lever on which responding for that trial had been initiated until the response requirement for that schedule had been met. If the response requirement had not been completed within two minutes from the start of that trial, the trial was discontinued and the lever light(s) were turned off. If however, a response on the appropriate lever had occurred during the final five second portion of the trial period, the trial period was extended until no responses on the active lever had occurred for five seconds or the response requirement for the schedule being presented on that lever had been met.

The sessions during this phase of the experiment could be conceptualized as consisting of blocks of trials consisting of five trials each. The first four trials were forced choice trials which included each of the four possible lever-light combinations in random order: VR - right lever alone, or VR - left lever alone, or FR - right lever alone, or FR - left lever alone. The fifth trial was a free choice trial which consisted of one of the two possible lever-light combinations (FR - right lever and VR - left lever or FR - left lever and
Figure 1. This is a state diagram of the basic features of the forced choice trial. After a variable amount of time has elapsed (ITI), one of the schedules is randomly selected with a probability of .5 to be presented on its lever. The availability of this schedule is signified by either a flashing light above the lever for the VR schedule or a steady light for the FR. If the response requirement is not met within two minutes, the trial is discontinued and another ITI is initiated. If the response requirement is met, water reinforcement is presented for five seconds accompanied by either a beeping tone (for the VR) or a steady tone (for the FR). After the five seconds has elapsed, the tones are discontinued and another ITI begins.
Figure 2. This is a state diagram of the basic features of the free choice trial. After a variable amount of time has elapsed (ITI), both of the schedules are presented on their respective levers, each accompanied by its discriminative stimulus. A flashing light above the left lever signifies the availability of the VR schedule on that lever, while a steady light above the right lever signifies the availability of the FR schedule. Once an initial response occurs to either lever, the other lever is deactivated and its lever light turned off, signifying that the schedule on that lever is no longer available. Should the animal complete the response requirement on the chosen lever, then reinforcement is presented for five seconds, accompanied by either a beeping or steady tone, depending on whether the VR or FR schedule was chosen and completed. After the five second reinforcement period has elapsed, the tones are discontinued and another ITI begins.
VR-right lever) selected at random. Thus, while the general pattern of four forced choice trials and one free choice trial remained consistent, the particular pattern of the possible lever schedule combinations varied between blocks of trials as determined by the randomization process. This process however was programmed so as to insure that by the end of a session an equal number of all the possible lever schedule combinations, for forced and choice trials alike, had occurred.

Sessions lasted until 50 trials had been presented. Each session therefore, consisted of 40 forced choice trials and 10 free choice trials.

Changes in response requirements

As mentioned above, the two schedules presented to the subjects were an FR 1 and a VR 5. It was assumed that eventually all of the subjects would demonstrate significant preference for the FR 1 schedule during the free choice trials. Significant preference for a particular schedule after a session was defined as the obtaining of reinforcement for having completed the response requirement for that schedule on at least 90% of the free choice trials presented. Within the present experimental condition, ten free choice trials were presented in which both the FR and VR schedules were concurrently available. In order for a subject to have demonstrated significant preference for the FR schedule, it would have been necessary for the subject to have initially responded to and have completed the FR schedule as opposed to the VR schedule on at least nine of the ten free choice trials. Once significant preference for the FR 1 schedule was apparent, the FR
requirement was systematically increased between sessions by increments of two until significant preference was apparent for the VR schedule. At this point, the FR requirement was systematically decreased by decrements of two until subjects once again demonstrated significant preference for the FR schedule. If after the completion of a particular session, the subject's preference remained relatively stable, then the FR requirement was changed in the manner described above. Stability was defined as

1. significant preference for either schedule or
2. a change in the degree of preference for the FR schedule by less than 20%.

If the preference measures for the FR schedule fluctuated by more than 20%, the FR requirement remained unchanged for the following sessions until the stability criterion was met.

**Condition two**

After five sessions in which the two schedules presented were FR 1 and VR 5, the majority of the subjects demonstrated no systematic changes towards significant preference for either schedule. The VR 5 schedule therefore was changed to a VR 10 in order to facilitate the development of such significant preferences. Condition two, then, differed from condition one only in that the choice was now between an FR 1 and a VR 10 schedule as opposed to a VR 5.

**Condition three**

In condition two, all of the subjects for group one and two of the six subjects in group two eventually displayed significant preference
for the FR 1 schedule. Systematic increases with respect to the FR requirement, however, failed to produce significant VR preferences in any of the subjects despite some of the rather exorbitant FR requirements which were eventually obtained (e.g. FR 37 versus VR 10 for Subject 103, FR 41 versus VR 10 for Subject 105). In order to facilitate a reversal of preference and to encourage a greater stability of preference measures on a day to day basis, 40 free choice trials were presented per session. Condition three, therefore, differed from condition two in that instead of a block of trials consisting of four forced choice trials and one free choice trials, they now consisted of four forced trials and four free choice trials. Sessions lasted for a total of 80 trials during this stage.

**Condition four**

After five sessions in the above condition, there were no systematic changes towards significant preference for the VR 10 schedule in any of the subjects. The following major changes therefore were implemented.

First of all, instead of a particular schedule being presented on either lever according to the process of randomization, that schedule was consistently presented on only one particular lever (right or left) throughout the remainder of the experiment. Since by this time the majority of the subjects were displaying some sort of position preference, the more severe response requirement (usually the FR) was consistently presented on the preferred side, while the less severe response requirement was presented on the less preferred side. For
example, at the end of condition three, Subject 101's overall preference measures for the VR 10 as opposed to the FR 23 schedule remained at the point of indifference despite an obvious discrepancy between the two. Subject 101, however, displayed a very strong position preference for the right hand lever, responding to that side on choice trials regardless of which schedule was being presented. In order to counteract this tendency, during condition four the FR 23 schedule remained consistently on the right hand lever during forced and free choice trials alike, while the VR 10 schedule remained consistently on the left hand side.

Eventually all subjects displayed appropriate significant preferences for the schedule with the less severe response requirement. Every subject was then continued on an FR 1 versus VR 10 procedure until a significant preference for the FR 1 schedule was obtained. At this point, significant preference for the FR was reversed to the VR by increasing the FR response requirement. Unlike condition two, however, the increments were not by two but by ten until significant preference for the VR 10 schedule was obtained. The FR response requirement was then decreased in decrements of ten until the subjects once again displayed significant preference for the FR schedule. This same process was then repeated, only in increments and decrements of five, and then in increments and decrements of two.

After the completion of the preference reversals with step sizes of ten, five, and two, the same procedure was repeated, only with a VR 5 schedule instead of a VR 10. With the VR 5 condition, after the significant preference reversals had been accomplished using step sizes
of ten, five, and two, an additional reversal was accomplished with step sizes of one as well.

