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MULTIPLE SCHEDULES:  
THE EFFECTS OF TEMPORAL FACTORS  
ON BEHAVIOUR.

A thesis  
submitted in partial fulfilment  
of the requirements for the Degree  
of  
Doctor of Philosophy in Psychology  
at the  
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by  
MAREE JOANNE HUNT

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## ABSTRACT

Domestic hens served in three experiments examining the effects of varying the temporal proximity of component schedules on behaviour on multiple variable-interval variable-interval schedules. In all experiments response rates on each component schedule and in successive subintervals of the components were determined. Data were analysed to obtain estimates of the parameters of the Generalised Matching Law for total responding and for responding in successive subintervals of components. Four hens served in the first experiment which examined the effects of reducing component duration while reinforcement rates in the component schedules were frequently reversed. The results indicated that values of the parameter  $a$  of the Generalised Matching Law generally increased as component duration was reduced. Changes in response rates contributing to the decrease in  $a$  values varied across hens. Local positive and local negative contrast were present in all hens' data in some conditions but not in others. The conditions in which these phenomena occurred varied across hens. For three hens values of  $a$  declined across successive subintervals of components at all component durations. This effect was also present at the longer component durations in the fourth hen's data but, for this hen's data,  $a$  values increased over successive subintervals when component duration was reduced.

The second experiment examined the effect of increasing and then decreasing the duration of an intercomponent blackout. Six hens served in this experiment. Blackout durations examined were 1 s, 10 s, 30 s, 60 s, 120 s, 180 s and 297 s. At each blackout duration the reinforcement rates in component schedules were varied. Response rates on both components of the multiple schedules tended to increase as the blackout duration was increased. Values of the parameter  $a$  decreased as blackout duration was increased and for five birds became negative. Changes in  $a$  values and response rates across successive subintervals similar to those seen in the first experiment were present when the blackout duration was 1 s. As blackout duration was increased these changes were attenuated. Values of  $a$  and response rates for overall responding observed when blackout duration was 1 s and 30 s were not replicated when blackout duration was then decreased.

The third experiment examined the effects of blackout duration using multiple-multiple schedules. In the first phase of this experiment the behaviour of six hens on the multiple schedules of the multiple-multiple schedules was compared with behaviour of the same hens on each multiple schedule when one schedule was presented in each condition. The results of this phase suggested that behaviour on each multiple schedule of the multiple-multiple was qualitatively similar to behaviour on the same multiple schedules when they were presented singly. In the second phase of this experiment three of the hens employed in the first phase were exposed to a series of conditions where the duration of an intercomponent blackout was varied. The blackout durations examined in the order they were presented were 1 s, 30 s, 60 s, 0 s, 120 s. For two of the hens' data values of  $a$  for overall responding decreased as a function of blackout duration. For one of these hen's data  $a$  values became negative. For the third hen's data  $a$  values decreased when the blackout duration was increased to 120 s. Absolute response rates contributing to these  $a$  values varied across hens. Within component changes in response rates also varied across hens. Values of  $a$  decreased across successive subintervals for all hens' data when no blackout separated components but this effect was present in only one hen's data in other conditions. In general changes in response rates and  $a$  values as a function of component or blackout duration were not explicable in terms of the changes in behaviour across successive subintervals of components.

These results were examined in terms of several theories previously proposed to explain multiple-schedule performance. It was concluded that none of these could easily accommodate the results obtained in the experiments presented here.

## DEDICATION

During my time at the University of Waikato I have had the great privilege of being taught and nurtured by Dr Michael Hills.

Having first set my sight on completing a Bachelors degree, it was his interest in me and encouragement of me that provided the confidence and impetus to further my academic career. In this process he has provided me with a model of academic integrity, and has served as an exceptional mentor.

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In 1911 Thorndike proposed the law of effect as a qualitative descriptor of behaviour. This law states that behaviours which are followed by positive consequences are likely to be repeated while behaviours followed by negative consequences are unlikely to be repeated. The law of effect thus identifies the consequence of a behaviour as the major variable controlling that behaviour. Subsequent analyses of single schedule performance have revealed that the frequency and conditions under which positive consequences (reinforcers) are made available influences the behaviour on which they are contingent (Zeiler, 1977). For example under a Fixed-Interval X-s schedule (FI X-s), where a reinforcer is contingent on the first response after X s has elapsed, response rates tend to be slow immediately after a reinforcer has been obtained and then increase rapidly until the next reinforcer is obtained. Under Variable-Interval X-s schedules (VI X-s), which differ from Fixed-Interval schedules in that the time period which must elapse between reinforcers is variable with the mean interval being X s, response rates tend to be higher and constant. In both FI and VI schedules as the value of X decreases, that is as the frequency of reinforcers increase, response rates tend to increase until some asymptotic level of responding is reached (Catania & Reynolds, 1968; Herrnstein, 1970; Nevin, 1973). Similarly studies which have examined other types of schedules have reported distinct and characteristic patterns of responding. It is therefore possible to predict in qualitative terms the behaviour of organisms given a particular schedule of reinforcement. Although attempts to quantify the relation between reinforcer frequency and absolute response rates on simple schedules have been made, rates of responding differ across subjects. Theoretical models have therefore had to incorporate free parameters, the values of which are not predictable *a priori*, and hence predictions of behaviour under such schedules may be considered more qualitative than quantitative.

