RESISTANCE TO CHANGE IN CONCURRENT SCHEDULES : A FUNCTION OF STIMULUS PRESENTATION AND LOCAL RATES OF REINFORCEMENT?

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Abstract

Resistance to change was formulated as an alternative to the measurement of response strength in terms of response rate changes in the presence or absence of reinforcement. In order to replace response rate as a measure of response strength resistance to change must meet certain criteria. As a measure of the strength of responding, resistance to change must be shown to fluctuate with the accepted strengthening force of that behaviour - reinforcement. That is, resistance to disruption should be greater in environments providing greater reinforcement. Studies with multiple schedules have reliably produced data that indicate resistance to change is related to the rate of reinforcement in a component. This research has further indicated that resistance to change is a function of stimulus-reinforcer contingencies. However, concurrent schedule performance has thus far not conformed to the expected principles of resistance to change, and has not produced the same results that are shown in multiple schedule experimentation. That is, studies with concurrent VI VI schedules show no between-component resistance differential.

This study asks and attempts to answer two questions relating to possible causes of the different resistance to change results between multiple and concurrent schedules. These questions are based on features that differentiate the two different schedule types.

(1) Is the difference in stimulus presentation between multiple and concurrent schedules important for the development of differential resistance to change?

(2) Are local rates of reinforcement and responding important to the development of a between component resistance to change differential?

To attempt to answer these questions this study arranged two series of experimentation. In the first a standard VI VI concurrent schedule (with reinforcer ratio of 3:1) was arranged, according to the Findley procedure, and the distinctive colour stimuli were presented one-at-a-time as is the norm in multiple schedules. The results of the resistance to change (response-independent food presented at two rates) tests in Series 1 did not support the conclusion that the successive presentation of stimuli in concurrent schedules resulted in differential resistance to change.

Series 2 of this study investigated the importance of local rates of responding and reinforcement in determining resistance to change. To achieve this the Findley concurrent schedule was further modified with a time constraint arranged on the changeover key. This constrained interchangeover time (CICT) restricted the time allocating abilities of the pigeon subjects. The CICT was a VI 60s schedule programmed onto the changeover key. This manipulation successfully created unequal local rates of reinforcement, as is enforced in the design of multiple schedules. Subsequent testing for resistance to change was not successful in producing between component differential resistance to change results.

These results raise doubts about the applicability of resistance to change as an effective replacement for response rate as a measure of response strength.

Introduction.

Response Strength

Response strength is a term that has been applied to the differential that exists between the number, speed or intensity of responding in a given environmental context. Each environmental context contains elements that reinforce certain behaviours exhibited by an organism. To reinforce is to strengthen. Thus, response "strength" is a property of behaviour that increases with increased reinforcement. The issue addressed in this paper is that of identifying the specific nature of that property - or indeed whether such a property exists. Generally, it has previously been accepted that the persistence of the rate of responding in the absence of reinforcement - or in extinction conditions - is the most applicable measure of the strength of that response. Although certainly a useful measure, the persistence of responding in extinction conditions is subject to substantial variations of results. Nevin (1974) summarised the findings of Kling (1971) who concluded that as the measure of persistence of response rate in extinction was variable that there must be further, or more accurate measures of that which constitutes the strength of a response.

In light of Kling's (1971) critique of the status quo regarding the strength of responding, studies have taken two directions. The first of these is that body of work embodied by Herrnstein (1970) which asserts that the strength of a response is to be found within the relationship between the absolute rate of responding and the rate of reinforcement in a given environmental context. The second series of studies have focussed upon the persistence of responding in a given environmental context when that responding is disrupted. This disruption most often takes the form of the introduction of additional reinforcement that is independent of the schedules maintaining responding. This is often introduced in the blackout periods that occur between the programmed components of the maintaining schedules. These studies which focus upon the resistance of responding to change are represented by the work of John A. Nevin (1974).

It is therefore appropriate to examine each of these approaches to the study of the strength of a response in turn. Firstly, then is presented a brief summary of the historical development of the notion of absolute response rate as a measure of response strength and a review of the more important and interesting studies in this field.

Absolute Response Rate

The Law of Effect (Thorndike, 1911) stemmed from the notion of "stamping in"- or the assumption that organisms "learned" about a new environment on the basis that their first successful behaviour was reinforced and therefore repeated. The principles expressed within the Law of Effect suggest an interaction between organism and environment in the learning process. Thus, it was established within behavioural science that an organisms behaviour was directly related to the consequences of that behaviour. This approach to the study of the acquisition and strength of an organisms behaviour was refined and much enhanced with the development of the free operant chamber (Skinner, 1939). This chamber allowed the subject to perform a large number of less taxing behaviours in succession without the interference of the experimenter. Typically these chambers provided a controlled environment wherein a task could easily be performed in high frequencies by a subject - for example pecking activities in birds and lever pushing in rat subjects. From the subsequent number and variety of studies conducted in free-operant chambers, certain patterns became apparent in the performance of subjects of varying species on varying task conditions. In reaction to this Herrnstein (1970) believed it should therefore be possible to establish a set of general principles and equations for the quantification of these results. Earlier results showed that simple schedules of reinforcement produced responding that displayed certain monotonic relationships to the schedules of reinforcement to which they were exposed.

A simple schedule arranges one reinforcement schedule on which an organism responds. Typically the experimenter is investigating the performance of an organism when exposed to a new situation or environment. In addition to simple schedules, multiple and concurrent schedules are the most commonly studied schedules of reinforcement. A multiple schedule arranges several schedules ("components") that run successively. Thus, an organism will respond on one schedule component until that component is complete and will then progress to the next component of that schedule. This design allows the study of the organisms behaviour in response to environments providing successive discrimination. Concurrent schedules also arrange more than one component in a schedule. However, the components in a concurrent schedule are arranged so as to run at the same time. The organism is then provided with the means to change from responding on one schedule component to respond on the other component. Concurrent schedules then, provide the means to study preference - or choice - behaviour in organisms.

As noted a general pattern of results emerged in studies using simple schedules of reinforcement. Similarly, patterns could be discerned in studies which employed multiple and concurrent schedules also. Given the consistency with which these results appeared, Herrnstein (1970), attempted a comprehensive evaluation and, in many cases, re-evaluation of foregoing data in an attempt to quantify the apparent strengthening relationship between the rate of responding and the rate of reinforcement in given schedule components

Herrnstein's Analysis

Herrnstein (1961) developed a system which, it was asserted, could accommodate the foregoing results through the introduction of a comprehensive system of equations based on the relative rates of both responding and reinforcement.

One of the earliest and perhaps most important discoveries concerning the relationship between the rate of reinforcement and the rate of responding is that of the matching law (Herrnstein, 1961). During the course of a simple experiment on concurrent scheduling Herrnstein discovered that the relative rate of an organisms responding approximately matched the relative rate of reinforcement that the organism received in that component of the concurrent schedule. This matching relationship was expressed as follows:

$$Pl/Pl+Pr = Rl/Rl+Rr. \qquad \text{[Equation 1]}$$

Where P indicates pecks and R is the reinforcement. The lower case letters represent the left or the right key.

Herrnstein (1970) published a thorough review of results obtained in the most noteworthy foregoing experimentation of operant conditioning. The objective of this study was to determine whether a single general equation or set of equations could be established as quantification of the concept of the strength of an organism's responding - or response strength.

The existence of the matching phenomenon in concurrent schedules in addition to the already established relationship, of increased responding with increased reinforcement in simple schedules, provided encouragement for a study of this nature. Further review of preceding results revealed discernible patterns in the performance of organisms in studies with multiple schedules of reinforcement. For example, some such studies produced evidence suggesting that a contrast effect could be considered the norm in the performance of subjects responding in multiple schedules of reinforcement. Initially identified by Reynolds (1961) the contrast effect was again reported by Catania (1963) in a concurrent-schedule study with pigeon subjects in which the performance of the subjects showed steady detrimental effects of responding on the target key as the reinforcement was increased on the other - non-target key.

Herrnstein (1970) believed that the consistency of these results in operant experimentation would lend themselves to a general formula that could effectively predict the results of experimentation undertaken with concurrent, multiple or simple schedules of reinforcement. Central to Herrnstein's development of a set of principles which effectively describe the common findings in operant experimentation is the degree to which the relative frequency of responding could be shown to be a function of the rate of reinforcement (Herrnstein, 1970. p. 247). An important test of the relative frequency of responding as a measure of the strength of responding is that of the success or failure of this same measure to be converted to the analysis of the absolute rates of responding. The initial focus of Herrnstein's study is that of the quantification of the studies of choice. These are most readily identified as those experiments utilising concurrent schedules of reinforcement. However, in an interesting development responding in simple schedules was also placed within the context of choice. This was based on the assumption that any situation - or environment, even those that are provided and controlled by the experimenter, consist of choice situations. Theses choices may as trivial as the grooming or cleaning behaviours exhibited by pigeons (see Herrnstein, 1970. p.255). However seemingly trivial, these activities must also provide the subject with an element of reinforcement. This must then be considered, and accounted for, in a quantification of response strength. Thus for a single response experiment, expected output of the target response may be written as:

$P = kR/R+Ro.$ [Equation 2]

Where k is a constant and Ro represents any extraneous reinforcement forthcoming from the environment. Herrnstein (1970) tested this formula on data gained in an earlier simple schedule experiment which employed simple VI schedules ranging from 10 to 300 reinforcers per hour (Catania & Reynolds, 1968). After analysis the results were found to be accurately represented by Herrnstein's formula. It was therefore assumed that the same principle should apply to the analysis of responding in one component of a concurrent schedule with only a slight variation in order to accommodate the added experimenter defined reinforcement:

$Pl = kRl/Rl+Rr+Ro.$ [Equation 3]

According to this equation a constant overall rate of reinforcement should produce the matching function, whereas variations in the overall rate of reinforcement would produce the contrast effect. As a test of this formula Herrnstein employed the results of Catania's (1963) study in which the original analysis provided an excellent case for the advent of contrast. In the first phase of the experiment the overall rate of reinforcement was held constant and the matching phenomenon was observed. The second phase of the experiment however, varied the rate of reinforcement on one key. This effectively altered the overall rate of reinforcement. Catania (1963) asserted that his results were conclusive evidence of the contrast effect as the initial analysis clearly showed that as the rate of reinforcement on the non-target key increased, the rate of responding on the target key decreased. Herrnstein's (1970) equation predicts that these results would occur. The use of Catania's (1963) results provides a platform to show that the equation does indeed fit the data of actual experimentation.

In contrast the multiple schedules present a more complicated issue regarding the effects of the interaction, if any, of the schedules. For, the components in multiple schedules are temporally separated and thus the interaction is more difficult to ascertain than that of the schedules in which the reinforcement to the components occurs concurrently. Thus, while the effect of the reinforcement for the non-target schedule in a concurrent schedule is present at all times that reinforcement is present for the target response. Thus, the formulation for the general principle of the performance of an organism responding on multiple schedules must in some way be related to the extent of the interaction that occurs in a single multiple schedule experiment. For example, as contrast has been identified as occurring in multiple schedules there must be an effect of the reinforcement in the other component on target component responding. The formula for performance in a general multiple schedule is as follows:

$$P1 = kR1/R1+mR2+Ro. \qquad \text{[Equation 4]}$$

Again Ro represents the extraneous reinforcers that are present in every experimental condition. The parameter m is the notation for the extent of the interaction between the reinforcement rates of the separate components of the multiple schedule. Thus, this equation may be interpreted as an equivalent of that stated earlier for the concurrent schedule experiments. The difference here is that the interaction effect (which is not shown) would equate to 1.0 because by the nature of a concurrent schedule the interaction must be maximum with both schedules present at all times.

In an effort to assert the adequacy of the equation for the evaluation of the performance of an organism in multiple schedules Herrnstein conducted a test using the results of an interesting experiment designed by Bloomfield (1967). Bloomfield arranged two multiple schedules in a test designed to assess the relationship between the rate of responding and the rate of reinforcement across schedule components as determiners of behavioural contrast. One of the schedules alternated a VI 60 component with a DRL schedule which reinforced IRT's of between 5 and 15 seconds. The other multiple schedule arranged alternating components of a VI 60 and a fixed ratio (FR) schedule. The FR schedule allotted varying ratios which ranged from 10 responses/ reinforcement to 500 responses/ reinforcement. Thus, while both of the multiple schedules arranged identical VI schedules on one component, the alternate components in each schedule were in effect reinforcing quite different rates of response behaviour. The results show that the rate of reinforcement is what determines contrast. As each of the VI components showed a detrimental effect of reinforcers being programmed on the other component of the multiple schedule. Contrast was still apparent when the reinforcement was contingent upon a very low rate of responding - or periods of non-responding - as is the case with the DRL schedules. The different reinforcement rate contingencies had similarly detrimental effects upon target responding. Thus, the response rate contingency was not the controlling factor in the determination of contrast. The overall rate of reinforcement was the controlling variable in the contrast effect. These results serve to enhance the status of the formula put forward by Herrnstein (1970) by showing that the imposed response contingencies did not effect the existence of the contrast effect. Thus, the formula seems an adequate explanation of performance within multiple schedules just as the earlier equations provide predictive and explanatory information regarding the performance of organisms in simple and concurrent schedules.

Response rate as a conditionable aspect of behaviour.

The use of response rate as a measure of response strength has focussed on the relationship between the rate of reinforcement and the rate of response. However, this point of focus is challenged by results that show that rate of responding can be manipulated independently of the rate of reinforcement. That is, response rate is itself a conditionable aspect of behaviour. As was illustrated in Bloomfield's (1967) study (above) which used a DRL schedule and still produced reliable contrast effects. A further clear example of this phenomenon is illustrated within the work of Blackman (1968), using the differential reinforcement of a low rate (DRL) of responding schedule. A DRL schedule delivers reinforcement immediately after an operant response only if a specified interval has elapsed between this and the preceding response. These differential schedules are assessed by the analysis of the distributions of the inter-response times (IRT's). IRT analysis organises the responses into pre-arranged groupings on the basis of the time elapsed between responses. These groupings are labelled bins. These bins are then totalled, expressed as percentages of the total responses in a session, and expressed as frequency distributions.

Blackman (1967) devised an experiment, using rat subjects, to illustrate the extent to which the responses of an organism could be "conditioned" with the introduction of IRT - reinforcer contingencies (see Blackman 1974, for review). He used a DRL 5 LH 3; VI 30s schedule. Reinforcement was scheduled on a VI 30s schedule, under which the reinforcer became available at irregular intervals with a mean of 30s. With the added contingency of the DRL schedule - in this case DRL 5 LH 3 - the reinforcement only became available if no response was emitted by the subject for 5s. This reinforcer was only then held for collection for a further 3s. Thus, only responses emitted 5 - 8 s after the previous response and when the VI 30s timer was completed could collect an assigned reinforcement. The results of this experiment showed that the rate of responding decreased substantially from that maintained by a standard VI 30s schedule. A standard VI 30s schedule typically maintains a moderate, steady rate of responding within the exposed subjects. In contrast the results of Blackman's study with a differential schedule produced a rate of responding that was lower. Data obtained from studies using a standard VI schedule show that the average rate of responding approximates 40 responses per minute. The average rate of responding for the subjects engaged in Blackman's differential schedule was closer to 9 responses per minute. Blackman (1967) also established the conditioning of responding in the reverse direction with the introduction of a differential reinforcement of high rate of response (DRH) schedule. This schedule programmed reinforcement on a VI schedule for short, as opposed to long IRT's. Under these conditions the average rate of responding for the component as a whole was maintained at a very high level. Blackman's manipulations did not include the rate of reinforcement - which was constant for both of the differential manipulations in each of the schedules. These results show conclusively that it is possible to manipulate the rate at which a subject responds to a schedule of reinforcement without altering the rate of reinforcement delivered, or programmed, by that schedule.

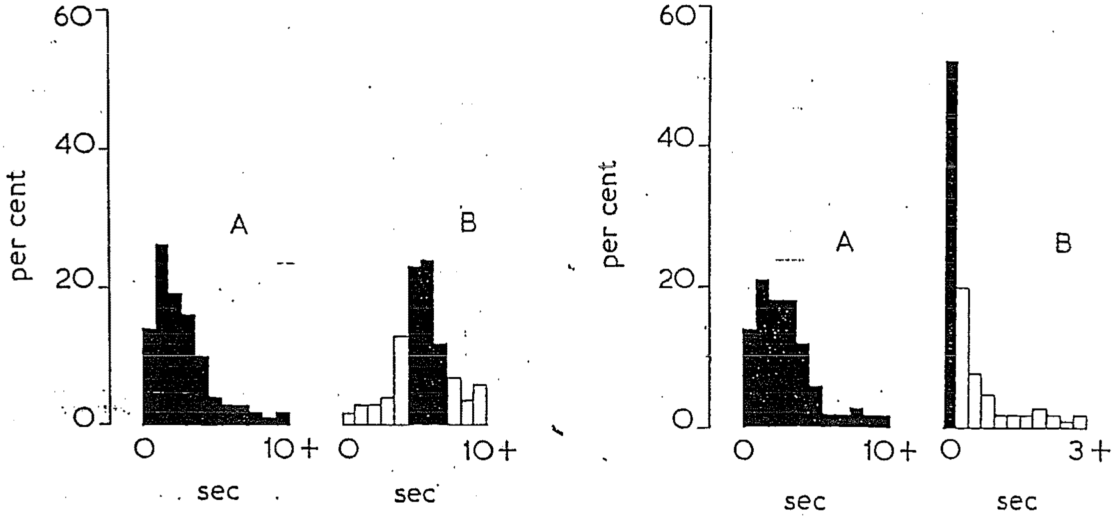

Figure A: Histogram showing frequency distributions of inter-response times IRT's. Left plot (A) shows IRT's from a VI 30s schedule. The right (B) plot shows IRT's from a VI 30s with added DRL 5s LH 3s. This figure illustrates the difference in response patterns when the response contingency is altered. The second pair of histogram plots illustrate the reverse effect of a DRH contingency. The left plot (A) shows a VI 30s schedule. The right (B) plot shows the same VI schedule with the requirement altered so that only responses less than 0.3s after the last response may be reinforced. Reinforcement rate was the same for both conditions. This illustrates conditioning of response rates independently of reinforcer rates. Graph is from Blackman (1967).