Since the FR schedule and the VR schedule were consistently presented on their respective levers only, the total possible number of lever schedule combinations for forced choice trials decreased from four to two. Each block of trials in condition four therefore consisted of only two forced choice trials followed by four free choice trials. Sessions lasted until a total of 60 trials had been presented or until approximately three hours had elapsed. During the previous conditions, one session was run each day. Starting at approximately half way through condition four, however, two sessions were run each day, one in the morning and one in the afternoon. This change was instituted due to time constraints. It did not result in any observable disruption in the ongoing preference measures.

**Changes in response requirements**

With the advent of condition four, a criterion for stability was employed which was somewhat different than the one described earlier for conditions one, two, and three. One difference was that in condition four, each of the FR requirements which did not result in significant preference was continued for at least three sessions in order to insure adequate exposure of that particular schedule to the subject. The stability criterion was also changed so that a particular FR value was continued as long as there was any trend in the preference measures in the direction of the attempted preference reversal. If, for example, the FR response requirement was being increased in increments of two
in an attempt to reverse the subject's preference from the FR schedule to the VR 10, a subject was continued on, say, an FR 3 as long as the resulting preference measures continued to show a trend towards an increased preference for the VR schedule. Once the degree of preference with respect to the VR schedule remained the same or decreased, the FR requirement was then increased from three to five, and the FR 5 schedule was then presented for at least three sessions. This procedure was continued until the subject was reinforced for completing the VR choice at least 90% of the time for a particular session. The FR response requirement was then systematically decreased, with the FR response requirement being decreased by two if three trials had occurred at the previous value, and if there was no downward trending in terms of VR preference.

Condition five

As noted earlier, the two groups differed throughout the experiment with respect to the average length of the ITI. The average ITI value for group one was 90 seconds and for group two it was 30 seconds. Three subjects, one from group one and two from group two, were presented with an additional condition in which a preference reversal was conducted with a VR 10 schedule and step sizes of two for the FR schedule. This condition differed from the earlier VR 10 reversal in condition four in that the average ITI length during condition five was now 200 seconds as opposed to 90 or 30 seconds.
CHAPTER III

RESULTS

Conditions Two and Three

In the initial phases of the experiment, the FR and VR schedules were randomly assigned to either of the two available levers. These conditions are therefore referred to as randomized lever conditions. As can be noted from Table I, the first condition involved the presentation of a VR 5 schedule and an FR 1. After five sessions in this condition, the VR 5 schedule was change to a VR 10 so that the choice was now between a VR 10 and an FR 1. Once significant preference was demonstrated for the FR 1 schedule, it was systematically incremented by steps of two. Four of the subjects in the ITI = v30" group never displayed a significant preference for the FR 1 schedule despite prolonged exposure to this condition (28 sessions). The proportion of reinforced choice responses for the VR 10 schedule generally hovered between .20 and .40, never falling below the significant preference criterion of .10. The FR schedule for these subjects, therefore, was never increased. On the other hand, all of the subjects in the ITI = v90" group, as well as the remaining two subjects in the ITI = v30" group, eventually displayed significant preferences for the FR 1
Table I. This table includes the sequence of experimental conditions and some of the characteristics of those conditions. The FR step size refers to the amount which the FR schedule was increased or decreased as significant preference was reversed to the VR schedule and then back again. The value of the VR schedule for each condition is listed in the third column. The fourth column tells whether or not the available VR and FR schedules randomly appeared on either the right or left lever. The fifth column contains the number of forced choice trials and the number of free choice trials in each of the ten blocks of trials for an individual session. The column on the far right contains the ITI values for groups one and two for each of the conditions.
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schedule. The preference functions for those subjects who eventually demonstrated significant preferences in the VR 10/randomized lever condition (condition two) are plotted in Figures 3, 4, and 5.

The preference functions for Subjects 101 through 106 are contained in Figures 3 and 4. All of these subjects were in the ITI = v90" group. The preference functions for those two subjects from the ITI = v30" group who eventually demonstrated a significant preference for the FR 1 are contained in Figure 5. In these figures, the proportions of reinforced choice trials for the VR 10 schedule are plotted for each daily session for the VR 10/randomized lever condition as well as for condition three (40 choice trials) and the first part of condition four (VR 10/non-randomized lever). The value of the FR schedule for each session is listed below its respective plot along the abscissa. The linear step functions in each graph refer to the scale on the right hand side, and are intended to represent the degree of position preference for one side or the other on a session by session basis. More specifically, these step functions indicate the proportion of reinforced choice responses to the right hand lever.

One of the most noteworthy features of the results for condition two was the fact that significant preferences were never obtained for the VR 10 schedule, despite the attainment of some rather large FR ratio schedules from the systematic FR increases. As the FR schedule was increased for Subject 101, for example (uppermost graph, Figure 3), the preference for the VR shifted almost immediately to the range of indifference (.30 < \(x\) < .50). As the FR value was systematically increased to a value of 15, however, preference remained in the range of
Figure 3. This figure contains the proportion of selected VR free choices for condition two (VR 10), condition three (40 choice trials), and the first part of condition four (non-randomization) for Subjects 101, 102, and 103. The preference measures for all of the sessions are plotted. The numbers along the abscissa represent the FR values for the sessions plotted. The step functions represent the proportion of reinforced choice responses on the right hand lever, and are scaled on the ordinate on the right side of the graph.
Figure 4. This figure contains the proportion of selected VR free choices for condition two (VR 10), condition three (40 choice trials), and the first part of condition four (non-randomization) for Subjects 104, 105, and 106. The preference measures for all of the sessions are plotted. The numbers along the abscissa represent the FR values for the sessions plotted. The step functions represent the proportion of reinforced choice responses on the right hand lever, and are scaled on the ordinate on the right side of the graph.
Figure 5. This figure contains the proportion of selected VR free choices for condition two (VR 10), condition three (40 choice trials), and the first part of condition four (non-randomization) for Subjects 108 and 109. The preference measures for all of the sessions are plotted. The numbers along the abscissa represent the FR values for the sessions plotted. The step functions represent the proportion of reinforced choice responses on the right hand lever, and are scaled on the ordinate on the right side of the graph.
Figure 5

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indifference, never shifting to significant preference for the VR 10 schedule. Even larger FR values were eventually obtained for the rest of the subjects in Figures 3, 4, and 5, with the same failure to reverse preference.

Throughout this condition, only ten choice trials had been presented per session. In condition three, the number of choice trials was changed to forty in the hopes of obtaining more representative and stable preference measures. This change did not result in the completed reversal of preference for any of the subjects. Finally, the randomized lever conditions were discontinued, and instead, the VR and FR schedules were presented on their respective levers only. This change resulted in fairly immediate shifts in preference to the VR schedule for all of the subjects plotted in Figures 3, 4, and 5. It should also be noted that for those four subjects who never displayed the initial significance preference for the FR 1 schedule, their preferences shifted to significant levels for the FR 1 after the non-randomized lever condition was implemented. For all of the subjects, therefore, preference reached significant levels for the more favorable of the two schedules soon after the randomized lever conditions were discontinued.