When two or more simple schedules are combined into a compound schedule the situation changes. For example in concurrent VI VI schedules, two VI schedules are simultaneously available. Animals' behaviour on each of the component schedules can then be described not only in terms of absolute response rate, a measure which as already stated varies considerably across animals, but also in terms of response rate on one component schedule relative to response rate

on the other component schedule. Although this second measure of behaviour must be viewed with some caution as it entails the loss of some information (Catania, 1981), this loss may be justified as use of this measure has two major advantages over the use of absolute response rates. Firstly, relative response rate has been shown to be amenable to quantitative description (Herrnstein, 1961, 1970; Staddon, 1968; Williams, 1983 and others). Secondly, its apparent usefulness in describing performance on compound schedules has served to demonstrate that the relation between response and reinforcement rates is influenced by the context of reinforcement (Baum, 1974). That is, when two simple schedules are combined in some way then an animals' performance on one schedule appears to be controlled not only by the reinforcement rate in that schedule but by the reinforcement rate in the other schedule as well. For example, in typical performance under concurrent VI VI schedules, changing the parameters of one VI schedule tends to produce changes in behaviour on the other schedule. It has therefore been suggested that it is relative reinforcement rate and not reinforcement rate *per se* that controls behaviour.

One of the earliest attempts to quantify the relation between relative reinforcement rate and behaviour was proposed by Herrnstein (1961). Herrnstein's model, now known as the Strict Matching Law, states that animals will match the relative number of responses made on one component of a two component concurrent schedule to the relative rate of reinforcement in that component. This relation between responding and reinforcement can be expressed as:

$$\frac{B_1}{B_1 + B_2} = \frac{R_1}{R_1 + R_2} \quad (1)$$

where B is the number of responses made, R the number of reinforcers obtained and the subscripts 1 and 2 indicate the component in which they occur.

Although this equation was tested empirically by Herrnstein (1961), and reported to describe the data well, Baum (1974, 1979) reviewing Herrnstein's and others' studies found this equation to be inadequate. Baum reported that relative rates of responding were frequently less extreme than would be predicted by the relative

reinforcement rates and that, in some instances, animals tended to respond consistently more than predicted on one schedule than another over a range of relative reinforcement rates. He proposed that response allocation on concurrent schedules could be better described by Equation 2 given below where  $B_1$ ,  $B_2$ ,  $R_1$ , and  $R_2$ , are as defined for Equation 1.

$$\frac{B_1}{B_2} = c \frac{R_1^a}{R_2} \quad (2)$$

In this equation, known as the generalised matching law (GML), the exponent  $a$  is considered to reflect the sensitivity of responding to the reinforcement ratios and the parameter  $c$  to reflect inherent bias toward responding to one alternative over another. This equation when written in logarithmic form, as in Equation 3, describes a straight line with a slope  $a$  and intercept of  $\log c$ .

$$\frac{B_1}{B_2} = a \log \left[ \frac{R_1}{R_2} \right] + \log c \quad (3)$$

When animals match relative response rates to relative reinforcement rates  $a$  will equal 1.0. If  $a$  is less than 1.0 animals are said to undermatch and when  $a$  is greater than 1.0 they are said to overmatch (Baum, 1974).

In a review of 103 data sets, Baum (1979) reported that Equation 3 described data from animals working on concurrent schedules well, with the median  $a$  value for the studies examined being 0.83. Thus relative reinforcement rate may be seen as the major variable controlling behaviour on concurrent schedules. If relative reinforcement frequency is the major variable controlling behaviour in one setting it could be expected to exert similar control in another context.