The above results, show that the rate of response may be manipulated independently of the rate of reinforcement. Blackman (1967) did not alter the rate of reinforcement but merely imposed constraints upon the response patterns that were reinforced. This shows clearly that response rate is affected by contingencies of reinforcement, not just reinforcers themselves. Thus it cannot be viewed as a reliable indicator of response strength. The emphasis upon the relationship between the rate of reinforcement and the rate of responding as the measure of response strength must then be questioned.. For, as a measure of response strength there are apparent shortfalls in the utilisation of only the rate of reinforcement and the rate of responding.

This finding does however concur with thoughts on response strength expressed by Kling (1971). Kling stated that response strength, in its usage at the time, incorporated more concepts than it adequately defined. For example, the term response strength was defined by the response rate exhibited within extinction conditions and also was the reference for the resistance of that response rate within the same conditions. As these two measures are seldom equal, Kling believed that response strength as a concept was used in a manner too general to adequately identify the intricacies of - in this example - the effects of extinction on the strength of a response. Thoughts of the kind expressed by Kling (1971) led to an increase of research into the adequacy of the accepted definition of response strength. The most notable, and progressive outcome of this renewed interest was the concept of resistance to change as a measure of the strength of a response.

Principles of Resistance to Change.

John A. Nevin (1974) advanced the study of resistance to change of responding in relation to rate of contingent reinforcement. The focus of this approach is the resistance of a response to variations in experimental conditions, or "disruptors". Resistance to change is of interest here because it may represent an alternative to the previously accepted indices of the strength of a response.

In most cases resistance to change research is conducted with multiple schedules. The subject performs in two or more components of these schedules until there is little session to session variation exhibited in behaviour. The level at which the behaviour stabilises in that schedule component then forms a baseline against which the behaviour exhibited in further manipulations may be assessed. Once stability is reached, a disruptor is then applied equally to each of the components in the schedule. This then allows the experimenter to assess the pre- and post-manipulation performance of the subject. By comparing the post-manipulation results with those of the established baseline the experimenter is able to judge the disruptability of responding in the two components. This allows the assessment of disruptibility as a measure of response strength. Of importance here is the relationship between disruptability and reinforcement. That is, does disruptability increase and decrease with reinforcement? If there is a reliable relationship between disruptability and the rate of reinforcement then this may provide a very effective means of assessing the strength of responding. For example, after equal application the component in which responding underwent the least change may be said to possess greater resistance to that disruptor. Because the only alteration has been the introduction of the disruptor, it is therefore possible to isolate the aspect of the pre-manipulation conditions which was the cause of the greater, or lesser, resistance.

The disruptors that are most commonly used in tests of resistance to change include: pre-feeding/satiation (Nevin, Mandell & Yarensky, 1981; Nevin, 1984; Nevin, Smith & Roberts, 1987; Nevin, 1992; Nevin, Tota, Torquato & Shull, 1990; Cohen, Riley & Weigle, 1993), extinction (Nevin, 1974, Nevin, Mandell & Atak, 1983; Nevin, 1984, Nevin et al, 1987; Nevin et al, 1990; Nevin, 1992; Harper & McLean, 1992; Cohen et al, 1993; McLean & Blampied, 1995; McLean, Campbell - Tie & Nevin, Press) and response-independent food presented within a component (Nevin, 1984; Cohen et al, 1993; Harper & McLean 1992) or alternatively, presented in the time-outs between schedule components (Nevin, 1974; Nevin et al, 1990; Cohen et al, 1993).

A practical example of the use of a disruptor in the assessment of resistance to change is provided by Nevin, Mandell & Yarensky (1981) in which pre-feeding was used to disrupt baseline responding. In this experiment, Nevin et al established baseline responding with the pigeon subjects in chained schedules. Once achieved this baseline was disrupted by varying levels of free feed given before the session. Pre-feeding was controlled to ensure that each of the subjects was similarly sated. This enabled the experimenters to compare results from the individual subjects from the pre- to post-manipulation conditions in each schedule component or "link". From this comparison, a relative measure is established. This measurement is that of the response rate in the presence of the disruptor divided by the pre-disruptor, or baseline, response rate. Any difference in the effect of prefeeding is therefore the result of the contingencies established in that condition. Thus, disruptors as tests of resistance to change provide a means of isolating a variable that may cause responding maintained by one schedule component to be more resistant to change, and therefore stronger, than that maintained by another schedule component.

Perhaps the best way to describe the principles of resistance to change is to review the experimentation which served to establish the concept in the study of learned behaviour (Nevin, 1974). In this study, Nevin sought to assess the effects of rate, delay and magnitude of reinforcement upon the resistance of a response to change as measured relative to an established baseline.

The first of Nevin's (1974) experiments was a study of the effects of the frequency of reinforcement upon responding as measured by tests of resistance to change. Using pigeon subjects in a three component multiple schedule the frequency of reinforcement was delivered at different, constant rates across the first two components. In the third component response-independent food was sometimes presented, at varying rates, to assess the resistance to change of the responding in the first two components. The maintaining schedules in Components 1 and 2 were VI 60s and VI 180s respectively. Response-independent food was presented at rates of 20, 60, 180, and 360 reinforcers per hour. The results in baseline showed, as expected, that response rate was higher in the component with the richer reinforcement schedule. The interesting result here was the effect of the tests of resistance to change. The presentation of the disruptor decreased responding in both components - also as expected. However the component that showed the greatest decrement with the introduction of the response-independent food was that with the leaner reinforcement schedule. Thus, the least affected of the two components - that with the greater resistance - was that which had the greater overall rate of reinforcement. In a second, similar experiment in the same series changes in response rate were assessed using extinction. The results were very similar to those reported for experiment 1 in which response-independent food was used.

To assess the effects of the magnitude of reinforcement upon resistance to change a third experiment was designed in which pigeon subjects were run with equal VI 60s schedules with the magnitude of reinforcement varied between components. This variation was achieved by changing the length of the subject's exposure to the food reinforcers. Initially the right key was correlated with 7.5s access to food and the left key correlated with 2.5s food access. Each key was operative for only one component of the schedule at a time. Testing for resistance to change was carried out with the introduction of response-independent food in the timeout periods between components. In later sessions the maintaining schedules were changed to VI 180s and VI 180s on the right and left keys respectively. There were two main findings from this experiment. First it was discovered that response-independent food had a greater disrupting effect when the schedule arranged VI 180s components than in the richer VI 60s components. This finding is consistent with the results of the first experiment. The second finding was that the responding maintained by the reinforcement of greater duration - greater magnitude - was more resistant to disruption than that maintained by reinforcement of lesser duration. Thus, the overall results of the effects of the magnitude of reinforcement were found to be consistent with the results for the effects of the frequency of reinforcement on resistance to change.

In the fourth experiment in this study the variable under manipulation was the delay of reinforcement. In this experiment the assigned tests of resistance to change were those of response-independent food, in the timeout periods between components, and extinction. Delays of reinforcement in the two components were varied over conditions as follows: 2.5s Vs 7.5s; 9.0s Vs 1.0s; and 5.0s Vs 5.0s. One of each of the paired values was assigned to either the green or red key. Sessions consisted of 25 components with the left key lighted followed by 25 sessions with the right key lighted. The results showed that the introduction of varied delay of reinforcement produced only a slightly greater response rate, in baseline conditions, in the component with the shorter delay. However, with the introduction of the response-independent food it was found that the component with the shorter delay showed greater resistance to change than did the component with the longer delay. There was no difference between the components in which the delay was set at equal levels (5s Vs 5s). The results of the tests using extinction as a disruptor, while somewhat irregular and not entirely conclusive, did broadly concur with those produced with the response-independent food disruptor (Nevin, 1974).

In this study Nevin (1974) showed that experimentation that incorporates a measure of resistance to change can be utilised to express the relationships between the maintaining schedule of reinforcement and the rate of responding that have appeared in the wealth of work on operant behaviour preceding its conception. That is that resistance to change appears to be affected by the reinforcer properties (rate, magnitude and delay) that have been shown elsewhere to influence response rate. Nevin's assertion is that through the utilisation of resistance to change, a viable alternative to the measures of response strength in terms of response rate is offered. Thus, with resistance to change confirming existing data gained through the study of response rate it remains to assess possible effects of extraneous influences upon resistance to change. Part of this investigation is an analysis of the possibilities of the generality of the application of resistance to change studies.

Generality of Resistance To Change.

Nevin's initial identification of resistance to change provided an alternative to the, then, predominant analysis of response strength based on changes in the rate of the response. As a result the following years produced many studies incorporating tests of operant resistance attempting to generalise upon and validate the results produced by Nevin (1974). Presented here are some of the more notable studies which have served as evidence of the generality of the resistance to change of learned behaviour. Bousaz (1978) published confirmatory evidence of the relationship between reinforcement rate and resistance to change. Pigeon subjects were trained on a multiple VI 60s VI 240s schedule until a stable baseline was attained. Bousaz then introduced aversive electric shocks on a VI 30s schedule for responding. This was to disrupt responding enabling the assessment of the resistance differential between the schedules. The results showed that the component maintained by the richer schedule of reinforcement was more resistant to the suppressive effects of the aversive shocks.

A further pigeon study investigated resistance to change within organised sequences of behaviour (Nevin et al., 1981). Based upon earlier findings that found that response rate and resistance to change were lower in the initial links of chained schedules, Nevin et al (1981) designed another test of resistance to change in chained schedules. In a chained schedule, responses in the initial link schedule make the terminal link schedule available, and when the conditions of this schedule are met a primary reinforcer is delivered. Thus, experimental work with chained schedules permits the investigation of the effects the distance of the reinforcer has upon both response rate and resistance to change. In this study it was expected, by virtue of proximity to the reinforcement, that the terminal link of the schedules would produce greater resistance to disruption - in this case pre-feeding, and signalled concurrent reinforcement. Over the series of conditions the schedule components varied in the duration of food access (Expt. 1) and also the length of the terminal link in the component was varied in addition to the duration of food access (Expt. 2). Results from the first manipulation showed that responding in the initial links of the schedules was more sensitive to variations in the duration of access to food. Responding at the initial link also occurred at a lower rate than did responding in the terminal links of the same schedules. With the introduction of the disruptors the results showed that the resistance of responding in the terminal links was greater than that produced in the initial links. The manipulation of the duration of the terminal links of the schedules (Expt. 2) effectively decreased or increased the rate of reinforcers per hour presented by the schedules. The results show that across all manipulations of terminal link duration that resistance to change was greater in this link than in the initial link of the same schedule (Nevin et al., 1981). Thus, resistance to change was positively related to both the rate of reinforcement and the duration of reinforcement access in the terminal link. These results clearly concur with those previously presented regarding chained schedules and also present further evidence to support Nevin's emphasis on resistance to change as a measure of response strength.

Thus far much of the evidence in support of resistance to change as a measure of response strength has come from studies which employed pigeon subjects responding on variable interval schedules. The results are also evident in learned behaviour of other species performing in different types of schedules. As there exist many individual studies of resistance to change, I will now simply review a comprehensive series of experiments conducted by Cohen, Riley & Weigle (1993) which embodies the major findings of resistance to change tests. In experiments designed to assess schedule generality Cohen et al ran a series of experiments with both fixed ratio and fixed interval schedules. In addition to experimentation with pigeon subjects Cohen et al also employed rat subjects in their experiments to assess resistance to change. These experiments followed the now typical pattern of tests of resistance to change with the subjects exposed to the schedules until responding stabilised at baseline, and then responding is disrupted with the introduction of response-independent food, presented either within the schedule components, or in the timeout between the scheduled components. Other disruptors used in this series of experiments were pre-feeding and extinction. The findings produced evidence that support Nevin's (1974) assertions on the relationship between resistance to change and reinforcement in learned behaviour. In addition, this study also provides evidence that support the generality of the concept of resistance to change both across variations of schedules and also subject species. For, the results published from this study clearly illustrate greater resistance of responding to varied disruptors in schedules which provide greater reinforcement rate, frequency or magnitude. This relationship holds with the use of fixed schedules and also generalises to rat subjects.

In order to gain acceptance as an innovation into the study of learned behaviour it is important for cross-species generality to be shown in experimental research. In a recent study Mace, Lalli, Shea, Lalli, West, Roberts & Nevin (1990) investigated the resistance of human behaviour, maintained by multiple VI schedules, to change. The subjects, mentally retarded adults, were assigned the task of sorting plastic dinnerware. This performance was reinforced according to a multiple VI 60s VI 240s schedule. Once a baseline level of responding was achieved a disruptor was introduced. The disruptor was a video program shown while the subjects performed the sorting task. Results showed that the baseline rates of responding were similar in both components of the schedule. However, in the resistance to change test responding that was maintained by the richer reinforcement schedule was more resistant to disruption than responding maintained by the leaner schedule.

In light of the findings supporting the generality of resistance to change, support for resistance to change as an alternative for assessing the strength of responding increased. That resistance to change has been shown to generalise across species and different experimental conditions, as well as confirming the findings of earlier response rate identification, lends weight to the validity of resistance to change as a measure of response strength. In light of the cumulating evidence of this validity of resistance to change Nevin, Mandell & Atak (1983) formulated a more formal theoretical statement of the resistance to change generalisation.

Nevin: Behavioural Momentum

Several of the studies reviewed above reported that the differences in response rate between components were not present in baseline, but resistance to change was nevertheless greater in the richer component. Nevin et al (1983) attempted to reconcile the apparently contradictory findings of the rate of responding and the resistance of that responding to change with the theory of behavioural momentum (Nevin et al., 1983). Behavioural momentum has its foundations within the principles of classical physics. The central idea is that of the presumed similarities between the momentum exhibited by physical objects in the environment and the momentum-like quality that is displayed by the performance of an organism in operant procedures. Within the physical sciences the momentum of an object is described in terms of the velocity of an object of a certain mass and the changes in this velocity that occur when a degree of force is applied to the object. This is represented, according to Newton's Law, by the formula:

$$V = F/m. \qquad \text{[Equation 5]}$$

Nevin et al (1983) asserted that the properties of the rate of responding could be expressed in notation that derives from Newton's work. For example, as the results of several prominent experiments showed, the performance of an organism, as identified by response rate, changes from the time the organism is exposed to new schedules of reinforcement until an asymptote level of performance is attained. Thus, response rate in this form may be seen to represent a velocity-like quality of a performance of an organism. The extent to which performance resists change is the mass-like property (Nevin et al., 1983).

When testing for resistance to change the comparison of two or more performances in pre- to post-disruption states allows the comparative assessment of the resistance to change of the performances. In terms of behavioural momentum the performance that is least disrupted, may be said to be more resistant to change and therefore possessant of greater behavioural momentum. Nevin et al asserted that the introduced variable acts in a manner that is analogous with that of the effect of a force on the momentum of a physical object. Thus, the Newtonian adaptation is a means of expressing the properties of learned behaviour within a strict theoretical framework. Behavioural momentum then expresses quantitatively the resistance to change effects that result from the introduction of disruptors in tests of resistance to change. The general expression of this resistance to change relationship is as follows:

$$V = a(x/m). \qquad \text{[Equation 6]}$$

Thus, the changes in the velocity of a behaviour - or response rate - are expressed as the function ,a, of the introduced variable, x, on the mass of the response, m.

In classical physics, if two objects of equal mass are exposed to equal external force then the velocity of the two objects will change equally. Thus, it follows that the same effect will be true for the performance of two organisms of equal velocity, if the same external variable is applied to both. For example, if an organism is responding on a schedule of two components which program equal reinforcement until asymptote performance is obtained then the velocity of the two performances may be said to be equal. If responding on these two components is then interrupted with the introduction of an external variable that is applied equally then it may be assumed that the velocity of the two performances would exhibit equal changes. However, if the two components differ in the maintaining schedules of reinforcement, the component with the richer reinforcement has been shown to undergo lesser changes in responding than the component with the richer schedule of reinforcement. Therefore, behavioural "mass" is determined by reinforcer rate.

Contingencies Affecting Resistance to Change

In general, it has bees accepted that the contingencies most important in the establishment and then strengthening of responding are operant contingencies. More recently, research into resistance to change has suggested that Pavlovian conditioning also has an important role in the strengthening of a response.

Pavlovian, or classical conditioning, describes the process by which a behaviour, or the performance of a response, is affected by the presentation of reinforcement in the presence of a specific stimulus. Therefore, in terms of probability, a performance will be strengthened, or enhanced, depending upon the likelihood of receiving a reinforcer in the presence of a specific stimulus as opposed to the probability of not receiving a reinforcer in the presence of a specific stimulus.

Both operant and Pavlovian conditioning are most effectively illustrated by those experimental manipulations that result in significant alterations in the established contingencies. For example, operant conditioning which establishes a response-reinforcement contingency will be adversely affected by the introduction of reinforcement that is not contingent upon the responses of an organism. Pavlovian conditioning however, will benefit from this same manipulation. In terms of multiple schedule responding, a schedule component is typically signalled by a specific discriminative stimulus and then programs response-contingent reinforcers. Early investigations into the strength of responding focussed upon the response-reinforcer contingency as the indicator of the strength of responding. These studies asserted that components that programmed rich reinforcer schedules produced strong behaviour because the response reinforcer contingency was strong (see Herrnstein, 1970). In the analysis the stimulus that discriminated between the components was treated as something of an indicator. This could then be used to determine the relative response rate of one component against that of another component indicated by a different stimulus. The discriminative stimuli are differently related to food probability. Hence, a Pavlovian (stimulus-reinforcer) contingency exists. It is well known that operant contingencies control response rate, the issue here is which of these two contingencies affects resistance to change.