The step functions for the subjects in Figures 3, 4, and 5 consistently illustrate an interesting aspect of the results. Significant position preferences were obtained for all of the subjects plotted in these figures except for Subjects 104 and 106. These significant position preferences were indicated by the fact that the step functions consistently remained either above .90 (right lever position preference) or below .10 (left lever position preference), while overall preference
for the VR schedule remained in the indifference region. The position preferences for all of the subjects became more pronounced as the FR values were systematically increased. During the latter sessions in condition two, therefore, subjects would respond only to one side during the choice trials. Since an equal number of VR and FR choices were presented to one side, VR preference measures would approximate .50. It is readily apparent, then, that the indifference with regards to the more favorable VR schedule in conditions two and three was largely the result of the tendency on the part of these subjects to constantly respond on just one side during the choice trials. Once the VR and FR schedules constantly remained on their respective sides in condition four, position preferences dissipated and in every case, exclusive choice responding was maintained on that side with the more favorable schedule.

Conditions Four and Five

Throughout the rest of the experiment, the non-randomized aspect of the procedure was maintained. After significant preferences were obtained for the more favorable of the schedules for all of the subjects, significant preferences reverted back to the FR schedule by changing the FR to a value of one for all of the subjects. The resulting preference measures for the rest of the experiment beginning at this point are contained in Figures 6 through 17.

Each of these figures present three aspects of the choice behavior for the individual subjects. The uppermost graph contains the proportion of reinforced choice responses for the VR schedule for the final
Figure 6. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 101. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 7. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 102. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 7

VR 10 vs VR 5

CHOICE VAR RATIO

FR VALUE

LATENCY IN SECONDS

INT in seconds

SUCCESSIVE FR CONDITIONS

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Figure 8. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 103. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 9. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 104. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 9
Figure 10. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 105. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 10

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Figure 11. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 106. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 11
Figure 12. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 107. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 12
Figure 13. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 108. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 14. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 109. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 14

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Figure 15. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 110. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR free choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 16. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 111. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR forced choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 16

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Figure 17. This figure contains several response measures with regards to the choice responding exhibited in conditions four and five for Subject 112. Only the values obtained from the last session at each successive FR value are plotted here. The top graph contains the proportion of free choice trials in which the subject selected and completed the VR option. FR values corresponding to those choice measures are represented by the step functions in the top graph, which are scaled on the right ordinate. The middle graph contains the median initial response latencies in seconds for both the FR and VR forced choice trials, while the bottom graph contains the median IRTs in seconds. The various key procedural characteristics of the different phases of condition four are noted on the top graph.
Figure 17
session in each FR schedule. The step functions for this graph no longer represent the proportion of reinforced choices for the right hand side, since these would simply coincide with the VR proportion values in the non-randomized lever conditions. Instead, the step function represents the value of the FR schedule for each VR preference plot, as scaled on the right hand ordinate. It should be noted that the size of the steps directly represents the increment sizes for the FR schedule in conditions four and five.

The middle graph for each subject contains the median latency for the initial choice response for both the FR and VR free choice trials on the final day of each FR value. The bottom graph contains the median inter-response times for free trial choice responding to both the FR and VR schedule for those sessions. The median temporal values were plotted in these figures as opposed to the arithmetic means because the median measures proved more representative of the total distribution of temporal measures when comparing the two. This is due to the fact that the medians were less sensitive to occasional unusually long delays and disruptions in free trial responding.

Figure 6 contains the preference measures for Subject 101 with regards to conditions four and five. Significant preferences were obtained for the VR 10 schedule when the FR schedule was also equal to ten, regardless of whether the increment sizes for the FR were ten or five. When the increment step size was two, significant VR preference was obtained once the FR schedule was increased to eight. The same was true for condition five (ITI = v200") where an FR value of eight was sufficient in reversing preference to the VR.
For the VR 5 schedule, relatively higher FR values were required before significant preferences were obtained for the VR schedule. With step sizes of two and one, however, the VR 5 schedule was definitely preferred to the FR 5.

The initial choice response latencies varied for both the VR and FR choices. They did seem to reflect, however, overall preference for the VR and FR schedules. For example, when preference for the VR schedule approached significant levels, the initial response latencies for FR choices were usually longer than for VR choices. When, on the other hand, significant preferences were obtained for the FR schedule, the VR response latencies were generally longer than for the FR schedule. This is especially well illustrated in condition five for Subject 101.

A close correspondence between the initial response latencies for the FR free choice responses, and the proportion of choice responses for the VR, was apparent for Subject 102 (Figure 7). During the VR 10 phase, each time significant preferences were obtained for the VR option, the FR initial response latencies lengthened considerably as well. This was also true in the VR 5 condition, for all of the preference reversals except the second one, where FR step sizes of five were employed. The initial response latencies for the VR free choices also fluctuated, to a lesser extent, though in a manner which did not correspond to choice responding in any obvious way.

During the VR 10 phase for Subject 103 (Figure 8), the initial response latencies for the FR free choices increased as the subject's preference for the VR condition increased to significant levels. The VR initial response latencies, however, fluctuated in a nonsystematic
manner, becoming especially pronounced during the VR 5 phase. Such fluctuations were also apparent for the initial response latencies for the forced choice VR trials, though they are not plotted here. They were, however, not nearly as pronounced as the free choice responses.

In the case of Subject 104 (Figure 9), both the VR and FR initial response latencies varied to approximately the same extent. Furthermore, the latencies for both schedules corresponded to the amount of preference for the VR choice. When, for example, significant preference was obtained for the FR choice, the VR initial response latencies increased while the FR response latencies decreased to the point where they were shorter than the VR ones. This is especially apparent in the latter part of the VR 10 phase.

At times, the FR initial response latencies for Subject 105 (Figure 10) corresponded to VR preference, but this correspondence was by no means consistent. The relationship between the two was especially erratic during the VR 5 phase, with an increasing variability of FR initial choice latencies being apparent as well.

For Subject 106 (Figure 11), the FR initial response latencies corresponded to VR preference in a clear-cut manner for the major portion of both the VR 10 and VR 5 phases, as well as for Subject 107 (Figure 12). In the case of Subject 107, each time significant preference for the VR choice was obtained, the FR initial response latencies increased. The VR initial response latencies, on the other hand, remained fairly consistent throughout the condition.

Subject 108 (Figure 13) was an altogether different story. The initial response latencies for the VR choice responses remained
consistently above those of the FR choice responses, regardless of the shifting preferences for the VR choice during the initial VR 10 phase. In the second phase, the ITI was increased to v200" while maintaining the VR choice at a value of 10. During this phase, initial response latencies became extremely long and erratic.

Interestingly enough, for Subject 109 (Figure 14), the IRTs for the VR choice responses fluctuated much more than the initial response latencies, though the IRTs did not seem to correspond to the VR preference measures at all. With regards to the initial response latencies, they remained fairly comparable for both VR and FR choice responding throughout condition four.