#### Multiple-Schedule Performance

In multiple schedules two or more schedules each associated with a distinct exteroceptive stimulus are alternated successively and independently of an animal's behaviour. Initial studies of performance on such schedules were primarily concerned with changes in the absolute response rates observed during a constant component when reinforcement rate was varied in another. Early studies

typically reported that absolute response rate in one component of a multiple schedule (MULT) increased when reinforcement and/or response rate in the other component decreased (e.g., Reynolds, 1961a, 1961b). This phenomenon, termed positive behavioural contrast, has been most reliably observed with pigeons when a MULT VI VI schedule was changed to a MULT VI Extinction (EXT) (Nevin & Shettleworth, 1966) but has also been reported with other species including hens (Siegert, 1980), humans (e.g., Rovee-Collier & Capatides, 1979; Waite & Osborne, 1972), and rats (Beninger & Kendall, 1975; Blough, 1980; Bradshaw, Szabadi & Bevan, 1978; Gutman, 1977; Gutman, Sutterer & Brush, 1975 and others). Positive contrast has also been found with different response topographies (e.g., Beninger & Kendall, 1975; Coelho de Rose, 1986; McSweeney, 1983; Schwartz, 1986), types of schedules (e.g., MULT FI FI, Blough, 1980; Coelho de Rose, 1976; Reynolds, 1961b) and various schedule manipulations in the altered component (Brethower & Reynolds, 1962; Ettinger, McSweeney & Norman, 1981; Reynolds, 1961a; 1961b; Sadowsky, 1973; Terrace, 1968; Weisman, 1969; Williams, 1976 and others). Negative behavioural contrast where response rate in an unchanged component decreases when reinforcement and/or response rate in the changed component increases, has also been reported (e.g., Ettinger, et al. 1981; King & McSweeney, 1987; McSweeney, 1982; McSweeney, Dougan, Higa & Farmer, 1986, Schwartz, 1986).

In many of the experiments demonstrating contrast, changes in reinforcement rate have also produced response rate changes in the altered component, and contrast has been found in some studies which have changed response but not reinforcement rate. It has therefore been argued that behavioural contrast occurs as a result of response rate changes in the altered component (Terrace, 1966, 1968). However a number of studies have reported contrast where reinforcement rate changes in the altered component were not accompanied by response rate changes in that component (e.g., Halliday & Boakes, 1974; Thomas & Cameron, 1974). Others have found no contrast when response rates in one component changed while reinforcement rates remained the same (Boakes, 1973; Boakes, Halliday, & Mole, 1976; Halliday & Boakes, 1971; Thomas & Cameron, 1974; Weisman & Ramsden, 1973). In general the majority of studies suggest that reinforcement rate influences contrast. There are a few studies (Brownstein & Newsom, 1970; Reynolds & Limpo, 1968

Terrace, 1968; Wilkie, 1973) that have found that changes in response rates in an altered component, while reinforcement rates were not changed, may produce contrast. These findings are, however, less common, more difficult to replicate, and hence may be described as less important (Williams, 1983). Furthermore a number of studies examining contrast have found that the magnitude of contrast observed, that is the extent of change in the constant component when the reinforcement conditions in the other component were altered, was proportional to the reinforcement rate in the altered component (Dysart, Marx, McLean & Nelson, 1974; McSweeney et al., 1986; Reynolds, 1961b and others). Thus studies of behavioural contrast in general suggest that relative reinforcement rate influences behaviour on multiple schedules. However, analysis of these studies typically concentrated on changes in absolute response rates in a constant component and in many instances only one condition involved differential reinforcement rates in the components. Accurate assessment of the usefulness or relevance of the GML to the behaviour reported in these studies is therefore difficult.

Nevertheless several studies of behaviour on multiples schedules have examined the effects of changing reinforcement rates on relative response rates. Additionally some studies examining contrast have used a sufficient number of schedules pairs to allow estimates of the GML parameters to be calculated. In a review of 22 multiple schedule experiments suitable for such analysis McSweeney, Farmer, Dougan and Whipple (1986) reported that the values of  $a$  obtained were much lower than those found to describe concurrent-schedule performance, with the median value of  $a$  for these studies being 0.46. Given this difference between values of  $a$  which typically describe multiple and concurrent-schedule performance it is possible that behaviour under the two types of schedules cannot be explained in terms of the same processes. Such a conclusion on the other hand may be hasty given that the variance accounted for in multiple-schedule performance by the GML was generally reasonably high. In their review McSweeney et al. reported that in the studies examined the GML, as expressed in Equation 2, accounted for a median of 91 percent of the variance in the data. Taken together the values of  $a$  obtained and the variance accounted for by Equation 2, indicate that changes in relative response rates observed on

multiple schedules may be largely attributed to the changes in relative reinforcement rates. However the changes in relative response rates may be considerably less than, although proportional to, the changes in reinforcement rates. Thus it appears reasonable to conclude that behaviour on concurrent and multiple schedules may be described as a function of the same basic variable; relative reinforcement rate. It would also appear that the form of the function relating relative response and reinforcement rates on the two types of schedule is similar. That is, on both types of schedule relative response rates appear to be a power function of the relative reinforcement rates. Thus while behaviour on multiple and concurrent schedules differ, the difference may be described solely in terms of the value of the exponent, that is the values of  $a$ .