Nevin (1984) identified an effective method for studying the role of the stimulus-reinforcer contingencies in the resistance of responding to change. Nevin (1984) established two components over three keys. The first component on each key programmed the same reinforcement (VI 120s) on each of the keys. The arrival of the second component was not contingent upon any response, and occurred when the first component had run full course - 60s. This component arranged one of three different VT rates of reinforcement, depending on which key had been lighted in component 1 across the three keys. These rates were set at VT 24s, VT 120s and extinction. Thus, across the different keys one of the stimuli signalled an increase in the rate of reinforcement, one represented no change in the rate of reinforcement, the third key stimulus represented the transition to no reinforcement - or extinction. In terms of a stimulus-reinforcer contingency affecting the resistance to change of responding it was expected that the transition to a component defined by a stimulus representing a richer reinforcement schedule would produce responding that was more resistant to change than would a transition to a leaner schedule of reinforcement. Component 1 was tested for resistance to change to assess the effects of the transition. The results showed that the baseline response rate was not affected by the reinforcement rate in the successive component. However, of specific interest is the finding that Component 1 in transition to Component 2 with a rich reinforcement schedule exhibited greater resistance to change. Conversely, the transition to a component that is defined with a stimulus that represents extinction would reduce the resistance to change of responding across the two components. The results of tests of resistance to change - in this case prefeeding, extinction and response-independent food concurred with these expectations. The transition to a stimulus defining a richer schedule of reinforcement produced responding that was more resistant to change than the transition to extinction defined by a separate stimulus.

Nevin, Smith and Roberts (1987) undertook a further study which replicated, Nevin's (1984) study, and extended the results in an important way. The specific difference was that of making the transitions from Component 1 to Component 2 contingent upon responding. The results of the resistance to change tests showed that there was no effect upon the resistance to change in Component 1. Thus the operant contingencies were ineffective. Making the transition response contingent did however affect the baseline response rate.

Thus although the contingency of the transition appears to affect the rate of responding this operant contingency exhibits little effect upon the resistance to change of that responding. Resistance to change was shown to be related to the stimulus-reinforcer contingency of a component. It is apparent that the dominant factor in resistance to change in multiple schedule responding is the stimulus-reinforcer contingency that exists in components and across components.

To further the understanding of the precise nature of the stimulus-reinforcer effects Nevin, Tota, Torquato and Shull (1990) conducted two experiments which introduced alternative reinforcement into components of multiple schedules. In the first experiment Nevin et al (1990) established responding in two component multiple VI VI schedules. One of the components (green key) arranged VI 60s reinforcement. The other component also arranged VI 60s reinforcement but was varied with the addition of alternative reinforcement. This component was thus a VI VT component with the VT food presented at varying amounts - ranging in value from VT 0s - VT 240s across conditions. In addition to the variation of the alternative food the VI aspect of this component was also varied, so that in some cases the VI and VT reinforcers were greater than, lower than, or equal to the rate of reinforcement that was maintained on the other component. It was expected that the baseline response rate would be adversely affected by the presence of alternative reinforcement. Furthermore that the resistance to change of the target key would be enhanced by the presence of alternative reinforcement. The results confirmed these expectations.

The second experiment was designed as a test of Catania's (1963) finding that in concurrent schedules the target response rate decreases as a function of the rate of reinforcement of a concurrent schedule component. Nevin et al (1990), therefore tested the implication that response-contingent food in a concurrent schedule has the same function as response-independent alternative reinforcement in a multiple schedule. Nevin et al (1990) arranged three pairs of concurrent schedules, each pair identified by a distinctive stimulus. In each case the right key represented the target response and the left key was the key on which alternative reinforcement was arranged. The components were arranged as follows:

C1: 45 reinf./hour left key	15 reinf./hr right key
C2: 0 reinf./hr left key	15 reinf./hr right key
C3: 0 reinf./hr left key	60 reinf./hr right key.

Components C1 and C2 represent a VI schedule with and without alternative reinforcement respectively. Components C1 and C3 permit a comparison between the response rate and the resistance to change of the target response when the overall reinforcement rate was the same but in C1 this reinforcement is distributed across two keys (representing alternative reinforcement) and in C3 the reinforcement is all received from the target key.

Thus it was expected that target response rate would be lower in Component 1, where concurrent reinforcement was programmed (Catania, 1963) than in Component 2 or 3. Another expectation was that because the overall rate of reinforcement was the same across components C1 and C3, that the resistance to change of responding in these two components would be equal. The results showed that the baseline rates of the target responses followed the expected pattern. C3 exhibited the highest response rate at baseline, component C2 exhibited a rate that was higher than that of the first component C1. C1 was the component with the concurrent schedule of reinforcement on the left key.

The components were then tested for comparative resistance to both prefeeding and extinction. The assessment of the resistance of the target response of each component to change was consistent with expectations, and thus served as confirmation of the importance of stimulus-reinforcer contingencies in the generation of resistance to change. In the comparison of C1 - with 45 reinf/hr on target key and 15 reinf/hr on the concurrent schedule - and C3 which programmed 0 reinf/hr on the target key and 60 reinf/hr on the concurrent schedule, showed that response rate at baseline was initially higher in C3 than in C1. The tests of resistance to change however, showed that the additional concurrent reinforcement actually increased the resistance of the component. C1 and C3 programmed equal total rates of reinforcement. However in C3 all of the reinforcement was programmed to the target key, whereas C1 programmed 45 of the 60 reinf/hr on the concurrent schedule. A Pavlovian view stipulates that the resistance to change in both of these components would be equal as the total reinforcement rate is the same. This was confirmed in the analysis of the results.

The above studies represent considerable evidence for the assertion that the rate of response and the resistance to change of an organism are indeed the results of two distinct and independent processes. The rate at which an organism responds is clearly determined by operant conditioning or the response-reinforcer contingency. In contrast the resistance of a response rate to change is determined by Pavlovian conditioning - or stimulus-reinforcer contingencies.

The implication of the above finding is that response rate and resistance to change are independent. Thus, it follows that the rate at which an organism responds and the resistance to change of an organisms responding are determined by different contingencies. Therefore response rate and resistance to change are independent.

Independence of resistance to change and response rate.

As part of the intensive investigation of the effects of reinforcement on the resistance to change of an organisms response Nevin (1974) conducted a test of the effects of different response contingencies upon resistance to change. In one component only those responses that terminated an inter-response time (IRT) of longer than 3s were reinforced if a reinforcement was scheduled by the VI 60s timer - a tandem VI DRL schedule. In the other component a limited hold and a short ratio requirement were added to the VI 180s schedule. Thus, when the VI timer scheduled a reinforcement three responses were required within 3s for the reinforcer to be presented to the subject - VI DRH schedule. Resistance to change was assessed with the introduction of response independent food at initially 60/hour and then 360/hour. Also, subjects were exposed to seven sessions of extinction.

In baseline the subjects responded at a higher rate in the component with the DRH contingency by a ratio of about 3:1. This responding was not affected by the reinforcement frequencies arranged by the VI schedules in the two components, although in other conditioning with the same reinforcement contingencies on response rate but different frequencies of reinforcement, the relative rate of responding in the component with the higher frequency of reinforcement was always higher than that in the component with the lower frequency of reinforcement.

The results of the introduction of both response-independent food and extinction as tests of resistance to change showed again that the component with the greater rate of reinforcement generated greater resistance to change. However, also discovered was that responding generated in the components with the DRL contingency was more resistant to disruption than was that generated by the component with the DRH contingency. Thus, it is apparent that the schedule that generates the higher rate of responding does not necessarily generate the greater resistance to disruption.

While these results permit the interpretation that response rates are not independent of resistance to change, further studies with these differential pacing schedules have identified bias in the above experiment. Fath, Fields, Malott & Grossett (1983) observed that the reinforcement in the DRL component, once set up, was available for the duration of the component, whereas reinforcement in the DRH component was cancelled after 3s if the requirements were not met. Thus subjects had a greater chance of receiving a reinforcer, even after very long pauses, in the DRL component. If reinforcement is more likely in one component of a multiple schedule then much greater resistance to change would be expected in that component.

As a result of this identified bias Fath et al (1983) designed a further experiment to assess the independence of rate of responding and resistance to change. This experiment controlled for this bias by holding the reinforcement rate constant and altering the rate of responding by placing contingencies on this responding that did not interfere with the reinforcement density. This was achieved by providing reinforcement to responses that terminated specified IRT bands when the VI timer had finished. For the DRL schedule the IRT band fell between 2.5 and 3.5s, with the DRH schedule assigned a band of between 0.5 and 3.5s. Also, in contrast to Nevin's (1974; Expt. V) study, the programmed reinforcement was held until the end of the schedule component. In between each component the stimuli key was dark for 30s. After baseline was achieved resistance testing was conducted with response independent food presented within the dark key periods. These presentations were varied and ranged from 2.5s to 15s in duration. The results showed that as the amount of response-independent food increased (in duration), the mean response rates decreased. Thus, different response rates maintained by schedules producing equal reinforcement densities are equally resistant to change. In contrast to Nevin's (1974) finding that the pacing contingencies producing a low rate of reinforcement produced responding possessing greater resistance to change, Fath et al (1983) found that the effects of the disrupting operation were equal. Therefore, the response rate contingencies did not affect the strength, as measured by resistance to change, of a given response. Thus, when the components were corrected for rate of reinforcement the resistance to change was approximately equal.

This adds further weight to the assumption that the resistance of a response to change and the rate of a response are independent. For, if the contingencies vary and the resistance of each is not significantly altered then this supports independence between the two. The use of response rate was criticised for this apparent sensitivity to the response-reinforcer (see above DRH and DRL findings) contingencies. That this type of variation in the contingencies did not affect the resistance of responding to change lends weight to the useability of resistance to change as a means of assessing response strength. For, by definition the "strength" of the behaviour, as determined by reinforcement, must be equal when that reinforcement is equal.

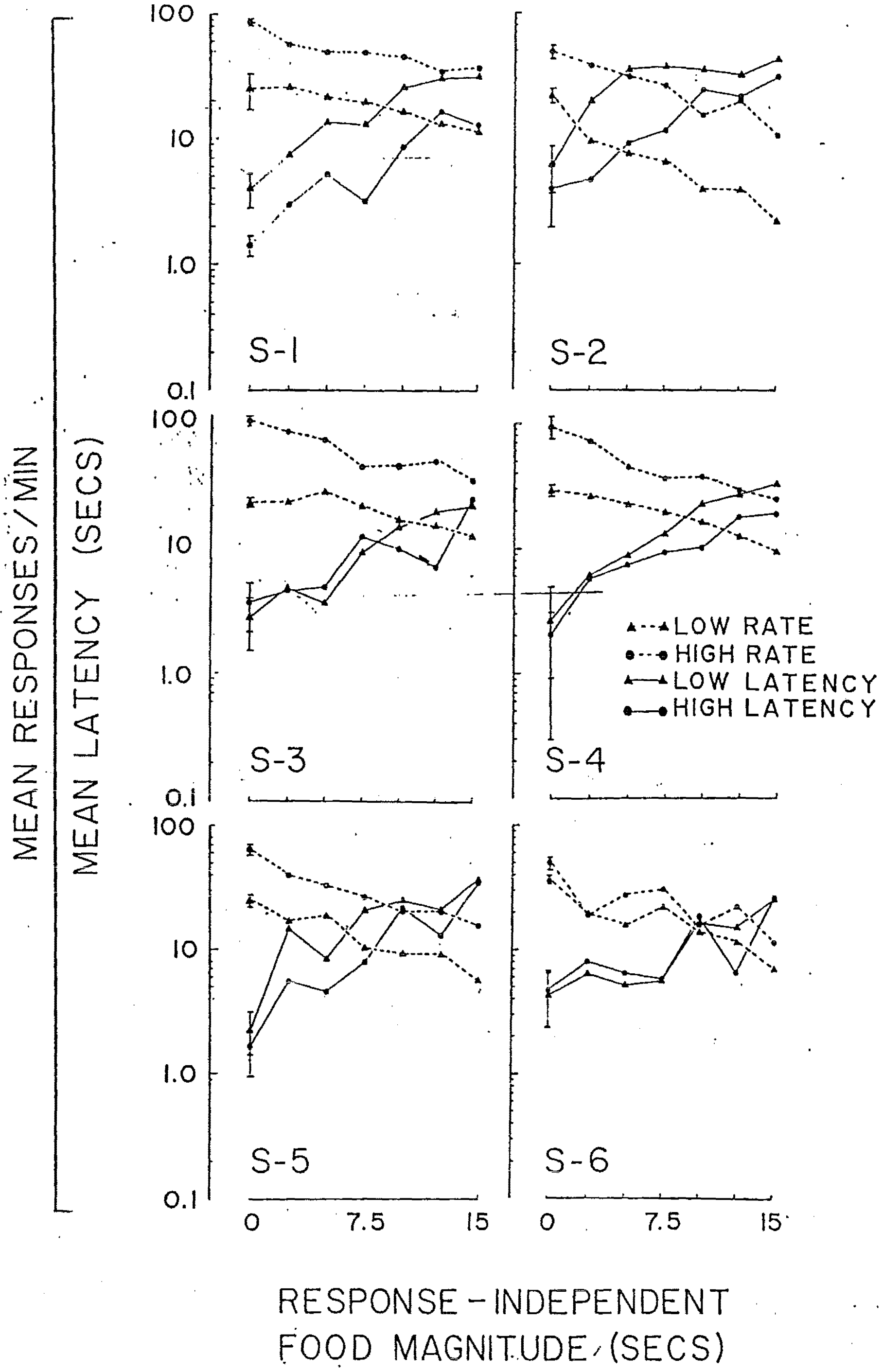

Figure B: Mean response rate and mean latency in two components as a function of response-independent food. The differential contingencies are denoted by triangles for high rate and circles for low rate. This figure shows that differential contingencies imposed on response rate had little effect on resistance to response-independent food. Graph taken from Fath et al (1983).

Contrary findings.

Although the generality of resistance to change findings has been established across species and many variations of schedules, most of the schedules examined have been multiple, or chained schedules. Furthermore, the disruptors that have been used, although varied, leave several unexplored options. This issue of the disruptor specific effects upon resistance to change is examined in detail under the heading: Types of disruptor. Another area of study within which resistance to change findings are somewhat less than comprehensive, is that of schedules of different contexts. This will be examined at length in the following section: Schedule context.

Types of disruptor:

Several experiments, incorporating the variation of the rates of reinforcement in schedules as a disruptor (Harper & McLean, 1992; McLean & Blampied, 1995), have produced results that are inconsistent with Nevin's (1974) hypothesis. For example, Harper and McLean (1992) conducted a series of experiments to assess the applicability of the Law of Effect (Herrnstein, 1970) on response-reinforcer relations in tests of resistance to change. In the first experiment a multiple schedule that established responding on two schedule components, that were differentiated by the magnitude of the reinforcement, was disrupted with the introduction of response-independent food presented in time out periods between components. The component that was maintained with the greater magnitude of reinforcement was less disrupted and thus more resistant to change. However further experimentation, which varied the rate of reinforcement as a disruptor, produced results that were inconclusive in terms of resistance to change. McLean & Blampied (1995) replicated the Harper & McLean (1992) study with the addition of a concurrent schedule. In Experiment 1 two components were established on the left key. These components established differential responding with maintaining schedules of different frequencies - VI 40s and VI 360s. On the right key two components were established with equal rates of reinforcement VI 120s VI 120s. Responding on the left key was disrupted by variations in the alternative reinforcement on the concurrent schedule. The results of Part 1 of this study showed that manipulations in contingent alternative reinforcement produced response rate differentials that are consistent with Nevin's previous findings (Nevin et al, 1981). That is the richer reinforcement component was more resistant to change than was the leaner reinforcement component. Responding on the right key was disrupted by variations in the maintaining schedules of reinforcement. This is similar to the manipulation used by Harper & McLean (1992). With this manipulation the resistance of the component with the richer schedule of reinforcement was less resistant to change than the leaner component. This pattern of response variation did not conform to those previously established in studies of resistance to change. As such, analysis of the results becomes subject to the effects of the discriminability hypothesis as identified by Kimble (1961). That is, the component maintained by the richer schedule of reinforcement may be more sensitive to alterations in the maintaining schedule than a leaner component. Because this alteration may be viewed as more easily discriminated in the rich than lean schedule this disruptor can then be viewed as possessing greater force than the same variation applied to a lean schedule

This issue of the discriminability of the introduction of changes in the rate of reinforcement as a disruptor is inextricably linked to extinction. Extinction has been employed to assess the strength of responding in schedule components since the development of experimental research with learned behaviour (see Thorndike, 1918; Skinner, 1938; Hull, 1943). More recently extinction conditions have been applied to tests of the resistance to change of responding. As a result there exists a large body of research based upon findings with extinction. A feature of this work is the existence of inconsistencies relating resistance to change and reinforcement in the schedules studied (see Nevin, 1988). An early identification of the problems associated with the use of extinction in the assessment of the strength of a response was presented by Kimble (1961), with the identification of the discrimination hypothesis of extinction. This hypothesis asserts that behaviour maintained by a richer reinforcement schedule will be more sensitive to variations in that schedule than will behaviour maintained by a comparatively leaner schedule. Nevin (1988), published a comprehensive investigation of the effects of extinction as tests of resistance to change. In this work two central processes were identified with the introduction of extinction as a disruptor. Firstly, the termination of the reinforcement condition; and second the change in the stimulus situation (Nevin, 1988). As earlier stated, disruptors in tests of resistance to change must be applied equally to all components under measurement. With the two processes of extinction, only the first can be assumed to apply equally to the components. The second process of extinction is more complicated, as the alteration of the stimulus condition inherently differentiates between the components. For, responding to stimuli formerly associated with more frequent, or richer, schedules of reinforcement would be exposed to lack of reinforcement sooner than responding maintained by a leaner schedule of reinforcement. This study was based around the partial reinforcement of extinction effect and was a comparison of the differences between continuous reinforcement (CRF) and intermittent reinforcement. It is now believed there exists a continuum of extinction (McLean & Blampied, 1995) and thus, the results above are applicable to discussion of the discriminability of rich versus lean schedules of reinforcement.