In the case of Subject 110 (Figure 15), significant preferences for the VR choice were accompanied by slightly increasing shifts in the initial response latencies for VR choice responding. The IRTs for the FR choice responding increased dramatically throughout the VR 5 phase.

For most of the subjects, the temporal measures from free choice responding were plotted as opposed to forced choice. This was because an initial comparison between the temporal functions from these two sources revealed that the proportion of VR choices corresponded more closely to the free choice temporal measures than to the forced choice. For Subjects 111 and 112, though, this was not true. The forced choice latency measures for these subjects corresponded more closely to the overall preference measures than did the free choice ones. In the figures for these subjects, therefore (Figures 16 and 17), the initial response latencies and IRTs for the forced choice trials are plotted.
For Subject 111, the initial response latencies remained stable throughout condition four. Occasionally, there were slight upward shifts in the initial response latencies for the VR forced choice responses which corresponded remarkably well to significant VR preferences. The remarkably close proximity of both the FR and VR initial response latencies was probably due to the fact that both approached the minimum latency measures apparent for any subject in this experiment, which perhaps represented the minimum latency that the subjects were capable of.

The same type of response latency measures were apparent for the forced trial responding of Subject 112. With this subject, the increases in the FR initial response latencies were much greater, although as was the case with Subject 111, they corresponded to the significant VR preferences obtained. As can be noted in the uppermost graph of Figure 17, the FR value for Subject 112 was eventually increased to 19 for the portion of the VR 10 procedure in which the step size was two. Even with the presentation of such a large FR option, this subject did not exhibit any increase in preference for the VR schedule. The FR schedule, therefore, was returned to a value of one and a larger increment size was used (step size = ten). This procedural variation was successful in obtaining a preference reversal, and when the step size of two was once again attempted, the subject's VR preference did eventually attain significance.

The median IRT plots for the majority of the subjects did not correspond well with the preference measures. Neither did they seem to correspond to the absolute FR or VR values. Additional analysis
of the response patterns revealed that once the subjects began responding on one of the schedules, they generally maintained a consistent rate until the schedule was completed. Exceptions to this were clearly apparent only for Subjects 108 and 110. In these cases, responding was at times erratic, possibly as a result of occasional equipment failure with regards to the dipper apparatus for Subject 108. It should also be noted that for most of the subjects, the IRTs for the FR schedule were consistently smaller than for the VR throughout conditions four and five (Subjects 103, 104, 106, 108, 109, 112).

While the above figures illustrate the susceptibility of free choice responding to preference reversals within the discrete trial procedure employed, they do not readily answer the following basic question. Which is more preferred, the VR or FR, given equal valued schedules? In order to answer this question, an FR value must be determined which will represent that point at which preference measures indicated complete indifference between that FR value and the standard VR schedules tested.

Figure 18 demonstrates the manner in which the FR equivalence value for a particular VR schedule was determined for each animal. Plotted here are the proportions of VR preference for the ascending and descending series of FR values. During the ascending FR series, the subject's preference was eventually switched from significant preference for the FR schedule \((p \leq .10)\) to significant preference for the VR schedule \((p \geq .90)\). During the descending series of FR values, preference was reverted back to the FR schedule. The initial step in determining the FR equivalence was the plotting of a linear function.
Figure 18. This figure demonstrates the manner in which the FR equivalence value for a particular VR schedule was determined for each animal. Each point on the graph represents the proportion of free choice trials in which the subject completed the VR schedule. Plotted here is the VR 5 (step size of one) phase for Subject 107. The initial step in determining the FR equivalence was the plotting of a linear function for both the ascending and descending series. They are pictured here as lines A and B, respectively. Line A was arrived at by simply connecting the last plot where significant preference was apparent for the FR schedule, to the first plot in which significant preference was apparent for the VR. Line B was arrived at in a similar manner, only the last point of significant preference for the VR was connected to the first point of significant preference for the FR. After these lines were drawn, vertical vectors (lines C and D) were inserted at those points where the ascending and descending preference functions crossed the point of indifference (p = .50). The two FR values at the point where each vector intercepted the abscissa were averaged in order to arrive at the FR equivalence value for the VR 5.
Figure 18

CHOICE vs. VR

A

B

C

D

FR VALUE

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for both the ascending and descending series. They are pictured here as lines A and B respectively. Line A was arrived at by simply connecting the last plot where significant preference was apparent for the FR schedule, to the first plot in which significant preference was apparent for the VR. Line B was arrived at in a similar manner, only the last point of significant preference for the VR was connected to the first point of significant preference for the FR. After these lines were drawn, vertical vectors (lines C and D) were inserted at those points where the ascending and descending preference functions crossed the point of indifference (p = .50). The two FR values at the point where each vector intercepted the abscissa were averaged in order to arrive at the FR equivalence value for the particular VR schedule. In this example, FR 6 (ascending series) and FR 4 (descending series) were averaged in order to arrive at an FR equivalency of 5.00 for the VR 5 condition.

As can be noted in Table II, in every case the ascending FR equivalence value was greater than the descending one. The averages of these equivalence measures are plotted in Figure 19. The primarily solid lines in Figure 19 represent where the indifference functions (horizontal dashed lines) would fall if equal valued FR and VR schedules resulted in equal preference. As can easily be seen in this figure, the indifference levels for each of the ITI groups fall beneath the primarily solid horizontal lines in both the VR 5 and the VR 10 conditions. In the ITI = v30" group, for example, the average FR equivalent for the VR 5 condition was 4.63. This meant that given a choice between equal valued FR and VR schedules (FR 5 versus VR 5), the animals generally
Table II. This table contains a list of the FR equivalency values for each animal for the VR 5 (FR increments of one) and VR 10 (FR increments of two) conditions. Figure 18 exemplifies the manner in which these values were arrived at. Also included are the step values signifying the amount by which the FR schedule was incremented and decremented (column 4), the ascending and descending indifference values (columns 3 and 4), and the group equivalency means (column 7). The three columns on the far right contain psychophysically based measures with regards to the amount of change necessary in the response requirement in order for preference to be reversed. The numbers in column 9 were arrived at by simply subtracting the descending point of indifference from the ascending one. The values in column 9 were divided by the value of the VR schedule (column 2) in order to arrive at the numbers in column 10. Column 11 simply contains the group averages of the various ITI values and VR conditions. Subjects are grouped in each condition according to their ITI values.
### Table II

**FR Equivalencies**

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<td>4</td>
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Figure 19. This figure contains the plots of the FR equivalency measures for the VR 5 (increments of one) and the VR 10 (increments of two) conditions. The numbers which correspond to these plots are listed in Table II. A normal logarithmic scale of the FR values is plotted along the ordinate, whereas each individual animal is labeled for the two VR conditions along the abscissa. Subjects are also grouped along the abscissa according to the ITI value for that condition. The points plotted here were determined from the average between those points representing indifference between the FR and VR (p(VR) = .50) for the ascending and descending preference functions in each condition as described in the caption for Figure 18. The horizontal dashed lines represent the arithmetic mean of the FR equivalents for each ITI value in either the VR 5 or VR 10 conditions. The horizontal lines with longer dashes represent that point on the ordinate where the value of the FR schedule equals that of the VR. For the VR 5 condition, for example, the longer dashed line falls at FR 5, whereas the line for the VR 10 condition falls on the FR 10.
preferred the VR to the FR. This was the case for all of the ITI groups in both conditions. The greatest absolute difference in preference between the VR and FR schedules was for the ITI = v200" group in the VR 10 condition. Here, the average FR equivalent to the VR 10 was 6.33, as opposed to 6.83 and 8.17 for the ITI v30" and v90", respectively.