This analysis serves to highlight the strength and weakness of the GML. Used as a descriptive tool the GML enables the difference between performances in different contexts to be identified but, given that the exponent  $a$  is free to vary and is largely undefined, as an explanation of the behaviour it is limited. As discussed, when used to describe concurrent-schedule performance, deviations from strict matching tend to be minimal (Baum, 1979) and therefore in this context the GML may be seen as having explanatory and predictive functions. That is, because deviations from matching are small, relative response ratios can be predicted with reasonable accuracy given relative reinforcement ratios. Although the actual process by which matching occurs is subject to some debate (see Commons, Herrnstein & Rachlin, 1982), animals could be described as allocating their behaviour between schedules so as to match approximately the 'work' done on a schedule to the reinforcers available for that 'work' relative to reinforcers available for the alternative behaviour. However, given the deviations from matching on multiple schedules are larger, the explanatory and predictive value of the GML is lost. Further examination of the parameter  $a$  therefore appears warranted. Of particular interest is whether variables which influence  $a$  values in the different contexts are similar. If the variables affecting  $a$  in the two contexts are similar then it must be assumed that features differentiating the two procedures either enhance or attenuate their effects such that their effects on performance differ in magnitude across the

procedures. In such a situation however it may still be feasible to develop an equation based upon the GML which has descriptive, explanatory, and predictive functions across procedures. If variables influencing  $a$  differ across procedures the future use of the GML in different contexts, as other than a descriptive technique, must be questioned. It may be argued instead, that variables which influence  $a$  in various contexts must be defined and if possible, specified in quantitative models of behaviour for each context. The results of some studies suggest that certain variables that influence  $a$  may be common to both multiple and concurrent schedules while the results of others indicate that some variables may affect performance in one context but not others.

#### Influences on the Values of $a$ in Multiple-Schedule Performance.

A frequent corollary of combining schedules has been the addition of some discriminative stimuli which are associated with the different schedules. Clearly animals' ability to match the ratio of responses to the ratio of reinforcements in a complex schedule will be limited if they are unable to discriminate between the discriminative stimuli and hence the schedules in operation (Baum, 1974).

A number of studies have examined the effects of the discriminability of stimuli on the magnitude of behavioural contrast. Typically these studies have used several different stimuli associated with a rich reinforcement schedule (S+) and another set of stimuli associated with a leaner reinforcement schedule (S-). In some of these experiments the magnitude of contrast was greatest in components where the stimuli associated with the two schedules were closest (e.g., Blough, 1980; Catania & Gill, 1964). However Mackintosh, Little and Lord (1972) report that response rates on S+ were higher when the stimuli were more disparate. Malone (1975) found that while the greatest magnitude of contrast was found with stimuli which were closer together within one condition, when the differences between all S+ stimuli and all S- stimuli were reduced the magnitude of contrast decreased. These results suggest that when stimuli are discriminable the greatest magnitude of contrast will be found when the S+ and S- stimuli are close together but that the magnitude of contrast will diminish if discrimination between all stimuli is poor. Studies examining the

magnitude of behavioural contrast therefore provide some evidence that stimulus discriminability does influence multiple-schedule performance. These studies do not, however, provide conclusive evidence that stimulus discriminability will influence values of  $a$  in the GML.

Values of  $a$  are determined by the ratios of response rates obtained in the two components for given ratios of reinforcement rates. The magnitude of contrast on the other hand is determined only by the change in response rates on a constant component when reinforcement rates in the other component change. If response rates on the altered component are unchanged by variables that increase the magnitude of contrast, then increases in the magnitude of contrast will also increase the ratio of responses (i.e., the differences between response rates on the component schedules will increase). If variables that affect the magnitude of contrast also however influence response rates on an altered component, changes in the magnitude of contrast may not influence the ratio of response rates.