A further important area of study has produced results which do not support Nevin's (1974) generalisations about resistance to change. This area is the disrupting effects of pharmaceutical agents. Cohen (1986) conducted an experiment with several conditions in which the disrupting variables were d - Amphetamine Sulfate, Sodium Pentobarbital, Haloperidol and Cholacystokinin - Octapeptide. The maintaining schedules were varied, and included chained random interval, multiple fixed interval and multiple random interval schedules of reinforcement. Based on previous resistance to change studies it was expected that the drug disruptors would show greater effect in the initial, as opposed to the terminal, links of the chained schedules, and would also disrupt responding more in the schedule component maintained by the leaner schedule of reinforcement. The results of this experiment however showed that the effect of the drugs was not differentiated between the initial and terminal links, or the lean and rich schedules of reinforcement. Cohen also incorporated a standard series of conditions in which the disruptor used was extinction. In these tests of resistance to change responding was disrupted as in Nevin (1974). That is, the components that were maintained by richer reinforcement schedules maintained performance that was more persistent in the face of disruption than did those components with a leaner schedule of reinforcement (Cohen, 1986). Thus, the tests with extinction as the disruptor acted as a control by illustrating that the experimental design was not at fault.

This conclusion, that drug effects do not reveal differential resistance to change, must be tempered by further studies in which the disrupting effects of pharmaceutical agents differed and which showed disruption effects that concur with those of Nevin's original hypothesis,(eg.Harper, 1995). Thus, the study of pharmaceutical agents as disruptors in tests of resistance to change is an area that requires further experimental attention.

Schedule context:

There are a number of other experiments which have produced results that are inconsistent with the resistance to change hypothesis. For example, Cohen et al (1993) failed to gain results that were consistent with those of Nevin et al (1981) with the introduction of response-independent food within the components of a multiple FR FR schedule. They established baseline responding in a multiple schedule with rat subjects and then disrupted this responding with the introduction of VT response-independent food during the component. This disrupted responding, but the change was not consistent with those predicted by the resistance to change hypothesis (Nevin, 1974). There was no consistent difference in the resistance of the richer or leaner schedules to disruption.

This, and some other experiments (eg Harper & McLean, 1992; McLean & Blampied, 1995; Cohen et al, 1993 (Expt. 3)), while inconsistent with Nevin's hypothesis, are useful in furthering the understanding of resistance to change by providing evidence which may be utilised to establish the boundary parameters of testing for resistance to change.

Cohen et al (1993) constructed a further series of experiments in an attempt to place these results in context. For example, it was assumed that a difference may have resulted from the use of rat subjects and simple schedules whereas most of Nevin's research has been conducted with pigeons responding on multiple variable-interval schedules. Thus, as part of a comprehensive study on resistance to change Cohen et al (1993) designed a series of experiments using both pigeon and rat subjects responding under a variety of maintaining schedules of reinforcement. Cohen et al (1993) replicated the design of the Cohen, Furman, Crouse & Kroner (1990) study and also extended the conditions in order to include pigeon subjects and both fixed and variable and ratio and interval schedules. This study served to further confirm the trend established in the earlier (Cohen et al, 1990) study. That simple schedule research represents a special case of the relationships established between the stimulus, response and reinforcement. The results showed that the evidence from simple schedule research did not support Nevin's (1974) generalisations about the resistance to change hypothesis.

Cohen et al (1990) used rat subjects on fixed ratio (FR) schedules of reinforcement. The schedule values varied, across conditions, between FR 40 and FR 240. Testing for resistance to change was conducted with the introduction of response-independent food within the schedule, and also with extinction conditions. Predicted results were that the richer schedule of reinforcement would be less affected by the disruptors than would the schedules maintained by lean schedules of reinforcement. However, actual results showed that the introduced response-independent food actually disrupted the various schedules to a similar extent. Also the findings for extinction ran opposite to those expected, with the greatest disruption observed in the component with the richer schedule of reinforcement.

Multiple schedules expose subjects to two or more components, for a short time period in succession, with each individual component signalled by an independent stimulus. In contrast, simple schedules expose subjects to the same schedule for long periods before a change is made. Within these schedules there is no discriminative stimulus, as the subject is exposed to only one schedule which is signalled by one stimulus. In addition, when the schedule is altered the stimulus is transferred to the next schedule. This difference raises an important, fundamental question regarding resistance to change and the relationship to the reinforcement obtained in a schedule and the stimulus that signals that reinforcement. For, if it is the absence of discriminative stimuli that contributes significantly to the lack of differential disruption in leaner components in testing, this suggests that the resistance of a response to disruption must rely in some way upon the stimulus that signals forthcoming reinforcement in a component.

The importance of discriminative stimuli in the assessment of resistance to change is illustrated in two important simple schedule studies. Hancock and Ayres (1974) established rat subjects responding on alternate schedules of differing sucrose concentrations. The schedules were alternated daily and the stimuli that signalled each of the schedules remained unchanged.. Thus, the same stimuli signalled both of the schedules. When the subjects were exposed to a tone and aversive electric shock pairing, responding was equally suppressed in both of the schedule conditions. However, a further study conducted under similar conditions found that the responding maintained by the richer concentration of sucrose was more resistant to change than was that in the leaner schedule (de Villiers & Millenson, 1972). The important difference between these experiments was that de Villiers and Millenson (1972) used different stimuli for each of the schedules. Although these studies were not formal tests of resistance to change, the effect was the same with aversive shock acting as a disruptor. Thus, the results are applicable to the study of resistance to change. The importance of the discriminative stimuli in testing for resistance to change suggests that the relationship between resistance to change of a response and the reinforcement that response receives depend upon the stimulus that signals that schedule of reinforcement. This finding contains an inherent assumption of the existence of Pavlovian, stimulus-reinforcer processes underlying the strength of an operant response. This point will be discussed at length later in this paper.

A final area of research that does not conform to the established pattern of resistance to change as a stimulus-reinforcer contingency is that of studies employing concurrent VI VI schedules.

Resistance to change in concurrent schedules.

Catania (1963) reported that responding on two keys in a concurrent schedule is independent, and approximates equalisation between the rate of responding on a target key and the rate of reinforcement received on that key. Catania also showed that the reinforcement scheduled on both of the keys in a concurrent schedule interact to determine the rate of responding on a given key, but that response rate on either key was independent of response rate on the other. Thus, there is a negative relationship between the rate of reinforcement on one key and the rate of responding on the target key. Therefore as the rate of reinforcement increases on the other key the rate of responding on the target key decreases. These findings were confirmed by Nevin et al (1990). However the analysis of the comparative resistance to change over the two keys in the one component with both scheduled and alternative reinforcement - Component A (Expt.2) - revealed a differential in the resistance of the two keys in the same component. This finding is problematic for resistance to change proponents as the Pavlovian, stimulus - reinforcer explanation of resistance to change dictates that the overall reinforcement rate in a given stimulus condition determines the resistance of the behaviour. As a result the expected outcome of the analysis of the two keys in the component is that they possess equal resistance.

For resistance to change to gain acceptance as a measure of the strength of a response it must be shown to fluctuate with the rate of reinforcement in maintaining schedules. The result of the assessment of the keys in Component A; that the leaner target key with 15 reinf/ hour showed greater resistance to change than the other key with 45 alternative reinf/ hour, suggests that there are further influences in the resistance to change of responding in concurrent schedules.

Rationale for the current study

Initial attempts to explain the problem posed by the apparent discrepancy between the state of knowledge regarding resistance to change and the results of component A in the Nevin et al (1990) study, focussed upon a possible location-reinforcer effect in concurrent schedules. Nevin (1992a) incorporated a location-reinforcer contingency into his quantitative theory of behavioural momentum. The first of the equations presented here is a quantitative formula for the analysis of two schedule components:

$$(m1/m2) = (rc1/rs1/rc2/rs2)a * (rk1/rs1/rk2/rs2)b. \qquad \text{[Equation 7]}$$

Where (m1/m2) represent the resistance ratios; (rc1 & rc2) are the rate of reinforcers received in the presence of the two components; (rk1 & rk2) represents the reinforcer rates correlated with key location and (rs1 & rs2) the overall session reinforcer rate. The exponents, a and b, represent the relative control by the component stimuli and the keys on which they are arranged. This formula may be simplified when applied to different experimental designs. For example, if applied to different components in the same experimental condition then the overall session reinforcement rate (rs1 = rs2) cancels out. Further, if applied to a two component multiple schedule arranged on the same key then the ratio (rk1/rs1/rk2/rs2) cancels leaving,

$$\log (m1/m2) = a \log (rc1/rc2). \qquad \text{[Equation 8]}$$

or $$m1/m2 = (rc1/rc2)a.$$

In terms of two key multiple concurrent schedules the differential resistance to change exhibited between keys in component A of Nevin et al 1990 is explained with the inclusion of the location reinforcer rates. Thus, because left key was correlated with greater cross-component reinforcement it follows that the resistance to change will be greater on this key. Nevin's (1992) analysis of past research supported this. This finding however is the result of the retrospective design of an equation upon which to fit data. Thus, this does not constitute a specific test of the effects of a possible location-reinforcer effect. A specific test of this effect was conducted by McLean, Campbell – Tie, and Nevin (1996). This will be discussed later in this section.

The issue of a location-reinforcer effect is of great importance because if it is a factor in the resistance to change of concurrent schedules as is suggested by Nevin's analysis (1992a), then this raises doubt as to the effectiveness of the prevailing Pavlovian explanation of the processes involved in resistance to change. For, if the location of a response key does affect the resistance to change of a target response then it must be assumed that there is also an operant influence at work in the formation of resistance to change of responding. The location of a key is present at all times in an experimental condition and thus, is not stimulus specific. The same is not true for multiple schedules as these schedules arrange components successively. In these cases the subject is restricted to responding in one component before the next component is made available. Thus, for an effect to be apparent, it follows that there is a relationship between the responses performed on a key in one location as opposed to the other key in a different location - therefore establishing a response-reinforcer contingency.

McLean et al (1996) designed an experiment to test the effect, if any, of a location-reinforcer contingency. This study established responding on two key multiple concurrent components and the reinforcer totals for each key, summed over components were varied. Component 1 was established with the rate and the cross key distribution of reinforcers held constant. Component 2 however, maintained the same total cross key rate of reinforcement but varied the distribution of these reinforcers between the keys. If as asserted the location of the keys in concurrent schedules acts as a stimulus, a differential would have become apparent in testing for resistance to change. However no such effect was apparent in the results. McLean et al concluded that there was no effect of the location from whence the reinforcers were signalled. These results were confirmed study conducted by Rau, Pickering and McLean (1996) varying the magnitude of the reinforcement to assess a possible effect of the location of the keys.

These results raise an interesting question regarding the difference in resistance to change results from tests with multiple schedules and those which employ concurrent two-key multiple schedules. It is well documented that there exists a clear positive relationship between the rate of reinforcement in a given multiple schedule component and the resistance of responding to change in that component. To explore these differences it is important to look at the differences in design between multiple and concurrent schedules.

There are two important differences between multiple and concurrent schedules. Firstly, one difference between concurrent and multiple schedules is one of the presentation of the stimuli. In multiple schedules, because of their design, the stimuli for the components are never present at the same time. For, as noted, the components are successive and follow one after the other. In concurrent schedules however, the stimuli that signal the components are programmed to different keys that are present at all times. In these schedules subject is “free” to change between schedule components

The second important difference between multiple and concurrent schedules is one of the local rates of reinforcement received in a component. Multiple schedule components are of a fixed duration and subjects are restricted to responding in that component until the component is complete. Local rates of reinforcement are therefore unequal by design. In contrast concurrent schedule components run at the same time and subjects are able to change between the components at any time. Thus, the local rates of reinforcement are equal in the components. Expressed in terms of time allocation this difference is denoted by the following equation:

$R1/T1 =\backslash= R2/T2$ for multiple schedules; [Equation 9]

$R1/T1 = R2/T2$ for concurrent schedules.

Where R is the reinforcement, and T is time spent responding in a component.

Resistance to change has been shown to adequately define and thus "measure" the strength of responding in multiple schedules. However, concurrent VI VI schedule responding has yet to be defined in the same way. It is therefore important to determine a method for isolating and neutralising this difference in the design of multiple and concurrent schedules – that of local rates of reinforcement.

Two questions are asked by the present research:

(1) Is there an effect of the difference in the presentation of the stimuli between concurrent and multiple schedules?

(2) What is the role of local rates of reinforcement in determining resistance to change?

Thus in this study, we explore a further implication of the equation:

$m1/m2 = (rc1/rc2)a.$ [Equation 10]

Data on the first question had been collected in the behavioural psychology lab

(University of Canterbury) when the author commenced work, and will be analysed here. With regard to the second question a possible method is outlined in a recent study investigated responding in concurrent schedules (Todorov, Souza, & Bori, 1993). This study arranged a concurrent schedule onto a single key. A second changeover key allowed subjects to "switch" between components. Todorov et al added a minimum inter-changeover time constraint (MICT) on this changeover key . The addition of the MICT in the concurrent schedule succeeded in transforming performance to model that of the type expected from a multiple schedule. That is, they found that when set at values above a minimum (50s) the MICT was successful in creating unequal rates of reinforcement in the concurrent schedule and produced responding patterns of the type more commonly associated with multiple schedules.

METHOD

Subjects:

Four homing pigeons, with prior experience in concurrent schedules arranged with the Findley procedure (see Findley, 1958), were maintained at 80 - 85% of their free feeding weights. Subjects were housed individually, with water and grit continuously available in the home cages. Subjects were fed, to ensure weight maintenance, at the end of each daily experimental session.

Apparatus:

Four similar experimental chambers, 34cm by 34cm by 34cm, were used with each subject always trained in the same chamber. Each of the chambers contained an interface panel with three response keys. The active keys were the left hand side key and the centre key. Both components of the concurrent schedule were programmed on the left hand side key. The centre key acted as the changeover key. A hopper containing wheat was mounted 6cm from the floor of the chamber, and was operated and lit with white light for three seconds during reinforcement. Scheduling and recording of all experimental events were accomplished using an IBM386 - compatible computer running MED - PC software.

Procedure:

Subjects were trained in 45 minute sessions seven days a week. A two - component concurrent schedule was programmed on the active response key. Subjects could switch between components by pecking the changeover key. Pecks on this changeover key incurred a short changeover delay of 3s. This changeover delay has previously been shown to reliably eliminate adventitious reinforcement of changeovers (Herrnstein, 1961). The response key was illuminated with the stimulus representing a given component until the subject responded upon the changeover key. After a changeover response was emitted, the stimulus key would then show the colour stimulus of the other component in the schedule.

The concurrent schedule was in effect for periods of 60s at a time, and was then suspended during a blackout period. This blackout lasted for a duration of 30s. During these periods the chamber was darkened and the response keys were inoperative. In the sessions of the experiment when the resistance of the subjects responding was assessed, these blackout periods presented the opportunity to present the subjects with the response - independent food that was used as the disruptor in this experiment. In the sessions that did not test the resistance of responding to change these blackouts periods merely represented periods during which the reinforcement was suspended. During this time the response key was also inactive.

Each of the components in the concurrent schedule were signalled by a separate, discriminative stimulus. In each component, a VI schedule was used to maintain responding. The VI schedules were 12 intervals taken from the Fleshler and Hoffman (1962) progression. The individual components were VI 80 s and VI 240s for two subjects (C5 and C6), and VI 60 and VI 180 schedules for the remaining two subjects (C7 and C8). The values of the maintaining schedules of reinforcement were established on the basis that the four subjects at these two levels of reinforcement produced similar overall levels of responding. Another feature of the schedule difference is the arranged reinforcer ratio which was 3:1 for all of the subjects.

An important procedural feature of this experiment is the incorporation of a reversal. The introduction of response-independent food - that presented in the black-out periods programmed into the sessions- was delivered at two levels. This response-independent was presented at rates of 50 reinforcers per session and 100 reinforcers per session in separate tests lasting for eight sessions. This presentation was on a random interval schedule. The VI schedules used in components were then reversed. Therefore after the reversal the stimulus that formerly signalled the richer component in the schedule was then correlated with the leaner schedule of reinforcement. Two further tests of resistance to change were then conducted. This reversal was incorporated to determine any effect of particular stimuli upon resistance to change.

A summary of the different conditions of the experiment is presented in Table 1. Before resistance testing began, subjects were exposed to the condition until responding stabilised, showing little day to day variation. Training to baseline before teat one was for a minimum of 26 sessions. Data from the last five sessions were then averaged and taken as representative of baseline performance, against which the tests of resistance to change could be assessed. In each condition testing involved the introduction of response-independent food when the response keys were darkened. As stated, this response-independent food was introduced at two rates. For the first test this rate was 100 reinforcers per session and in the second test (after a minimum 30 sessions of training) it was 50 reinforcers per session. Thus, a pair of tests represented one full assessment of resistance to change. After the first presentation of the dark key food the subjects were returned to the baseline schedules of reinforcement until again asymptote responding was achieved. Then again the subjects were exposed to the second of the two levels of dark key food.

Table 1.1:Table of Conditions

Variable-interval schedules in Component 1 and Component 2 for each bird in each condition with the colour of the stimulus on the response key indicated. The minimum number of training sessions given prior to each resistance to change test is also given.