In all, there appeared to be no conclusive systematic relationship between the value of the ITI and the degree of preference exhibited for the VR as opposed to the FR schedules. For the VR 5 condition, the group with the longer ITI exhibited the greater amount of preference for the VR as signified by the value of the average FR equivalent. Likewise in the VR 10 condition, the group with the longest ITI value (ITI = v200") demonstrated the greatest amount of preference for the VR schedule. On the other hand, there was a large degree of overlap between the ITI = v30" group and the ITI = v90" group. Various statistical analyses of the group differences proved insignificant in every case, preventing one from definitely concluding that longer ITI values result in greater differential preference for the VR schedule (see Appendix I). It should also be noted that the most extreme FR equivalency measure apparent in the present study was that of Subject 112. As can be noted from Figure 17, this subject displayed a rather marked insensitivity to systematic FR increases within the VR 10 (increments of two) condition. The equivalency measures of the subject, therefore, should be viewed as suspect and not seriously considered when evaluating group differences.

Each of the subjects in the ITI = v200" group for VR 10 had experienced another ITI value in this condition as well (Subject 101,
ITI = v90"; Subjects 108 and 111, ITI = v30""). Two of these subjects, 108 and 111, showed less preference for the VR schedule when the value of the ITI was increased (see Table II). Subject 101 demonstrated slightly greater VR preference under the longer ITI condition.

The three columns on the far right in Table II contain psychophysically based measures which represent the amount of absolute change necessary in the FR response requirement in order to a significant change to occur in the subject's preference. The Weber ratios in column 10 and the means for those ratios in column 11 remained fairly consistent across the various standard VR values tested.

In order to evaluate the general form of the latency and IRT distributions, the quartile measures were computed for every session throughout the experiment. The initial response latency distributions were for the most part positively skewed, while the IRT distributions were more symmetrical. The form of the distribution did not seem to vary in any systematic manner with regards to the various parametric variations in the present experiment.

Figure 20 shows how sharply the preferences shifted as a function of the FR step size. In the VR 5 condition, for example, the initial reversals in preference were accomplished using FR step sizes of ten. After significant preference had been reversed to the VR schedule and then back to the FR, preference was once again reversed, only this time using step sizes of five as opposed to ten. One might expect preference to shift more rapidly with the larger step sizes. This is in fact what occurred for most of the subjects. For four of the six subjects in the ITI = v90" group, the slopes of the preference shifts were steeper when
Figure 20. This figure contains the ascending preference functions for the VR 5 condition where the FR schedule was incremented by steps of ten (solid slopes), and then by increments of five (dashed slopes). The slopes were arrived at by connecting a line between the proportion value for FR 1 to the initial significant preference proportion value (p ≥ .90). The FR value for each successive session is listed on the abscissa. The subject number for each pair of slopes is listed above them; the upper set of functions is for those subjects in the ITI = v90" group, while the lower set is for the ITI = v30" group.
the step size was ten as opposed to five. The same was true for three of the four subjects in the ITI = v30" group. Only one subject demonstrated a steeper preference slope for the step size of five—Subject III.

One reason why different ITI values were tested within this discrete trial choice procedure was due to the possibility of ITI length having an effect on the sensitivity of the subject's responding to differences between the FR and VR schedules. If, for example, a shorter ITI increased sensitivity to schedule differences, one would expect the ITI = v30" group to display steeper slopes in its preference functions than the ITI = v90" group. This is not the case, however, when comparing the slope functions between the two groups, where there appear to be no consistent differences. A comparison by the author of the slope functions for the VR 10 condition (FR increments of ten and five) likewise revealed no clear-cut difference between them with respect to overall ITI length.

One question which has been previously asked in choice experiments is the extent to which there is any pattern of alternation between levers or keys on successive choice responses (Silberberg, Hamilton, Ziriax, and Casey, 1978). Data with regards to this question is contained in Table III. The numbers in column 1, for example, represent the probability of a left lever free choice given that the immediately preceding forced choice trial was presented on the left lever. Likewise, the numbers in column 2 represent the probability of a left lever free choice given that the immediately preceding forced choice was on the right lever. Earlier studies have suggested that there is a tendency on the part of
Table III. Included here are the conditional probabilities of a particular free choice given the type of immediately preceding forced choice trial. The numbers presented for each animal are averages representing the entire VR 10 (step size of two) condition. Only the initial free choice for each block of free choices was used in arriving at the probabilities. These probabilities were calculated by dividing the frequency of occurrence of a particular free choice which was preceded by one type of forced choice, by the total number of those free choices. The numbers in column 1, for example, were arrived at by taking the number of left lever free choices preceded by a left lever forced choice trial, and dividing that by the total number of left lever choices. Likewise, column 2 was calculated by dividing the left lever free choices preceded by a right lever forced choice trial by the total number of left lever free choices. Column 5 tells which schedule was on which lever for this condition. For Subject 101, for example, the VR schedule was presented on the left lever and the FR on the right.
### Table III

**Conditional Probabilities**

<table>
<thead>
<tr>
<th>Subject</th>
<th>( p(\text{LC/L}) )</th>
<th>( p(\text{LC/R}) )</th>
<th>( p(\text{RC/R}) )</th>
<th>( p(\text{RC/L}) )</th>
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subjects to alternate between levers on successive choices (Silberberg et al., 1978; Stephens, 1980). Should this be the case in the present study, one would expect the conditional probability for one type of free choice to be greater when it is preceded by a forced choice on the other lever as opposed to a forced choice on the same lever. When contrasting columns 1 and 2, and columns 3 and 4, it is evident that the probabilities between each of these two sets of columns are comparable. The fact that the probability of a choice response to a particular side remains the same regardless of which side the previous choice response was presented on suggests that there is no obvious tendency on the part of the subjects to alternate between levers on successive choices.

Stephens (1980) noted a tendency to alternate between levers on the initial free choice trial, whereas in the present study, subjects did not display such a tendency. This discrepancy can be accounted for in terms of procedural differences. In the Stephens study, the successive forced choice trials within a block were regularly alternated between levers, making it likely that subjects would simply continue this pattern of alternation with the free choice trial following the block of forced choice trials. In the present study, on the other hand, the side that was active for a particular forced choice trial was always randomly determined.

Table IV includes the conditional probabilities of a particular free choice given the type of choice on the immediately preceding free choice trial. Only the within-block sequential dependencies for free choice responding were examined here. The conditional probability measures, therefore, are based on the last three of the four free
Table IV. Included here are the conditional probabilities of a particular free choice given the type of choice on the immediately preceding free choice trial. The numbers presented for each animal are averages representing the entire VR 10 (step size of two) condition. These probabilities were calculated by dividing the frequency of occurrence of a particular free choice which was preceded by one type of free choice, by the total number of those free choices. The numbers in column 1, for example, were arrived at by taking the number of left lever free choices preceded by a left lever free choice on the preceding trial, and dividing that by the total number of left lever choices. Likewise, column 2 was calculated by dividing the left lever free choices preceded by a right lever free choice by the total number of left lever free choices. Column 5 tells which schedule was on which lever for this condition. For Subject 101, for example, the VR schedule was presented on the left lever and the FR on the right.
Table IV

Conditional Probabilities

<table>
<thead>
<tr>
<th>Subject</th>
<th>p(LC/LC)</th>
<th>p(LC/RC)</th>
<th>p(RC/RC)</th>
<th>p(RC/LC)</th>
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choice trials for each block. A comparison of columns 1 and 2 reveals a tendency on the part of the subjects to continue choosing the side which had previously been chosen in the free choice trial. The same conclusion can be reached when comparing the conditional probabilities in columns 3 and 4. The fact that subjects continued choosing the previously chosen schedule within a block of trials could well account for the perseveration (errors of habituation) which were apparent at the molar level.

An additional aspect of the data to be considered here relates to the "runs" and "pauses" in ratio responding in the present procedure. Though cumulative records are a convenient way to do this, another means of representing these characteristics is by plotting the mean value of successive IRTs for both VR and FR responding throughout the entire session. These values are plotted in Figure 21 for three subjects: 101, 102, and 108. A comprehensive analysis revealed that these subjects were representative of both groups as a whole. As can be seen from this figure, all three subjects demonstrated relatively longer IRTs (or pauses) towards the middle of the VR distribution. Subjects 102 and 108 displayed relatively longer IRTs after the first and second VR responses as well (successive IRT 1 and 2). The IRTs for ratio responding, on the other hand, remain fairly stable except for the initial IRT of Subject 108. This characteristic of VR responding could very well account for the fact that for most of the subjects, the median FR IRTs were consistently smaller than the corresponding VR IRTs (see Figures 6 through 17).
Figure 21. The forced choice mean IRTs for the final session of each FR value in the VR 10 (step size of two) condition are plotted for Subjects 101, 102, and 108. The VR 10 was comprised of component values of 1, 2, 3, 5, 6, 8, 11, 14, 19, and 30. Since occasionally the animals responded to a component of 30 in the VR schedule, there was a maximum of 29 IRTs possible. Also plotted here are the IRTs for FR forced choice responding.
Figure 21

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As was noted above, longer IRTs were apparent towards the middle of the distribution of successive IRT averages. It was thought that perhaps these longer IRTs were due to the fact that animals occasionally stopped responding on the active lever and emitted a burst of responses on the deactivated lever during a free choice trial. Closer examination of the data, however, revealed that such interruptions in VR responding occurred very infrequently, especially in the latter phases of the experiment. Whenever VR responding was interrupted by a burst of responses on the deactivated FR lever, the interruption occurred after the first or second VR response. Such "changeovers", then, could not account for the longer IRTs in the middle of the sequential range of IRTs.

Finally, the amount of responding which occurred throughout the ITI was carefully examined for any systematic trends. Two consistent features of ITI responding were noted for all of the subjects. First of all, the overall amount of ITI responding for each of the subjects systematically decreased throughout the entire experiment. Whereas initially some subjects emitted literally hundreds of ITI responses; towards the end of the experiment, most subjects emitted only four or five ITI responses for an entire session. The second most noteworthy feature of the ITI data was the fact that for most of the subjects, the majority of ITI responses consistently occurred to a particular side. Given this characteristic, it was thought that perhaps the proportion of ITI responding to a particular side could be used as a sensitive index of position bias on the part of the subjects. In fact, when the FR equivalencies were plotted as a function of the ratio of ITI responses on the VR lever, a clear correlation between the two was apparent (see...
Figure 22). This correlation was significant at the .05 level when using the Pearson Product-Moment correlation test with a t-score transformation (Weinberg and Schumaker, 1976). When examining Figure 22, however, it is apparent that even when the preference measures are corrected for possible position bias, most of the FR equivalency measures are located well below the linear function representing indifference between equal valued FR and VR schedules.
Figure 22. The FR equivalencies listed in column 7 of Table II are plotted here as a function of the corresponding ITI ratios. The filled circles represent the equivalencies for the VR 5 condition and are scaled according to the top row of values along the abscissa. The open circles represent the equivalencies for the VR 10 conditions and are scaled according to the bottom row of values along the abscissa. The ITI ratio for a particular equivalency was arrived at by finding the average number of ITI responses per session on both the VR and FR levers for that condition. The VR value was then divided by the FR value in order to obtain the ITI ratio. The dashed line represents the least squares fit for the obtained plots. The formula for this linear function is in the upper right hand corner of the graph. The solid line represents the location of the linear plot given no preference for the VR over the FR schedule. The arrow shows the point of origin for this line, where the ITI ratio is equal to 1.0 (indicating no bias) and the FR equivalency is equal to the value of the VR schedule. As can be noted from the graph, most of the ITI/equivalency plots fall below the solid line, indicating a preference for the VR schedule over the FR even when the equivalencies are corrected for response bias.
CHAPTER IV

DISCUSSION

The following is a brief summary of the most noteworthy features of the results. Throughout the randomized lever conditions (conditions two and three), four of the six animals in group two never displayed significant preferences for the FR schedule when given a choice between FR 1 and VR 10. All of the subjects in group one eventually displayed such preferences. This is especially interesting in light of the fact that the only difference between the two groups at this point of the experiment was the value of the ITI. For group one, a variable ITI of 90" was employed whereas for group two, a variable ITI of 30" was used.

In those cases where a significant preference was eventually displayed for the FR 1 schedule, the value of the FR schedule was then systematically increased in order to reverse the significant preference from the FR to the VR schedule. Though such increases did succeed in disrupting the significant preferences for the FR schedule, they did not result in a complete reversal of preference to the VR. Instead, the majority of the subjects eventually demonstrated strong position preferences which were not eliminated until the non-randomized lever conditions were instituted.

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As a result of the preference reversals obtained in the non-randomized lever conditions, FR equivalencies were obtained for each animal for various VR schedules. The values of these FR equivalencies were smaller than that of the VR schedules in 20 out of 25 cases, indicating a rather clear-cut preference for the VR as opposed to an equal valued FR schedule. The extent to which the VR was preferred over the FR did not seem to be related to the ITI value employed for a particular group. As significant VR preferences were obtained throughout the various conditions, there seemed to be a corresponding increase in the initial response latencies for the FR choices. This relationship was generally apparent in 10 of the 12 subjects.