Series 1: Changeover key VI 0s

Test 1: high rate: Mean = 100 reinforcers per hour.
Test 2: medium rate: Mean = 50 reinforcers per hour.

Subject	Component 1	Component 2	Min. sessions	Min. sessions
	Green key	Red key	before Test 1	Before Test 2
C5	VI 240	VI 80	40	49
C6	VI 240	VI 80	33	30
C7	VI 180	VI 60	26	30
C8	VI 180	VI 60	35	30
Reversal	**Red key**	**Green key**		
C5	VI 240	VI 80	38	42
C6	VI 240	VI 80	50	42
C7	VI 180	VI 60	50	42
C8	VI 180	VI 60	50	42

Table 1.2 Series 2 : Changeover key VI 60s

Test : 1 high rate : Mean = 100 reinforcers per hour.
Test : 2 medium rate : Mean = 50 reinforcers per session.

Subject	Component 1	Component 2	Min. sessions	Min. sessions
	Green key	Red key	before Test 1	Before Test 2
C5	VI 240	VI 80	30	38
C6	VI 240	VI 80	30	38
C7	VI 180	VI 60	30	40
C8	VI 180	VI 60	30	43
Reversal	**Red key**	**Green key**		
C5	VI 240	VI 80	80	20
C6	VI 240	VI 80	80	20
C7	VI 180	VI 60	80	20
C8	VI 180	VI 60	80	20

In addition to the reversal procedure the subjects were also exposed to further experimental manipulation. This manipulation was introduced to assess the effects of time constraints upon the performance of the subjects in the pre-reversal conditions. The manipulation that was employed was the introduction of a constrained interchangeover time (CICT). According to which changeovers were impossible for, on average, 60 seconds after the last changeover. The CICT is an adapted method of modifying the concurrent schedule procedure to make it more closely resemble the conditions that prevail in multiples schedules (for review see Todorov, Sousa & Bori, 1993). For example, the time between the changeovers is restricted such that the subject must remain in a component until the CICT timer runs out. In this case the CICT was established using a variable interval 60 second schedule (VI 60s). This VI schedule comprised 6 intervals from the Fleshler & Hoffman (1962) progression. The CICT was introduced upon completion of the first complete series of resistance to change tests – i.e. after the reinforcement reversal. Subjects were trained in the modified concurrent schedule for a minimum of 140 sessions. Subjects were then responding in components similar to those in Condition 1, with the addition of the CICT VI 60 (see Table 1 Series 2 for CICT – VI 60s conditions).

Once the CICT was introduced, subjects were then exposed to the variation in the controlling schedule for a period until responding again reached an asymptote level. The last five sessions were again taken as a baseline against which the tests of resistance to change were to be assessed. Subjects were again exposed to pre- and post-reversal resistance to change tests using the same procedure as that employed in Conditions 1 and 2. As before the test was run in eight consecutive sessions. The average of these eight sessions comprised the data that was compared with that obtained from the last five baseline sessions of the experiment in each condition.

Thus, the eight resistance to change tests of the experiment formed two series. The first series, Conditions 1 and 2, provided data regarding the resistance to change of the performance of pigeon subjects responding in a Findley concurrent schedule. The second (Conditions 3 and 4) followed the same procedural outline as the first series if conditions. The addition of the CICT – VI 60s was the only difference between Series 1 and Series 2 of the experiment.

RESULTS

Series 1: Effects of response-independent food upon the resistance to change of concurrent responding (Conditions 1 and 2).

This series (see Table 2)explored the effect of response-independent food - that presented in the blackout periods - on responding in the components of the Findley concurrent schedules. The dark key (response-independent) food was presented at two rates. The first exposure of the dark key food was at the mean rate of 100 reinforcers per session. In the second test, the mean rate of presentation was of 50 reinforcers per session. After exposure to each of the two levels of the disruptor, the reinforcement schedules programmed in the presence of the two stimulus colours were reversed, and the tests repeated. The purpose of this reversal was to establish the effect of any preferences between the stimulus associated with a component upon responding in that component under disruption. That is, the reversal was employed as a means of determining the presence of stimulus bias.

Figure 1 (right column) shows the effects of introducing both rates of dark key food on the components. For each test, response rate is expressed as a proportion of the baseline rate of responding in each component. As is shown in Figure 1, the data for the four subjects shows that responding on the richer schedule appears more resistant to the introduction of response-independent food, at both rates. At the higher rate of response-independent food this effect is greatly reduced for subject, C5.

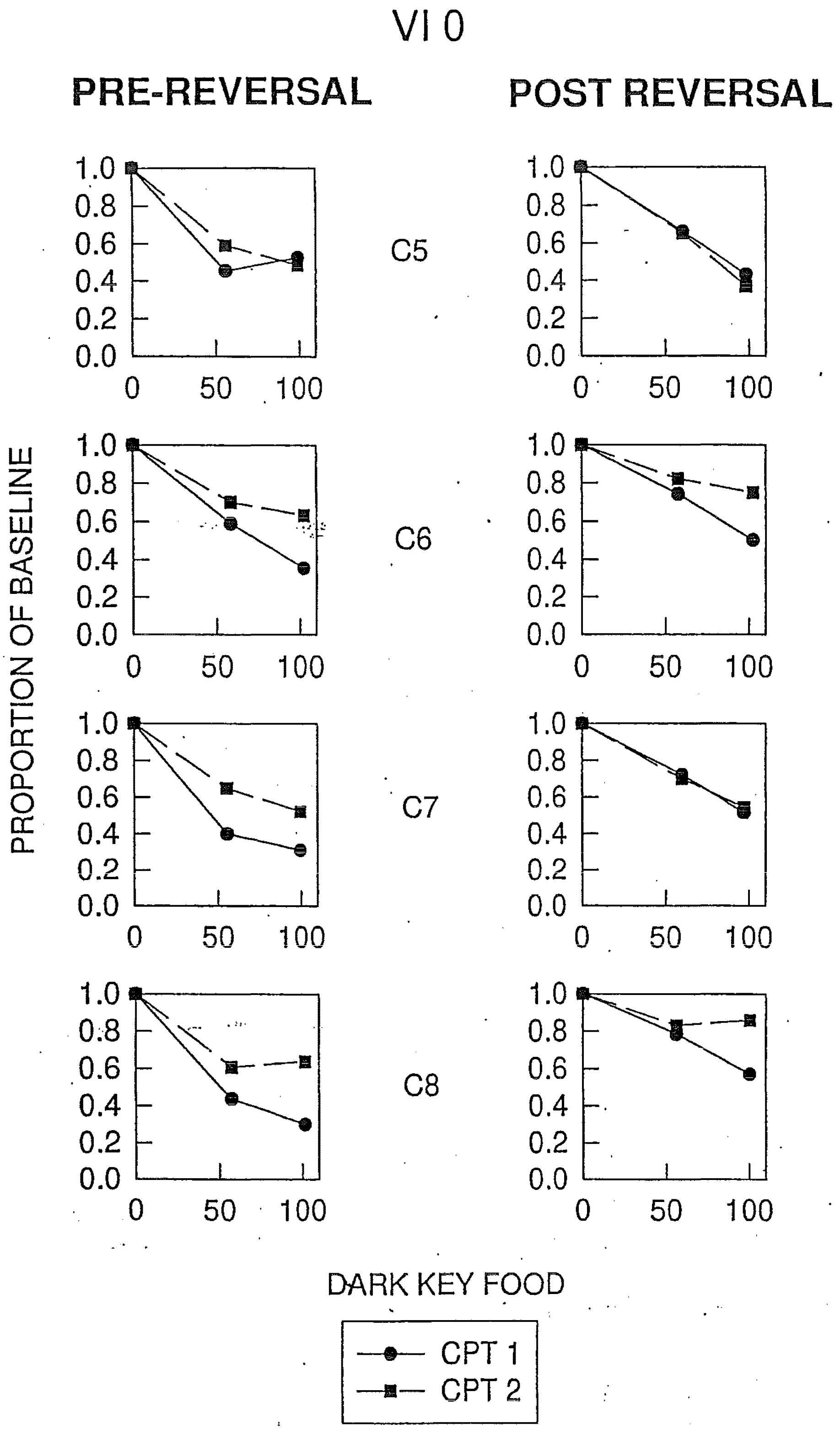

Figure 1: Responding in each component of the concurrent schedule as a function of the rate of response-independent food given in the test of resistance to change. Response rates are expressed as proportions of baseline. The concurrent schedule was arranged on one key. This figure shows responding in the Findley concurrent schedule with no constrained interchangeover time on the changeover key. In the right column the circle symbols represent the lean component (VI 240s for subjects C5 & C6; VI 180s for subjects C7 and C8) and the squares represent the rich component (VI 80s for subjects C5 and C6; VI 60s for C7 & C8). The left column shows results from the reversal procedure.

Condition 2 (see Table 3)of this first series of the experiment represents a reversal of Condition 1. Thus, the stimulus that previously signalled the lean component now signalled the rich component. The purpose of this reversal was to assess the effect, if any, of the colour of the stimulus upon the resistance to change of responding in that component. Subjects were trained in the reversal for a minimum of 32 sessions before the first resistance test was conducted. Figure 1 (right column) shows, the previous separation of the components representing a differential in the resistance to change between the two components is nullified when the reversal is imposed. The post-reversal data show no consistent differential between components. Two of the subjects, C5 and C7, show no difference in the resistance of responding to change with the introduction of response-independent food. The remaining subjects show slightly greater resistance in the lean component over the rich component. Further, this difference is manifest only with the introduction of the higher rate of response-independent food. This finding is in opposition to that forecast by behavioural momentum theory. Further, the effect is very slight and, overall, is not conclusive. Therefore the most that can be concluded from the data in Figure 1 is that there existed stimulus effects upon the resistance of responding to change in this concurrent schedule for at least two birds. For subjects C6 and C8 resistance to disruption was greater in the component that was previously correlated with the rich component, but in this condition signalled the lean component.

Series 2: Effects of introducing a constrained inter-changeover time (CICT) (Conditions 1 and 2).

Figure 1 showed data from conditions with no VI schedule operating on the changeover key. Figure 2 shows data from the second series of this experiment, in which a changeover time constraint was imposed. This prevented the subject from changing components of the schedule for, on average, 60s after one had been selected. Figure 2 shows responding on each schedule, expressed as proportions of baseline in Series 2 of the experiment. Data for the pre- and post-reversal of reinforcement schedules are shown in different columns. The overall results from Figure 2 show that there is again no clear pattern in the effect of response-independent food on the components in either the pre- and post-reversal conditions.

Prior to reversal, the data for subject C5 show a separation of the components suggesting that Component 2, the richer of the two components, possesses greater resistance to change than the leaner component, Component 1. C6 also shows some separation of the two components, again with richer component exhibiting greater resistance to change, but the separation is strong only for the lesser rate of response-independent food presentation. When the rate of response-independent food was increased, the difference between the two components is reduced. The figure for C7 shows no clear resistance differential, as is the norm for responding in concurrent schedules. The data for C7 show that both components of the schedule were affected almost equally by the introduction of the disruptor. This is true for both rates of the disruptor presentation. The results for C8 show a very interesting development. The presentation of the lesser rate of response-independent food appears to have produced a sizeable *increase* in the response behaviour of the subject.

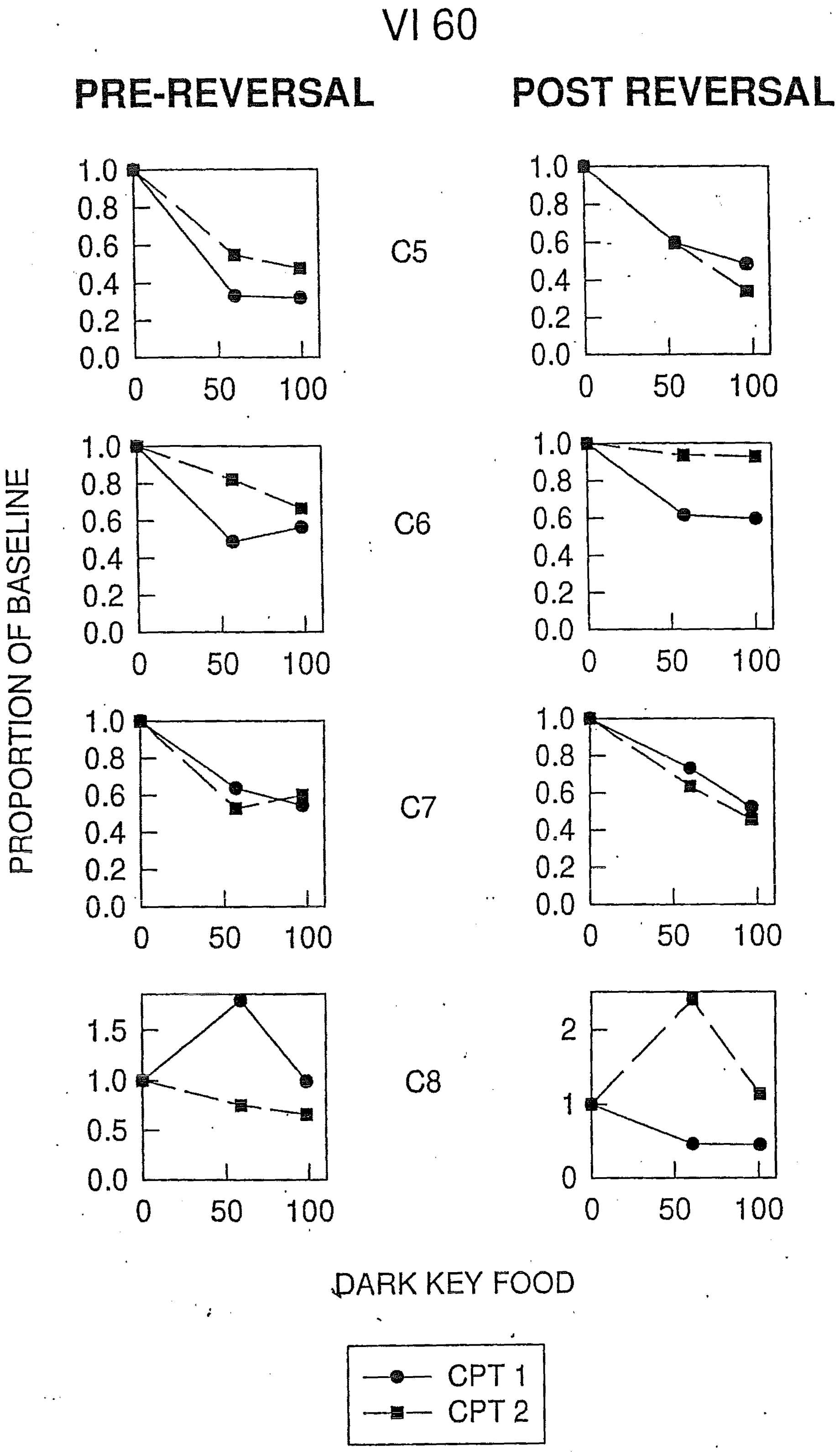

Figure 2: Responding in each component of the Findley concurrent expressed as a proportion of baseline. Proportions of baseline are plotted as a function of the introduction of response-independent food. This shows the results from Series 2 with the constrained interchangeover (VI 60s) time imposed. The figures in the left column are for the pre-reversal condition. The circle symbols represent the lean component. The square symbols represent the rich component. As with the figures for Series 1 (Figure 1) the right column shows the result of the experimental reversal. The symbol-reinforcement relationship is thus inverted

Responding in the presence of the disruptor in the lean component increased to a level of approximately 0.7 times greater than that exhibited in baseline conditions. This occurrence is unusual as it is contrary to the expected results for responding in both multiple and concurrent schedules of reinforcement. Previous studies (see Nevin, 1974; 1983; Nevin et al., 1983 etc.) have shown that the introduction of response-independent food decreases responding in a given multiple schedule component. Most commonly, in both concurrent and multiple schedules the greater the presentation of disruptors the greater the decrease in responding (see Catania, 1963). However, for C8 the high rate of response-independent food, had only a minimal decreasing effect in the lean component. The rich component of the schedule produced results slightly more consistent with those most often described. However, here also the decrease was very minimal. It appears that these results are subject specific.

Post-reversal, (right column) the proportion of baseline data reveal that for two of the four subjects, there is no discernible differentiation between the components in resistance to the introduced disruptors. For subject C5, the separation between the components that was apparent in the pre-reversal conditions with the CICT VI 60s was not apparent when the relationship between the schedules and the stimuli were reversed. Thus it may be concluded, as with the series with CICT VI 0s, that the separation effect was the result of some bias toward that stimulus colour. This raises doubt that the effect in the pre-reversal series was due to the stimulus-local reinforcer rate contingency. C7 in both pre- and post-reversal conditions exhibited no substantial stimulus effects, and the resistance of the individual components was so similar as to suggest no differential between the two arising from stimulus-local reinforcer rate contingencies.

The results for C6 show some separation of the components, with the rich component showing greater resistance to change for both rates of the disruptor presentation in pre-reversal conditions. The right column results show that this was evident after the reversal. Further, the component which showed greater resistance to disruption was the lean component - now signalled by the stimulus previously associated with the rich component. Thus, the results for C6 conform to the earlier pattern (Condition 1) in showing stimulus effects. The remaining subject, C8, again produced interesting, if unusual results. With the introduction of the disruptor, the response rate in the lean component actually increased to a rate that approximated an increase of 1.5 times that recorded in baseline conditions. This increase was however only apparent with the lower rate of response-independent food. The greater rate of response-independent food produced responding that very high but less than that observed in baseline. A further feature is that this occurred in only one component of the schedule. In both the pre- and post-reversal conditions the increase affected only the lean component of the schedule.