With regards to the run rate of VR responding in the present study, the IRTs appeared to be relatively longer after the first and second responses and towards the middle of the successive IRT sequence as well. Sherman and Thomas (1968) noted that oftentimes their rats exhibited a break in VR responding which occurred after the first response. These pauses disappeared when Sherman and Thomas eliminated the FR 1 component from their VR schedule. In the present study, it is not unlikely that the different length IRTs across successive VR responses are related to the value of the components making up the VR 10 schedule (FR 1, 2, 3, 5, 6, 8, 11, 14, 19, 30). Further testing with different types of distributions is necessary, however, before a more definitive statement can be made regarding the relationship between the components making up the VR and successive VR IRTs.

Several additional aspects of the above mentioned results also merit further discussion. Of particular interest is the fact that
while the value of the ITI did not seem to influence the overall preference measures in any systematic manner, it did result in a differential acquisition of significant preferences during the randomized lever conditions. This was witnessed by the fact that all of the subjects in the ITI = v90" group acquired significant preferences for the more favorable FR 1 choice as opposed to only two of the six subjects in the ITI = v30" group. These differences, however, dissipated once the non-randomized lever conditions were implemented. Other discrete trial procedures have noted similar effects with regards to ITI length and performance on difficult learning tasks. For example, poorer acquisition was apparent with shorter inter-trial intervals in a matching to sample task with monkeys (Jackson and Pegram, 1970; Jarrard and Moise, 1970). In the present study, either a flashing or steady signal light indicated which schedule was currently available on that lever. Rats have been known to have difficulty with similar types of visual discriminations in the past. Perhaps a different stimulus modality, such as an auditory one, would have been more appropriate in signalling the available schedules, and served to eliminate the acquisition deficits related to overall ITI length as well.

The position preferences obtained during the randomized lever condition were also of interest. Position preferences have often been noted in various types of procedures involving difficult discriminations (see Boivin, 1980, for a more thorough review). It is possible that the difficulty of the signal light discriminations in conjunction with gradual increments in the FR response requirements served to make position based responding likely. As mentioned earlier, one means of
facilitating the acquisition of difficult discriminations is to employ more salient stimuli as $S^D$'s for the various components. One might also make the occurrence of position preferences less likely by using more discriminable step sizes when systematically changing the FR response requirements. This procedural variation, along with the consistent presentation of the FR and VR schedules on their respective levers, served to facilitate the discrimination between the two schedules and eliminate position based responding altogether. The discriminability of the choice options, therefore, becomes an important consideration, especially in discrete trial choice procedures.

As noted earlier, increases in the initial response latencies of the FR choices corresponded fairly well to the occurrence of significant VR preferences. A correspondence of this sort has also been noted in another study employing a similar discrete trial choice procedure with ratio schedules (Stephens, 1980). Since the FR schedule was usually increased to accomplish such preferences, it can also be stated that the increases in the FR initial response latencies were as much related to increasing FR response requirements as to any shift in, for example, VR preference. The fact that in the present study, the VR initial response latencies remained static for only some of the subjects (101, 104, 107, 108, 111, 112) despite continual shifts in the amount of VR preference, would not completely support such a view. This does not rule out, however, the importance of the absolute FR values in determining the form of the initial FR response latencies, latencies which one might be tempted to use as an additional measure of preference.

In previous ongoing FR schedules of reinforcement, for example, the
length of the post-reinforcement pause has been found to be directly related to the overall size of the FR schedule (Felton and Lyon, 1966; Mintz, Maurer, and Gofseyeff, 1967). In the Mintz et al. study, a cue which corresponded to the length of the following ratio run directly controlled the duration of the PRPs (post-reinforcement pauses) in pigeons. The larger the ratio represented by the cue, the longer the pause. Since the post-reinforcement pause of ongoing schedules could just as easily be conceptualized as a pre-responding pause, such measures could be considered analogous to the discrete trial initial response latencies in the present study. When considered in this manner, it is not difficult to see why the FR initial response latency increases corresponded well to systematic FR increases and to the coincidental shifts in VR preference, even in those cases where VR initial response latencies also changed systematically.

One of the major purposes for the present study was to evaluate the efficacy of the method of limits discrete trial choice procedure in evaluating preference between different response requirements. As mentioned earlier, Fantino (1969) found that the duration of the initial links in concurrent chain schedules was an important factor in determining the degree to which the subjects preferred one schedule over another. The longer the initial links, the greater the indifference between the two. The ITI did not influence responding in an analogous manner in the present discrete trial procedure, since overall ITI length did not seem to influence preference in any significant way. Should further research indicate that this is definitely the case, this feature
would serve as additional evidence attesting to the advantage of using discrete trial choice procedures in evaluating preference.

In the method of limits as commonly employed in the area of psychophysics, the experimenter presents two stimuli and increases or decreases one of them until the subject reports that he detects a difference. Fechner originally recommended starting the variable stimulus (comparison) at a value which was clearly discriminable from the standard stimulus, and then changing the value of the variable stimulus such that it became less and less discriminable from the standard one over successive trials. Those points at which the subject can no longer detect a difference between the two was referred to as the just noticeable difference (JND).

When measuring the sensitivity of a subject's preference to various differential consequences, estimates of sensitivity which were analogous to the JND included the "just noticeable" learning, and the reinforcement difference limen (RDL) of Campbell (1955, 1956, 1958) and Tarpy (1969 a, 1969 b), respectively. These measures were based on the absolute physical difference of the stimulus consequence necessary in order to produce at least a 75% preference for the more favorable response. The 75% criterion, though, is admittedly an arbitrary one (Campbell, 1955). In the present study, the "just reinforcing" difference measures contained in Table II were based on the absolute difference in the response requirement necessary in order to reverse preference from 50% on the ascending FR series, to 50% on the descending one. The results from these measures showed that absolute difference in response requirement necessary to complete the preference reversal
increased as the VR standard increased. The Weber ratios also remained fairly constant. Herrnstein and Loveland (1975) noted a similar type of result when measuring preference between concurrently available VR schedules of reinforcement. When the two ratio schedules summed to a value of approximately 60, "exclusive preference was attained with a smaller relative difference between the two... than when the sum was 120".

These results are in agreement with a similar type of study conducted by Tarpy (1969b), in which he attempted to find the RDL for different amounts of force requirement for lever pressing in an escape procedure. Tarpy noted that a "proportionally smaller difference in effort is required to produce differential leaning in the middle ranges than at the extreme points of the function". He also found that these proportional values were, for the most part, in accordance with Weber's law.