Quantitative Analysis

Figure 3 (see Table 4 for data)shows the log mass ratio of responding in the two components, plotted against the log ratio of the rates of reinforcement. This figure presents the data with CICT VI 0s and that of CICT VI 60s in separate columns for the sake of comparison. The log ratio of reinforcement is calculated by dividing the obtained rate of reinforcement in Component 1 by that in Component 2. The logarithm of the resulting figures for each condition is then taken (log (R1/R2)). This procedure is followed for each of the eight conditions of the experiment. For each of the two pre-reversal and post-reversal conditions the log ratio of reinforcement was then averaged. Thus, the above shows the

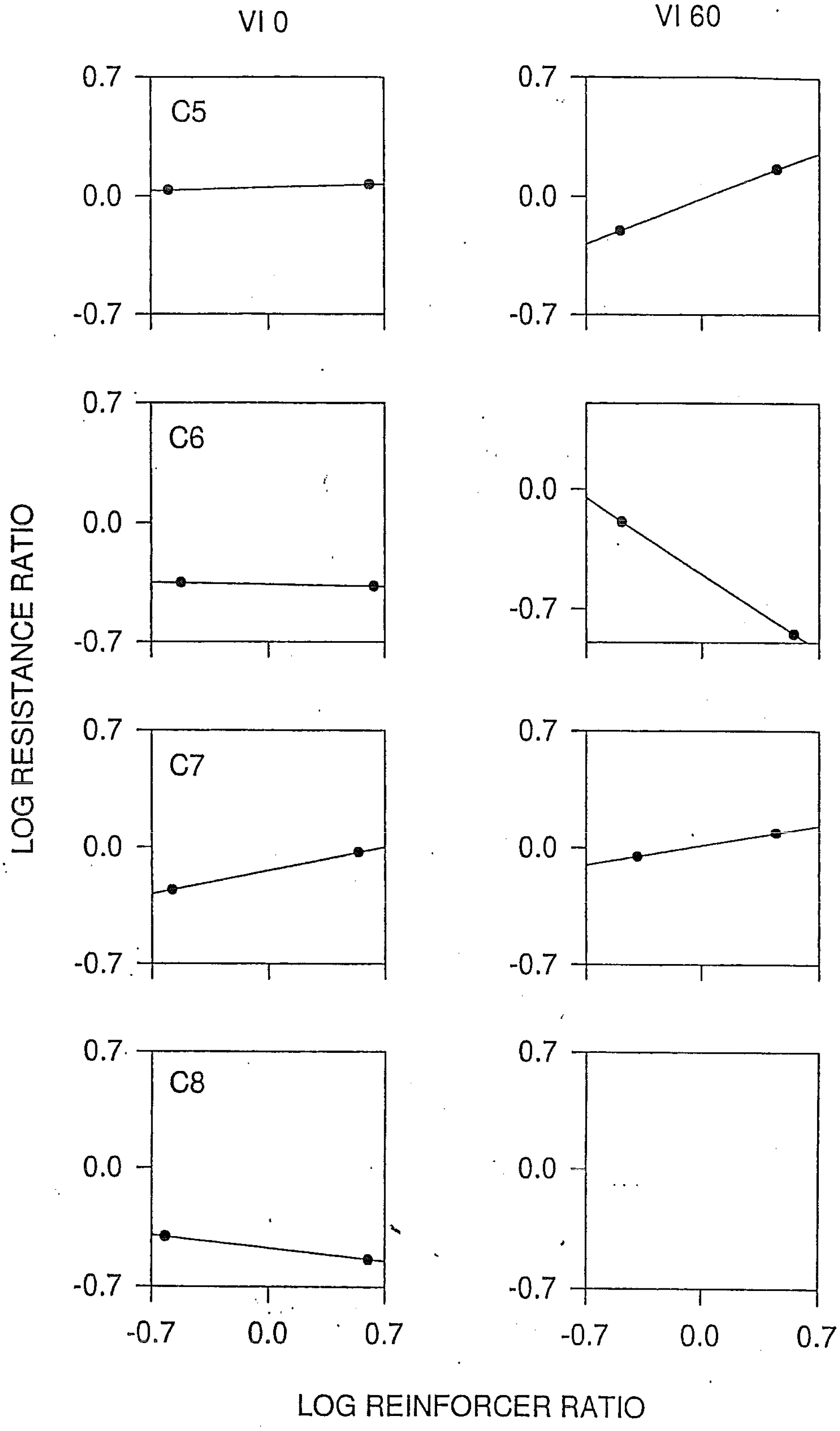

Figure 3: Log resistance ratios (log(m1/m2)) plotted as a function of log reinforcement ratios (log (R1/R2)). The slope of the line quantifies the effect on resistance to change of the reinforcer ratios. The position of the line in the figure shows the relative stimulus effect. The negative log reinforcer ratio plot represents the pre-reversal and the positive log reinforcer ratio plot represents the post-reversal data. The left column shows data with VI 0s (or no time constraint) on the changeover key. The right column shows data with a CICT VI 60s on the changeover key.

figures for the first two conditions (CICT VI 0s) in the left column of the page and the figures for the remaining two conditions (CICT VI 60s) in the right column.

The log mass ratio of behaviour was calculated from the obtained rates of responding in the two components in the presence of both rates of the disruptor. The logarithm of this rate of response was calculated and plotted against the rate of presentation of the response-independent food, and a regression analysis was performed. From this curve fitting procedure the slope of the function relating log rate of response to rate of free food was obtained. This slope data was obtained for each component for each condition of this experiment. The slope for Component 2 was then divided by the slope for Component 1. The logarithm of the resulting ratio of slopes was then obtained.. This procedure was carried out for each condition of the experiment. The log mass ratio represents a measure of the relative resistance to change (at both disruption levels) of responding in the two components. For example, a negative log mass ratio indicates that the resistance to change in Component 2 was greater than that in Component 1.

In Figure 3 (left column) there is no consistent pattern in the relations between log mass ratio and the log ratio of reinforcement. This shows that the ratio of reinforcement exerted no consistent control over the log mass ratio - or resistance ratio. In each case the pre-reversal condition is represented by the negative log reinforcer ratios. The post-reversal condition is represented by the positive log reinforcer ratios. Overall, the figures for subjects C6 and C8, show stimulus effects that relate to the colour of the stimuli.

The right column data (with CICT VI 60s) for C6 show, further to this effect show a negative slope. The direction of this slope indicates that the stimulus that signalled Component 1 before the reversal and Component 2 after the reversal generated greater resistance to change than the other stimulus, for reasons other than the stimulus-reinforcer explanation of resistance to change. The experimental design established the lean reinforcement schedule with Component 1 before the reversal and Component 2 after the reversal.

Subject C8, in keeping with the unusual proportion of baseline data, exhibited behaviour that prohibited analysis of the log mass ratio and the log ratio of reinforcement data. In the regression analysis of the proportion of baseline data a problem became apparent. Due to the increase in responding that was observed with the introduction of the disruptors, the regression analysis produced slope values that could not be utilised in the resistance ratio formula. This was the result of a combination of a very strong negative slope and a slight positive slope. In the process of dividing Slope 2 by Slope 1 the extreme negative slope was reduced. However, the output was still a negative value. From this it was not possible to obtain a logarithm value. Consequently, it was not possible to produce a post reversal plot for this subject. This is the reason for the absence of a figure for CICT VI 60s for subject C8.

The figure for subject C7 confirms the proportion of baseline data showing modest differentiation between the components both with the CICT VI 60s and the CICT VI 0s. The slope of the data for C7 indicates that the reinforcer ratio positively affected the resistance ratio for this subject. The figures for CICT VI 0s and CICT VI60s show that in each case the rich component, exhibited greater resistance to change relative to the lean component. Therefore, although there is little apparent difference with the introduction of the time constraint on the changeover key, the data for C7 conform with those that we might expect in the context of behaviour momentum. This effect however is very slight and can not be assumed to be conclusive.

The figure showing the CICT VI 0s (left column) data for the remaining subject, C5, presents a flat line that passes through zero. This shows that the log mass ratio was unaffected by the reinforcement ratio. Thus the reversal of the correlation of the stimulus to reinforcement for this subject produced no effect indicating, as expected from Figure 1, an absence of differential reinforcement ratio control over the resistance ratio. This implies that for this subject resistance to change was equal in the two components. The next (right column) figure, showing the data (see Table 5) with the CICT VI 60s is very interesting. The positive slope indicates that the pre-reversal Component 1(relative to Component 2 was less resistant to change than was the post-reversal Component 1 (relative to Component 2). This is very interesting as it suggests that the introduction of the CICT has separated the rich and the lean components of the schedule. For in the pre-reversal conditions Component 1 was the lean component and in the post-reversal conditions Component 1 was the rich component. For this subject the implementation of the minimum interchangeover time constraint induced response behaviour that would not be unusual for results of a standard multiple schedule experiment. The data for this subject concur with behaviour momentum expectations. Thus, it appears that the introduction of the CICT was successfully generated differential resistance to change between the rich and lean components of the concurrent schedule.

Figure 4 represents a repeat of the above process - that followed to attain the log mass ratio for responding, using local rates of responding and reinforcement. The local rate of responding is the number of responses in a component divided by the amount of time spent in that component (i.e., B1/T1). It is important to note that the local rate of responding, as calculated by the above procedure, equates to the analysis of responding in multiple schedules. For, in multiple schedules the rate at which a subject responds in a component is always the local rate because the subject must respond in a component until the timer for that component expires. Thus, the above calculations allow for the direct comparison of response patterns in concurrent schedules with those found in multiple schedule studies.

The log mass ratio was obtained from the log of the local rates of responding. This was plotted against the rate at which the response-independent disruptors were presented. Again, a straight line was fitted to the resultant plot. The slopes of these lines were divided as before to give the log mass ratio. The log local ratio of reinforcement was also assessed for each condition of the experiment. The local rates of reinforcement are calculated from the amount of reinforcement that a subject received divided by the amount of time spent in that component (i.e., log R1/T1).

Figure 4 presents the data, in graphical form, for pre- and post-reversal conditions for both the series with CICT VI 0s and CICT VI 60s. The most apparent difference between the CICT VI 0s and CICT VI 60s figures is that of the separation of the log ratio of reinforcement between the pre- and post-reversal conditions. The data with CICT VI 0s (left column) show the log local rate of reinforcement shows very little difference between the pre- and post-reversal conditions. This is interesting because this shows that the reversal of the correlation of the stimulus with the reinforcement schedule components had little effect

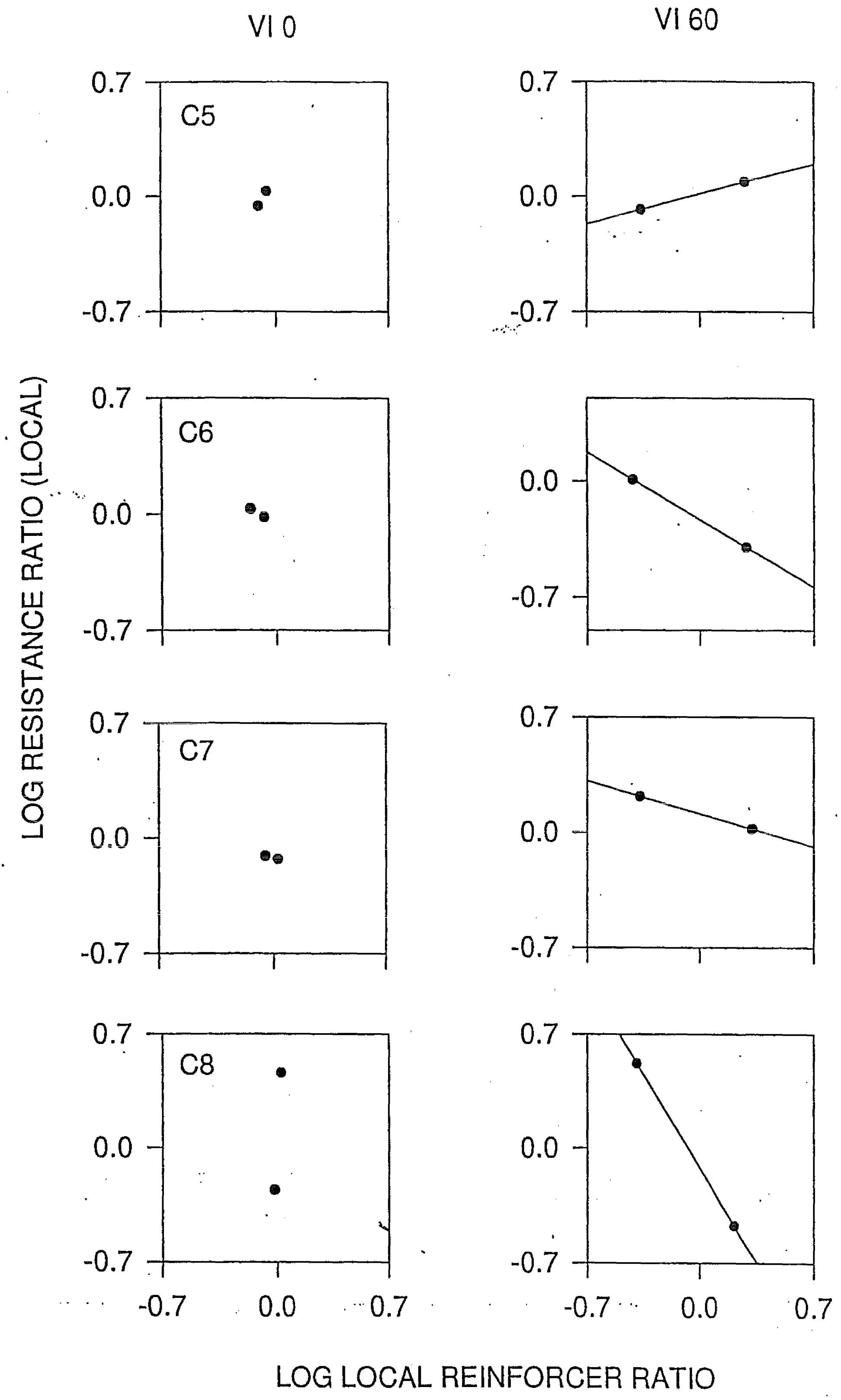

Figure 4: Log resistance ratios plotted as a function of the log reinforcer ratio. Local rates of responding and reinforcement were used to compute ratios. However, in this data the local rates were assessed by dividing obtained reinforcement, and responses made, by time spent in a component. The axes represent the log local resistance ratio – x-axis, and log local reinforcer ratios - Y-axis.

upon the obtained ratio of local reinforcement rates. The column showing the data with the introduction of the CICT VI 60s (right column) represents a clear separation in the log of the obtained ratio of reinforcement. Thus, the CICT successfully produced unequal local rates of reinforcement in the concurrent schedules

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Although the CICT successfully achieved unequal local rates of reinforcement as the left and right columns show respectively, this inequality was not manifest as a resistance to change differential. The figures in the right column show no consistent pattern of resistance to change between the subjects. This is evident from examination of the slopes of the right column figures. For example the slope of the data for subject C8 indicates that resistance to change was controlled by the local reinforcer rate ratios. However, the negative slope indicates that that this relationship is the inverse of that predicted by behaviour momentum theory. This suggests that performance in the component with the lean reinforcement schedule, when adjusted for time spent responding there, was more resistant to change. The data for Subject C7, with the CICT VI 60s shows a slight negative slope with overall positive log mass ratio which indicates that Component 1 showed greater resistance to change in both pre- and post-reversal conditions.

The fourth subject, C5, produced data that show a positive trend in the tests of resistance to change. Thus, the pre-reversal data shows that resistance to change was greater in Component 2 - in this case the rich component - and post reversal was greater in Component 1 (now correlated with the rich schedule of reinforcement). As with the analysis in Figure 3, the data here for the log mass ratio and the log local reinforcement ratio show that the introduction of the time constraint, with the one-at-a-time stimulus presentation, combined to produce differential resistance to change between the rich and the lean components.

The data presented above suggest that the experimental manipulations employed in this study successfully altered a typical concurrent VI VI schedule to produce conditions that are more typical multiple schedules. In terms of resistance to change, the expected results were found in the data of only one of the subjects - C5. The implications of this, and the other results will be discussed at length in the next section.

DISCUSSION

Nevin's (1974) resistance to change was proposed as an alternative to the previously predominant analysis of response strength, assessed in terms of the rate of response, and has shown great generality. In the most general terms resistance to change results from the relationship between the rate of reinforcement and a specific stimulus-defined environment. In comparative environments, most often represented by schedule components that arrange different rates of reinforcement, the component that presents the greater rate of reinforcement generally results in behaviour - or responding - that possesses greater resistance than another behaviour maintained or generated by a leaner rate of reinforcement and occurring in a different stimulus context. However, in order to replace response rate as a measure of the strength of responding, resistance to change must be shown to be reliably affected by reinforcement rates. That is, in environmental conditions that reinforce responses at different rates, the condition with greater reinforcement, must show greater resistance to disruption. If there are cases that do not follow this pattern then consideration must be given to the validity of resistance to change as a measure of response strength.

Resistance to change has exhibited considerable generality since the first studies (Nevin, 1974). For example Bousaz (1978) showed that the general principle was upheld when the disruptor used was aversive electric shocks. Harper (1995) showed similar findings with the use of pharmaceutical disruptors. Further studies have also shown that resistance to change is apparent with many different species of subject, from Nevin's (1974) initial pigeon studies, to Cohen et al's (1993) rat studies and also studies employing human subjects (Mace et al., 1990). The wide range of applications and confirmatory studies have provided excellent support for the use of resistance to change as a means of determining the strength of responding in subjects, and the processes by which this strength may be generated.

However, many of these studies were conducted with multiple schedules of reinforcement. Resistance to change in multiple-concurrent schedules has been shown to adhere to the same principles of the stimulus-reinforcer relationship as have multiple schedule performance. However, one of the most notable confirmatory studies (Nevin et al., 1990) also produced some results that raised the question of further influences at work in determining resistance to change in concurrent schedules. Component A of Part 2 of this study produced evidence of a differential in the resistance of two keys signalling the same multiple schedule component. In this case one of the keys was the target response key and the other was that with alternative reinforcement programmed upon it. This is very important because both keys in the concurrent schedule component share the same stimulus-reinforcer context and therefore the same overall rate of reinforcement.

This discrepancy in the results of resistance to change between multiple and concurrent schedules was initially attributed to the possible influence of an effect of the location of the key and the presentation of reinforcement (Nevin, 1992). Nevin (1992) attempted a quantitative analysis of the results of the Nevin et al (1990) and several earlier studies to assess whether the data would conform to equations that account for the results in terms of a location-reinforcer effect. The results of this study suggested that a location effect could be a factor in tests of resistance to change in concurrent schedules. However, a later experiment designed to specifically explore the location-reinforcer effect found that the location-reinforcer effect was not apparent in concurrent schedule (McLean et al., 1996).

Multiple versus concurrent stimulus - reinforcer contingencies.

This raises a very important issue regarding the differences between multiple schedules and concurrent schedules. Two of the differences between concurrent and multiple schedules have been identified and form the basis of the present study into the absence of differential resistance to change of components maintained by different rates of reinforcement in concurrent schedules. The first of these was that of the presentation of the stimuli that signalled the individual components in the concurrent schedule. The second difference is that of local rates of reinforcement. Firstly, traditional arrangements of concurrent schedules placed the individual stimuli that signalled the components on two separate keys. These keys were, by nature, spatially separated and were both continuously present during each experimental session. Thus, by the nature of the experimental design, the subject responded to one of two different keys that were always present. This meant that location was the only discriminative stimulus. The first series of this study explores the possibility that the exposure of the subject to both stimuli at all times during the experiment degrades the stimulus-reinforcer relationship that might otherwise develop between each component stimuli (ie. location) and the rate of reinforcement in that component at that location. To achieve this the design of the typical concurrent schedule needed to be altered. This study placed both of the stimuli on the same key. In this case the individual stimuli were different colours (red and green) that were presented one at a time and were dependent upon a changeover response to alternate. Pecks upon this changeover key changed responding from one component to the other by changing the stimulus colour on the response key. This was achieved using the Findley (1958) procedure.

The results shown in Figure 1 indicated that the efforts to mimic the stimulus presentation typical of multiple schedules did not produce results that could conclusively assert the one at a time presentation versus the continuous presentation of both stimuli was responsible for the lack of resistance differential between components in concurrent schedules.

The use of distinctive colour stimuli that were presented one at a time was not a determining factor in resistance of concurrent responding to change. This raises the possibility that the stimulus-reinforcer context of the two stimuli were the same, regardless of the different method of presentation. There are at least two possible reasons for this: Firstly, in this study the changeover key was lighted throughout the experiment. This raises the possibility that the experimenter defined colour stimulus was not the only stimulus associated with each component. This point will be further discussed at the end of this section. The second issue regards local rates of reinforcement. Concurrent schedules allow switching between components that have no formal temporal definition. As a result subjects tend to match the amount of time spent responding in a component to the amount of reinforcement received therein. Hence, the components are effectively reinforced at equal rates when time is taken into consideration. Thus, although one component is programmed with approximately three times the reinforcement of the other the performance of the subject equates the components in terms of reinforcers/time. It seems likely therefore that the Pavlovian contingency was the same for the two components because the local rates of reinforcement in concurrent schedules are effectively equal. Thus, the stimulus presentation may still be an important manipulation, but it may also be necessary that local rates of reinforcement differ between components.

Local rates of reinforcement.

The absence of conclusive findings, with the manipulation of the stimulus presentation in the schedule, was somewhat surprising. However this does allow the experimenter to exclude one of the more prominent differences between multiple and concurrent schedules as causal in the difference in the resistance to change results between the two different types of schedules. As a result, Part 2 of this study manipulated another important source of difference between multiple schedules and concurrent schedules. In multiple schedules the components are of pre-determined duration and follow successively. Another feature of multiple schedules is that the component schedule stops when the component is not present. As a result the local rate of reinforcement is different for each component as a function of the two different rates of reinforcement. Concurrent schedule components do not stop when the subject is not responding therein. This enables the subject to allocate time in such a way as to maximise reinforcement (i.e. spend time in the other component). As a result matching occurs with the amount of time spent responding in each component to the amount of reinforcement received therein.

This difference is given by the following equations:

$R1/T1 \neq R2/T2$ for multiple schedules and, [Equation 11)

$R1/T1 = R2/T2$ for concurrent schedules.

Where R denotes reinforcement and T, time.

Part 2 of this study was a manipulation of the time allocating abilities of the subjects in an effort to eliminate this difference, and make the concurrent schedule more similar to a multiple schedule. This was achieved with the imposition of a VI schedule upon the changeover key. This took the form of a constrained interchangeover time after the previous switch. This prohibited the subject from switching between components for an established time period (VI 60s) after a changeover response was made. This constrained component duration and therefore enforced unequal local rates of reinforcement.

The constrained interchangeover time manipulation was successful in altering the local rates of reinforcement. Thus with time constrained the local rates of reinforcement more closely resembled those found in multiple schedules. Figure 4 showed clearly the separation of the local rates of reinforcement between the two schedule components. Expressed as a ratio of the local rate of reinforcement the pre- and post-reversal data show the comparative obtained rate of reinforcement, divided by the amount of time spent responding in that component, for the rich versus lean and the lean versus the rich component were very different. The separation that is apparent in this figure shows that the constrained interchangeover time constraint did create inequality in the local rates of reinforcement between the rich and the lean components of the schedule as intended.

Thus, from the above evidence it can be concluded that the imposition of the time constraint upon the changeover key was successful in altering the local rates of reinforcement in the same way as is the norm for results of standard multiple schedule studies.

The overall results of the resistance to change tests showed no consistent effect. Thus, achieving different local rates of reinforcement in the components of this schedule did not produce differential resistance to change results in the two components. Thus, the presentation of distinctive colour stimuli on one key and the constrained changeover which created different local rates of reinforcement did not produce the expected results.

The combination of these two manipulations altered the concurrent schedule to the extent that the "concurrent" schedule in this study very closely resembled a multiple schedule in terms of stimulus presentation and component exposure. The absence of differential results for tests of resistance to change suggests that there are other issues that determine resistance to change, and that significantly differentiate multiple and concurrent schedules.

Analysis of Matching relationship.

As stated the introduction of the constrained interchangeover time was successful in creating inequality in the local rates of reinforcement. This showed no consistent effect in the results of resistance to change tests. The concurrent schedule in Part 2 of this study is very similar in procedural design to a typical multiple schedule, yet the resistance results are not similar to those produced in a typical multiple schedule. To further assess the extent of similarity between this concurrent schedule and a typical multiple schedule the issue of performance similarities must be addressed: This raises a further important question: Is the matching performance in this "concurrent" schedule similar to that in multiple schedules?

To answer this question an assessment of the effects of the above experimental manipulations in terms of the matching law is necessary. With the success of the time constraint manipulation (creating unequal local rates of reinforcement) it was possible to assess the matching behaviour in this study as a standard concurrent schedule and as a modified concurrent schedule.

Before an analysis of the matching data obtained in this experiment, it is important to briefly recap the debate that has surrounded matching. As described by

Baum (1974) the matching law:

$(B1/B2) = a(R1/R2)b.$ [Equation 12] was put forward as a quantitative description of responding in concurrent schedules. Subsequent experimentation has shown that this has been shown in many studies with concurrent schedules of reinforcement. Of most importance here is the data for the sensitivity to reinforcement that result from the matching analysis. The constant, a, from the matching equation denotes sensitivity to reinforcement. Concurrent schedules tend toward very high a - values 0.8 - 1.0.

The application of the matching law to the data from multiple schedules has produced quite different results. That is a low a - value (0.2 - 0.5), indicating low sensitivity to reinforcement is found. Because of the low value of the sensitivity indicator substantial research has been undertaken to isolate possible reasons. One early example of this is the study published by Shimp and Wheatley (1971). This experiment presented pigeon subjects with two component multiple schedules and manipulated component duration and the relative frequency of reinforcement to assess the effect of different ranges of component duration upon sensitivity to reinforcement of the subjects. They found that as component duration was shortened the relative frequency of responding approached the relative frequency of reinforcement in that component. Subsequent evaluation of this study exposed a flaw in that the test period was, for some manipulations, **only 1 - 2 days**. In addition the experimeters achieved very high sensitivity (a) values for all of the component durations tested in the experiment, which is unusual. Although important, the criticism this experiment received does not nullify the potential importance of the findings. The implication that certain manipulations can equate the characteristics of multiple and concurrent schedules is very important for operant research. For, if the manipulation of the duration of the components in a multiple schedule can produce results similar to those in concurrent schedules then this raises important issues about what characteristics actually differentiate the two types of schedules.

Another early study that supported the assertions made by Shimp and Wheatley (1971) is that of Merigan, Miller and Gollub (1975). Merigan et al conducted a multiple VI VI in which the relative duration of food presentation was manipulated. The alternation of the components was also manipulated. They found that when the components were programmed onto individual keys and the alternation was reduced to approximately 5s they found that the relative response rate closely matched the relative duration of reinforcement. However, responding was relatively insensitive to reinforcement when the components were programmed onto a single key.

Other studies, in reaction to results such as those of Shimp and Wheatley (1971), attempted an evaluation of the possible difference in sensitivity to reinforcement at different stages of individual components. White, Pipe, McLean and Redman (1985) varied the distribution of reinforcement in a multiple VI VI schedule. The component durations were established at 15s for one series of conditions. In the next series the components were set at 60s. White et al (1985) recorded responses during successive 15s subintervals of the 60s components, to compare the series of 15s components and the series with 60s components. They found that data from the first 15s subinterval of the 60s components showed greater sensitivity to reinforcer ratios than the other subintervals. Sensitivty in this first subinterval was also higher than in the series with 15s components. The overall results however failed to show a difference in the sensitivity between the two component durations. This result is then, contrary to the evidence supporting the short component effect on the matching phenomenon (see also Charman & Davison,1982).

Due to the variation in the results from experimentation with matching in multiple schedules McSweeny, Farmer, Dougan and Whipple (1986) undertook a review of the literature to assess the possibility of a matching law description of the processes involved in multiple schedule responding. One study analysed by McSweeny et al, that showed a high level of sensitivity to reinforcement, was that of Dysart, Marx, McLean & Nelson (1974). Dysart et al. (1974) used White Carneaux pigeon subjects, with random schedule components and arranged response operandum on a single key. The results showed a mean undermatching indicator of 0.62. The mean of the studies in which the components were alternated was approximately 0.42. This study also presented 3-minute components.

In the most general terms there seems to be supportive evidence for the argument that the matching law (Equation 8) provides adequate explanation for responding in both multiple and concurrent schedules. Accordingly, many have come to view concurrent schedules as being very similar to multiple schedules, the difference being that concurrent schedules are actually multiple schedules with very short, and unequal, components. However, the review of both multiple and concurrent schedule experiments (McSweeny et al., 1986) found that component duration had no systematic effect upon the undermatching parameter. Therefore there is little evidence that responding on multiple schedules with short and unequal components approaches responding on concurrent schedules.

It is important here to examine the difference in application of the matching law to concurrent as opposed to multiple schedules. The difference between the matching law as applied to multiple versus concurrent schedules is linked to the difference of control over the schedule components by subjects in these studies. The analysis of response-reinforcer sensitivity in concurrent schedules is based upon the total session data. Thus the analysis compares the ratio of the rate of responding in sessions with the ratio of obtained reinforcers per session. The matching law applied to multiple schedules compares the ratio of response rates with the ratio of obtained reinforcers in conditions where fixed component durations constrain the time available for responding and obtaining reinforcement. Thus, in concurrent schedules the analysis is that of the overall rates of responding and reinforcement. In multiple schedules however, the analysis is the local rates of responding and reinforcement. This difference is important as subjects in concurrent schedules can alter the ratio of responding by adjusting the amount of time they allocate to components. By contrast subjects performing in multiple schedules are restricted in the amount of time they can allocate because the component duration is established by the experimenter. Thus, the ratio of responding in multiple schedules is only affected by the response performance of the subjects. Thus, to display increased responding in a component with increased reinforcement, in a multiple schedule a subject must respond at a higher rate. In concurrent schedules this is achieved by allocating more time to that component.

This study provided an opportunity to evaluate the effect of constraining the time allocating abilities of the subjects. For, initially the schedule in this study was a standard concurrent schedule with the stimuli for the two components arranged on one key. The CICT altered the schedule by effectively pre-determining the duration of the now random components. It was expected that the CICT would have the effect of altering the sensitivity value from a high value as expected in concurrent schedules to the much lower value that is the norm for multiple schedules.

As Figure 4 showed the effect of the introduction of the constrained interchangeover time was not conclusive in terms of the effect upon the resistance to change of the two components of the schedule. This analysis was based upon the obtained ratio of reinforcers from each session. Figure 5 presents the results of the matching analysis.

log [(B1/T1)/(B2/T2)]

Vs. log [(R1/T1)/(R2/T2)].

Above is a representation the log local response ratio versus the log local ratio of reinforcement. Figure 5 (left column) shows the matching relationship of the local rates of responding and reinforcement before the introduction of the constrained inter changeover time. The matching law is usually applied to concurrent schedules on the basis of session totals. In this case however we are comparing the similarity or dissimilarity of responding in this modified concurrent schedule to that typically associated with multiple schedules. As a result the matching analysis was conducted with ratios of local rates of reinforcement and responding. This enables the comparison of the pre- and post modified concurrent in the same context as multiple schedules. Multiple schedules, because of the pre-determined component duration are always assessed in terms of local rate ratios

Concurrent schedules allocate responding in the same proportion as time. The same is true for the relationship between time allocation and reinforcer ratios. Thus, it was expected that the matching analysis for the pre-CICT concurrent schedule would show little variation with the data plots grouped closely around the point 0,0. Figure 5

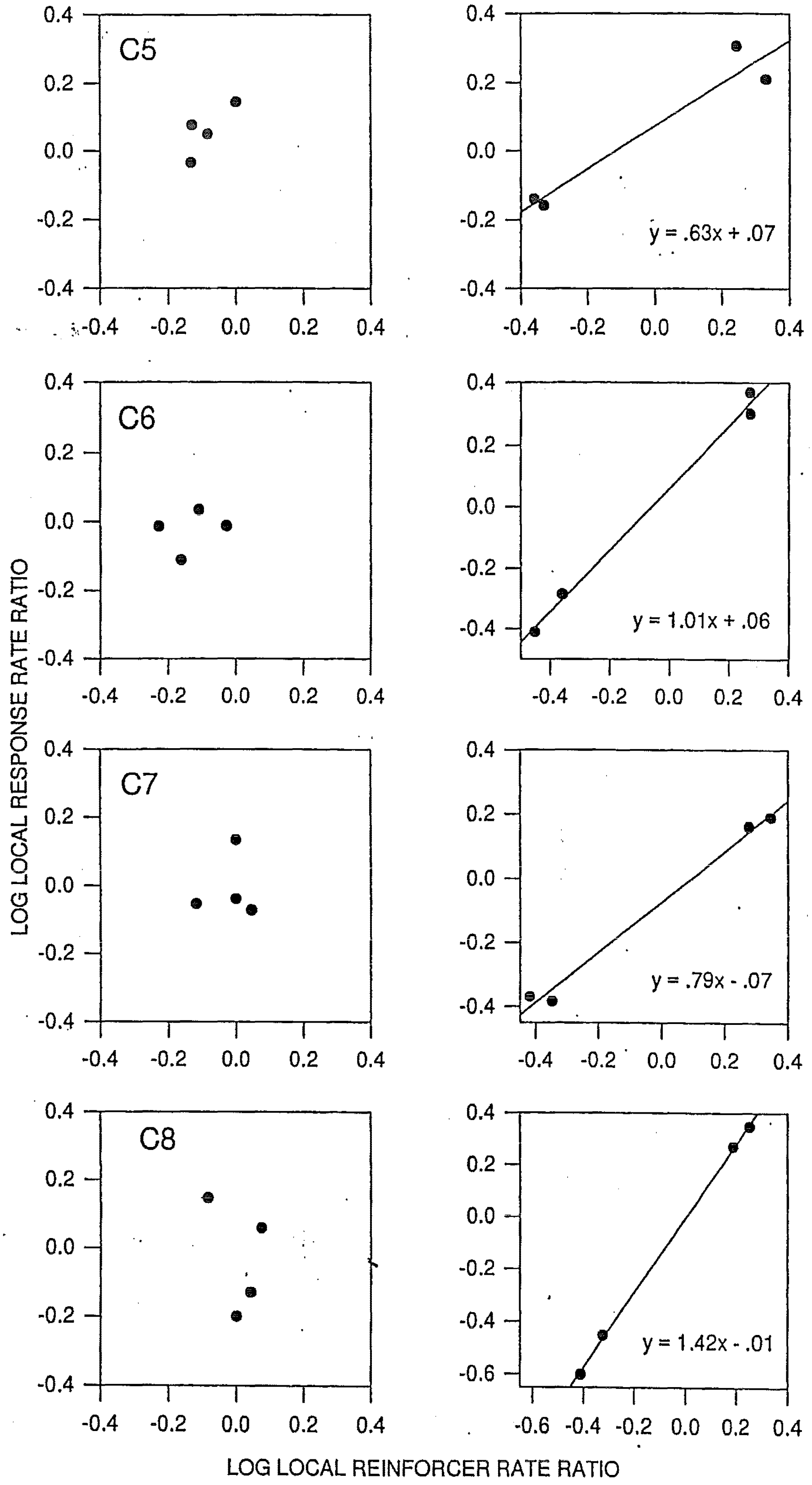

Figure 5: Plot of data from the matching analysis. Each plot represents the log local response ratio - log[(B1/T1)/(B2/T2)] as a function of the log local reinforcer ratio - log[(R1/T1)/(R2/T2)]. The left column shows data from Series 1 with no constraint on the changeover key (VI 0s). The right column shows data from Series 2 with a VI 60s schedule programmed onto the changeover key. The data in these plots are fitted with a regression line and the slope is indicated.

shows this to be true for three of the four subjects. Subject, C8, in keeping with previous results, produced further data that do not concur with the expected trend of the matching of local response and local reinforcer rate ratios.