In both the Campbell and Tarpy studies, each different comparison was administered to a separate group of subjects. One could therefore classify their procedures as being based on the method of constant stimuli in psychophysics (Campbell, 1955). The present study differed from the above in that a within subject design was used with the method of limits. One problem which has been consistently noted with this method is the fact that oftentimes different JNDs will be obtained, depending on whether the variable stimulus is initially discriminably higher than or discriminably lower than the standard stimulus. This is because of a tendency on the part of the subject to continue repeating the same choice response that the animal has been consistently
emitting, and incidentally, being reinforced for. Such tendencies have commonly been referred to as errors of habituation (Gescheider, 1976), and can serve to falsely increase ascending and descending thresholds. Such tendencies are apparent in the present procedure as well. Note, for example, the fact that the FR equivalence for the ascending series of FR values is higher than the FR equivalence for the descending series in every case in Table II. In short, when the subjects had been consistently choosing and being reinforced on the FR lever, the FR schedule had to be increased significantly in order to get them to switch over to the VR choice. Likewise, when the subjects were displaying preferences for the VR choice, the FR had to be diminished, oftentimes to a value of one, before significant FR preferences were once again obtained. Such perseveration on the currently preferred schedule might easily be considered to be similar to the errors of habituation commonly observed in psychophysical procedures. Furthermore, such perseverative tendencies could be accounted for in terms of the sequential dependencies of choice responding at the more molecular level (see Table IV).

Baum (1970) has noted similar tendencies in concurrent schedules of reinforcement, where subjects persist in a particular preferred component even though the favorability of that component has been diminished. He has referred to this phenomenon as the hysteresis effect.

Gescheider suggests that one means of accounting for such tendencies is to alternate the direction of the variable stimulus change on successive trials. For one trial, the comparison would be greater than
the standard stimulus and would be decreased in order to obtain the JND. The next trial would consist initially of the comparison being smaller in value than the standard, with systematic increases being presented. The JNDs of a number of such trials would then be averaged in order to obtain the differential threshold. In the present study, the FR equivalencies presented in Figure 19 were in fact averages of the ascending and descending FR equivalence values. While such averages may adequately account for the perseverance apparent in the subject's preferences, there are those who are uncomfortable with equivalence measures which are not directly based on the subject's choice behavior.

One means of procedurally eliminating perseverance in discrete trial procedures of the type employed here would be to use the method of constant stimuli, only with a within subject design instead of a between group design. In this procedure, the various values of the comparison stimuli are randomly selected from a predetermined distribution. Each comparison is then compared with the standard stimulus. In the present study, an example of a method of constant stimuli would be the comparison of a VR 5 to each of ten FR schedules ranging in values from one to ten, with the order of the FR comparisons being randomly selected. Such a procedure might well allow for preference functions which are "untainted" by errors of habituation or hysteresis.

The threshold tracking or titration procedure is another method which could efficiently be employed with a discrete trial procedure, and reduce the likelihood of errors of habituation (Blough and Blough, 1977).
Lea (1976) has in fact already attempted an application of the titration method. In this study, an attempt was made to find the range of indifference between various pairs of periodic ratio and interval schedules of reinforcement. Two operative keys were usually available to pigeons. The schedule available on one key, the standard key, remained unchanged throughout the session. The schedule on the comparison key was changed after the occurrence of each reinforcement. If the previous reinforcement had been presented for completing the response requirement on the standard key, then the schedule on the comparison key was changed so as to make it slightly more favorable by lowering the response requirement in the case of ratio schedules of reinforcement. If, however, reinforcement had been presented for completing the schedule on the comparison key, then the comparison schedule was made slightly less favorable. Once the schedules again became available immediately after each reinforcement, an initial peck to either key made the other key inoperative and forced the bird to complete the requirement for that schedule only. This procedure did yield reasonable results, in that the indifference level arrived at for pairs of FR schedules was usually at that point where the FR values were equal. In addition, its measures of indifference were totally dependent on active responding on the part of the birds, making the choice measures more viable.

In summary, the discrete trial choice procedure does have definite advantages over other types of choice procedures used to evaluate preference. Unlike concurrent and concurrent chain schedules, the choice measures are completely independent of any type of changeover responding.
The preference measures also appear to be relatively independent of the overall delay in reinforcement (ITI length), a characteristic which Fantino did not observe with concurrent chain schedules. A more definitive statement regarding this feature of discrete trial choice procedures, however, should await additional testing with other ITI values. In the discrete trial procedure, other response measures such as the initial response latencies of choice responses seem to hold promise as additional measures of response preference. Further research is necessary with regards to this measure as well. This is in order that the relationship between the initial response latency and the absolute response requirement, independent of preference, might be better understood. The present study has also pointed out that the degree of discriminability between the choice options is an important consideration in discrete trial choice procedures. The way in which the comparisons are varied in terms of psychophysical methodology is an important consideration as well. Perseveration tendencies which are likely in the method of limits can doubtless color one's choice functions and lead to preference measures which have the disadvantage of being based on averages, thus being once removed from the subject's actual choice behavior. The titration method and the method of constant stimuli are likely alternatives which have not been found to encourage perseveration on a response option to as great an extent. These procedures have proven very useful in evaluating the sensitivity of sensory functions, and certainly merit strong consideration in the evaluation of response outcome preferences as well.
In conclusion, the fuller evaluation of discrete trial procedures within the framework of psychophysical methodology await the testing of the procedures along a number of different parametric variations. Only with further testing can it be known whether procedures of this sort can once and for all provide the long-awaited, all-encompassing framework for evaluating preference in general.
APPENDIX I

Results of Statistical Analysis

I. Split plot design for subjects undergoing both VR 5 and VR 10
SPF - 2.2 design

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>d.f.</th>
<th>MS</th>
<th>F</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (ITI)</td>
<td>1.10</td>
<td>1</td>
<td>1.10</td>
<td>.17</td>
<td>not sig.</td>
</tr>
<tr>
<td>Subj. w. groups</td>
<td>52.2</td>
<td>8</td>
<td>6.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (VR)</td>
<td>80.0</td>
<td>1</td>
<td>80.00</td>
<td>20.05</td>
<td>p &lt; .01</td>
</tr>
<tr>
<td>AB</td>
<td>2.55</td>
<td>1</td>
<td>2.55</td>
<td>.64</td>
<td>not sig.</td>
</tr>
<tr>
<td>B x subj. w. groups</td>
<td>31.95</td>
<td>8</td>
<td>3.99</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

II. t test for ITI = v30" and ITI = v90" in VR 5

\[ t = 1.29 \]
\[ d.f. = 8 \]
Decision: not sig.

III. Simple ANOVA for ITI = v30", v90", and v200" in VR 10

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>d.f.</th>
<th>MS</th>
<th>F</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>16.23</td>
<td>2</td>
<td>8.115</td>
<td>.525</td>
<td>not sig.</td>
</tr>
<tr>
<td>Within</td>
<td>185.50</td>
<td>12</td>
<td>15.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>201.73</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion: Statistically, there are no significant differences in the obtained FR equivalency measures between different ITI valued groups.