The introduction of the CICT was successful in separating the local rates of reinforcement (see Figure 4) as is the norm in multiple schedules. Thus, it was expected that the analysis of matching would also to produce results that conform with those expected from a similar analysis performed on a multiple schedule, as was shown by Todorov et al (1993). That is that the measure of response reinforcer sensitivity would produce a positive slope of about 0.2 – 0.6. The right column (Figure 5) shows the effects of the CICT VI 60s introduction. These figures show that all subjects exhibited very high sensitivity to response and reinforcer ratios when the allocation of time was restricted by the CICT.

Thus, the analysis of matching data showed that the concurrent schedule, with CICT VI 60s on the changeover key produced results that are quite different from those expected from a typical multiple schedule. Thus far we have shown that the imposed time constraint was successful in altering the local rates of reinforcement and responding so that they resembled those of multiple schedules. The results of the matching analysis (Figure 5) show that the matching slope for local response and reinforcer rate ratios was very high (Mean = 0.963). A multiple schedule would be expected to produce a slope value of between 0.2 and 0.6. These findings are unusual as we would not expect responding to show as strong a relationship to the maintaining rate of reinforcement in each component when the time spent in that component was restricted. In this study the ratio of reinforcement was 3:1. As a result of the imposed component duration it was expected that subjects would respond in the rich components at a higher rate than in the lean components. These results however, suggest that performance has altered from the time allocation matching typical of concurrent schedule performance to response rate matching that surpasses that expected from multiple schedule research. These results are very interesting and as yet remain unexplained.

Thus it may be said that the experimental manipulations employed in this study, the presentation of one at a time stimuli and the constrained interchangeover time, successfully altered the concurrent schedule to possess procedural equivalence to a standard multiple schedule. However in terms of both resistance to change and the above matching analysis performance was not similar to that expected in a typical multiple schedule. This indicates that there are further, as yet unidentified influences that differentiate resistance to change (and it seems response performance!) in concurrent and multiple schedules.

Thus far resistance to change has shown to generalise across many experimental conditions and many species of organism. Concurrent schedule resistance is however poorly understood. Location has been shown not to reliably affect resistance to change, and here the separation of the local rates of reinforcement, in combination with the one at a time presentation of component stimuli has also failed to produce a resistance differential between the components of a concurrent schedule. It remains then to place the state of resistance to change research in the context of behavioural momentum theory.

Nevin (1992) Behavioural Momentum theory.

Behavioural momentum theory developed from the study of resistance of responding to disruption. Resistance to change developed out of dissatisfaction with the ability of the accepted measure of the strength of responding. This measure, changes in the rate of responding in different experimental conditions is best outlined in Herrnstein (1970). Experimentation which assessed the applicability of this measure in different contexts found that this measure was subject to manipulations independent of the rate of reinforcement. As a measure of response strength the most important issue is that changes in the strengthening of behaviour (rate of reinforcement) be reflected in the measure of that strength. That response rate was shown to vary independently of the rate of reinforcement raised doubts as to the functional applicability of this as a measure of response strength.

Resistance to change developed as a result of this identified problem with the rate of response as a measure of response strength. Resistance to change measures the changes in the performance of operants when disrupted. Thus, it was asserted, if two operants are reinforced at different rates then that which is maintained by the richer reinforcement schedule would exhibit less detrimental effects. Many studies have shown this to be true in various conditions (see Nevin, 1974; Nevin et al., 1990 for examples). Resistance to change and response rate are independent and it was assumed that as such resistance to change would not be affected by the same issues that create difficulty for the use of response rate as a measure of response strength. Fath et al (1983) went someway toward confirming this by showing that resistance to change was not affected by differential response contingencies. Response rate has been shown to be determined by operant response-reinforcer contingencies. Resistance to change seems to be affected by Pavlovian stimulus-reinforcer contingencies (see Nevin et al., 1990; Mace et al, 1990). However there are some studies that have presented results that run contrary to the resistance to change explanation of response strength (see Nevin et al., 1990 Expt 2; Cohen et al., 1993 for review). These studies include the effects of some pharmaceutical agents, responding maintained by simple schedules and that maintained in FR FR schedules of reinforcement.

A further area of discord with the resistance to change generalisation is that of responding in concurrent schedules. At the outset it was believed that the reasons for this failure of generality would be reflected in the manipulations used in this study. The results did not support this belief. This raises important issues for the study of resistance to change. Concurrent schedules typically present two operants, each reinforced at different rates of reinforcement and it is expected that the operant maintained by a richer reinforcement schedule have greater strength. At this time research suggests differences in strength in concurrent schedules are not related to resistance to change. Yet the necessary conditions for differential resistance would seem to be present. A typical arrangement consists of two independent operants that are maintained by different rates of reinforcement. Resistance to change proponents assert that the operant maintained by the richer reinforcement will be "stronger" than that maintained by the leaner reinforcement. Thus, it follows that the component maintained by the richer rate of reinforcement would possess greater resistance to the introduction of disruptors.

A possible explanation for the failure to find resistance to change differentials in concurrent schedules was outlined by Nevin (1992) in the context of behavioural momentum. Nevin asserts that because subjects in concurrent schedules are "free" to allocate the amount of time spent responding in a component the result is that the local rates of reinforcement are equal in two components of a concurrent schedule. In such an environmental context a subject may distribute time equally between components. Upon disruption, however performance in the richer component will be less disrupted. As a result the subject will spend more time responding in this rich component. The allocation of time spent in the rich component will continue until responding in this component is more affected by disruption. This will occur as a result of spending more time in this component than reinforcement received. Thus the component with fewer programmed reinforcers effectively becomes the "rich" component. For although the rate of reinforcement is unchanged the subject is spending very little time responding therein. Thus when time is accounted for the "lean" component actually represents the greater probability of reinforcement. As a result the subject will devote more time to this component. This process continues until the subject performs in the concurrent schedule in such a way as to cause the equalisation of the local rates of reinforcement (Nevin, 1992). Thus when time spent in schedule component is considered the two components are effectively equal. Therefore no differential in the resistance of responding between the components is expected.

Thus, to proceed logically it could reasonably be expected that a procedural manipulation that created inequality in the local rates of reinforcement in concurrent schedules would produce a resistance differential between the two components of the concurrent schedule. This study represented a specific test of this assertion. Through the introduction of the constrained interchangeover time we effectively replicated a multiple schedule in terms of local rates of reinforcement. This is evident in the results section of this paper. However, the manipulation used here, while successful in creating this inequality in the local rates was not successful in creating resistance differentials between the components of this "concurrent" schedule. Another feature, previously discussed was that of stimulus presentation. This study presented the stimuli for the components one at a time and used different colours on the keys. Thus, procedural equivalence with a multiple schedule was created with a specific distinctive stimulus correlated with each component and a time constraint programmed on the changeover key. These manipulations successfully created unequal local rates of responding and reinforcement as is the norm for multiple schedules. These same manipulations were not successful in realising differential resistance to change in the components of a concurrent schedule.

Therefore it seems that behaviour momentum theory cannot adequately explain performance in concurrent VI VI schedules at this time.

Implications for further study:

There are several notable implications to be gained from the above study that may be incorporated into further the study of resistance to change and behavioural momentum theory. The first of these is the reversal manipulation that was used in each of the series of this study. Each series contained two conditions. The first condition of each series was the tests of resistance. This was the introduction of response-independent food at two rates. The second condition of each series was the reverse of the first two. Thus, in Condition 2 the stimulus-reinforcer contingency was the reverse of Condition 1. In Condition 1 the component with the rich rate of reinforcement was signalled by the green key with red for the lean component. The reversal, in Condition 2, reversed this relationship so that green and red signalled lean and rich respectively. The aim of the introduction of this reversal was to determine the effect of stimulus effects, or bias, in the responding of the subjects in the study.

As noted there was considerable evidence of a stimulus effect throughout this study. Subjects C6 and C8 showed a strong preference for the green colour stimulus in test of resistance to change. This provides an excellent example of the necessity of including the experimental reversal employed in this experiment. For, the results shown in Figure 1 (right column), and to a lesser extent Figure 2 (right column), show clear evidence of greater resistance to change in the component with the rich rate of reinforcement. In this case the effect was shown to be a stimulus effect. In the absence of the reversal procedure this effect would be difficult to detect and would have increased the risk of misinterpreting the data. In this study the reversal proved an essential manipulation that was invaluable in the interpretation of the data and results.

As earlier noted subject C5 produced data that could be expected from a behavioural momentum assessment of resistance to change in a concurrent schedule with unequal rates of reinforcement. Thus, the preference shown by subjects C6 and C8 toward stimulus colour is very important. For without the stimulus effects the results may have been very different. As is however there is not enough evidence to conclude a resistance to change explanation of the strength of responding in concurrent schedules. This serves as an example of the importance of the experimental reversal. It is the opinion of the author that testing for resistance to change include a reversal of the type mentioned above as a means of placing results in true context.

A further issue to arise from this study again concerns stimulus presentation. In this case the stimuli were presented one at a time in an attempt to distinguish the stimulus-reinforcer contingency as is the case in a typical multiple schedule arrangement. Thus one of the two colour stimuli was presented on the response key at one time. The results did not support the assumption that this arrangement was sufficient to differentiate resistance to change in concurrent schedules. This said, there were no noticeably negative implications of this arrangement, and it may still be necessary to arrange the stimuli in this way in further studies with concurrent schedules. A possible problem with this manipulation is that of the changeover key. In this study the changeover key remained lighted at all times during the sessions. In retrospect it is speculated that this raises an issue of the degradation of the stimulus-reinforcer contingency between the colour stimulus and the rate of reinforcement. For, the presence of the changeover keylight may have acted as a further stimulus common to both of the components in the concurrent schedule. If true then this may have influenced the formation of distinct stimulus-reinforcer contingencies in the two components. The introduction of the one at a time stimulus was specifically designed to enhance the relationship between the stimulus and the reinforcer as it is in multiple schedules. At the time of the presentation of this paper, work with a Findley concurrent schedule with the changeover key switched off while inactive is progressing. The results are awaited with anticipation.

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Appendices

Appendix 1: Table 2: Results from the experiment for Condition 1. In these conditions the discriminative stimuli were presented successively in a Findley concurrent schedule. The different columns present response rates in Components 1 and 2 respectively (B1 and B2), the obtained reinforcer rates in Components 1 and 2 (R1 and R2) and the time spent in each component given in 0.5s (T1 and T2). The presented data represent the mean of the last five baseline sessions (BL), and the mean of the eight sessions of resistance to change tests (T1 – eight sessions and T2 – eight sessions).

	B1	**B2**	**R1**	**R2**	**T1**	**T2**
Condition 1	Component 1	Component 2	Reinf/sess.	Reinf/sess.	0.5s	0.5s
Subject C5	VI 240s	VI 80s				
Baseline:	808.20	2355.40	9.80	38.60	649.80	2644.40
Test 1:	425.00	1145.60	8.25	36.25	649.10	2665.30
Baseline:	894.80	2154.20	9.40	37.40	855.80	1449.60
Test 2:	405.00	1271.00	7.50	35.75	705.75	2623.30
Subject C6	VI 240 s	VI 80s				
BL:	494.80	1492.00	11.40	36.40	994.80	2304.20
T 1:	175.50	945.50	8.00	35.13	676.75	2652.50
BL:	485.20	1695.00	11.20	39.40	742.80	2535.80
T 2:	286.38	1188.75	9.50	37.50	752.63	2549.00
Subject C7	VI 180s	VI 60s				
BL:	461.60	1641.20	12.60	50.80	774.00	2426.00
T1:	142.88	854.75	9.00	44.75	701.38	2555.25
BL:	688.20	1806.80	14.00	49.40	705.20	2497.20
T 2:	274.75	1173.38	10.38	50.38	448.63	2768.38
Subject C8	VI 180s	VI 60s				
BL:	178.40	1205.00	11.40	48.60	612.40	2609.40
T 1:	53.50	769.75	3.88	50.00	233.25	3028.00
BL	236.60	1406.00	12.20	49.80	585.80	2618.00
T 2:	103.50	855.63	7.38	48.63	514.75	2728.88

Appendix 2:

Table 3: Data for Condition 2. This Condition is a reversal of the stimulus-reinforcer relationship in Condition 1. In the reversal the rich and lean components are reversed. This table again presents the mean data. The mean of the last five baseline sessions, and the last eight test sessions. Column allocation is the same as that in Table 2.

	B1	**B2**	**R1**	**R2**	**T1**	**T2**
Condition 2	Component 1	Component 2	Reinf/sess.	Reinf/sess.	0.5s	0.5s
Subject C5	VI 80s	VI 240s				
BL:	2458.80	449.40	39.40	9.60	2734.20	561.20
T 1:	1057.13	165.63	35.75	4.75	2904.13	443.00
BL:	2426.20	474.60	39.60	9.80	2782.40	506.60
T 2:	1605.13	309.50	39.00	8.25	2791.38	507.30
Subject C6	VI 80s	VI 240s				
BL:	1868.80	313.00	39.00	9.20	2790.00	808.00
T 1:	942.13	234.63	34.75	9.00	2513.13	808.38
BL:	1762.00	255.20	38.20	8.80	2895.00	406.80
T 2:	1308.50	209.88	38.75	8.75	2787.38	504.00
Subject C7	VI 60s	VI 180s				
BL:	1488.60	536.20	49.80	13.40	2457.20	742.40
T 1:	767.00	291.63	48.00	12.13	2529.75	690.75
BL:	1565.80	524.80	49.60	15.40	2435.40	753.60
T 2:	1133.25	367.50	49.88	13.75	2553.38	651.13
Subject C8	VI 60s	VI 180s				
BL:	798.00	198.80	47.00	11.60	2519.60	708.80
T 1:	455.63	170.38	40.88	10.88	2368.50	906.13
BL:	1096.60	169.00	50.00	13.00	2639.60	564.80
T 2:	859.38	140.25	49.25	9.75	2762.75	463.25

Appendix: 3

Table 4: Data for Condition 3. The data are the mean values of the last five sessions of baseline and the eight sessions of each resistance to change test. The columns are allocated in the same manner as Table 2.

	B1	B2	R1	R2	T1	T2
Condition 3	Component 1	Component 2	Reinf/sess.	Reinf/sess.	0.5s	0.5s
Subject C5	VI 240s	VI 80s				
BL:	848.8	1725.8	9.4	29.4	1401.8	1950.4
T 1:	272.75	824.75	7.5	31.25	1248.88	2107.88
BL:	876.8	1475.6	10	29.2	1515.2	1836
T 2:	291.63	810.13	7.5	31.25	1248.88	2107.88
Subject C6	VI 240s	VI 80s				
BL:	457.6	1029.4	10.2	28.6	1564.2	1788.8
T 1:	258.5	687.25	8.88	27.13	1478.75	1895
BL:	365.8	1101.2	9.4	30.2	1555.4	1789.4
T 2:	179	906.38	7.75	32.13	1021.25	2326.63
Subject C7	VI 180s	VI 60s				
BL:	537.6	1212	13.8	33.4	1682.6	1622.2
T 1:	292.88	727.75	13.5	35	1416.13	1876.63
BL:	474.6	1310.4	14	34.6	1536.6	1757
T 2:	301.63	694.75	12.5	33.75	1562.63	1740.5
Subject C8	VI 180s	VI 60s				
BL:	143.4	793.4	9.8	40.8	1116.6	2164.8
T 1:	142	522.63	11	36.63	1294.5	1996.38
BL:	120.2	838	8	37.4	1222.4	2093.2
T 2:	214.75	629.88	11.38	37.75	1338.63	1955.38

Appendix: 4

Table 5: Mean data for Condition 4, which was the reversal of the stimulus-reinforcer conditions that existed in Condition 3. The columns are allocated as in Table 2

	B1	**B2**	**R1**	**R2**	**T1**	**T2**
Condition 4	Component 1	Component 2	Reinf./sess.	Reinf/sess.	0.5s	0.5s
Subject C5	VI 80s	VI 240s				
BL:	1394.6	744.8	26.8	11	1823	1536.6
T 1:	677	255	27.75	8.13	2006.38	1365.38
BL:	1485.8	406.6	30.4	9.6	2138.6	1209
T 2:	890.5	242.63	32.13	8.75	2252.38	1088.13
Subject C6	VI 80s	VI 240s				
BL:	1209.8	287.4	32	9.2	2145	1198
T 1:	720.25	267.38	29.63	9.75	2056.13	1291.13
BL:	1203.8	334	33.2	9.2	2155.2	1181.4
T 2:	741.38	313.13	27.25	10	1812.88	1550.74
Subject C7	VI 60s	VI 180s				
BL:	1149	612.8	36.6	13.6	1797.2	1485
T 1:	598.5	278.63	36.5	12.75	1892.88	1393.5
BL:	1111.2	544.8	37.4	13	1930.6	1352.2
T2:	810.38	345.13	39	13.25	1963.38	1305
Subject C8	VI 60s	VI 180s				
BL:	898.4	240.6	38.4	12	2203.2	1077.6
T 1:	403.25	274.5	34.88	13.38	1826	1473
BL:	1020.8	138.4	44.6	7.6	2524.2	750.8
T 2:	469.5	332.63	35.25	14.25	1736.63	1550.75