This independence of contrast and the ratio of response rates is demonstrated in two studies examining contrast by McSweeney. In the first of these studies (McSweeney, 1978) contrast was not observed when a MULT VI 120-s VI 120-s was changed to a MULT VI 120-s EXT. That is, response rates on the VI schedule did not change when the other component was changed to extinction. In the second experiment (McSweeney, 1983) contrast was observed when a MULT VI 15-s VI 15-s was changed to a MULT VI 15-s EXT. However, in this second experiment response rates on the extinction component were also higher than those observed in the first experiment. When the response rates on the VI schedules relative to response rates on the EXT components were compared across the two studies, the relative rates of responding on the VI schedules were generally higher in the first experiment, that is in the experiment where contrast was not observed (McSweeney, 1983). Although  $a$  values are not calculable when no reinforcers are scheduled in one component in such situations, higher relative response rates in the VI component may be seen as reflecting closer matching of response to reinforcer rates. Thus conditions in the second experiment, that is higher baseline rates of reinforcement, would appear to favour the development of contrast but conditions in the first experiment may

be seen to favour matching. Therefore experiments which have identified variables which influence the magnitude of contrast do not provide conclusive evidence that these variables will influence  $a$ .

Some direct evidence exists on the effect of stimulus factors on values of  $a$  obtained. White, Pipe and McLean (1983, 1984) found that values of the parameter  $a$  varied with stimulus discriminability such that values of  $a$  decreased as the tilted lines, used as discriminative stimuli, became more similar. As predicted by Baum (1974), Bourland and Miller (1981) and Miller, Saunders and Bourland (1980) demonstrated that similar effects are present in animals' performance on concurrent schedules. The discriminability of stimuli may thus contribute to undermatching on both concurrent and multiple-schedule performance. However, if this variable contributes to the differences in  $a$  values which typically describe performance on the two types of schedules, then some aspect of multiple schedules must lead to multiple-schedule performance being affected to a greater extent.

In concurrent schedules stimuli are often spatial whereas in multiple schedules they are usually exteroceptive. Jones (1988) found that in a delayed-matching-to-sample task, hens were better able to report correctly a sample stimulus based on location than they could one based on hue. This procedural difference may therefore be considered relevant. In support of this, Merigan, Gollub and Miller (1975) found higher  $a$  values for performance on a multiple schedule using two keys, compared with  $a$  values obtained under the same conditions but with a single key. The contribution of this procedural variable to the discriminability of stimuli may however be limited. Charman and Davison (1982) found no consistent differences in the values of  $a$  obtained when two keys, as opposed to one key, were used. Moreover  $a$  values reported to describe behaviour on concurrent VI VI schedules using a Findley changeover key procedure, where discriminative stimuli are not spatial, are typically not lower than  $a$  values obtained using a standard two-key procedure (Davison & McCarthy, 1988).

Another variable which may differentially affect discriminability on the two types of schedules is the presence (or absence) of the

alternative stimulus. Under two-key concurrent schedules both stimuli are usually present at all times whereas under multiple schedules only one stimulus is present at a time. The effect of this difference is also questionable. Animals working on concurrent schedules which use the Findley changeover key procedure also have only the stimulus associated with the schedule they are currently working on present and, as stated above, this does not appear to affect behaviour.

It appears that the discriminability of stimuli is one variable which contributes to  $a$  and should constitute one of the parameters which would ideally replace  $a$ . This idea is not new and one model proposed by Davison and Jenkins (1985) to describe concurrent-schedule performance has incorporated such a parameter. However, given the above discussion it is unlikely that this is the only variable contributing to the value of  $a$  in the GML, at least as it applies to multiple-schedule data. This conclusion is to some extent supported by the results of a study by Charman and Davison (1983). In their study the animals' behaviour indicated they could discriminate the discriminative stimuli used in a multiple schedule, and considerable undermatching typical of multiple-schedule performance was obtained.

In a review of studies of multiple-schedule performance Williams (1983) noted that the species employed and the location of the stimuli have been reported to influence the magnitude of contrast observed. The results of studies relating to these two variables are equivocal. Some studies have reported that behavioural contrast was not evident when rats as opposed to pigeons were used as subjects (e.g., Freeman, 1971; Weiss, 1971) but others by Beninger and Kendall (1975), Bradshaw, et al. (1978), Dougan, McSweeney and Farmer (1985), and others have demonstrated contrast with rats. Similarly Redford and Perkins (1974), Schwartz (1975), and Spealman (1976) report that contrast failed to occur when the discriminative stimuli were located remote from the response key while other investigators have reported contrast with diffuse stimuli such as houselights (e.g., Beninger & Kendall, 1975), noise intensity (Blough, 1980) or with stimuli presented on another key (e.g., Williams & Heyneman, 1981). Nevertheless contrast with the

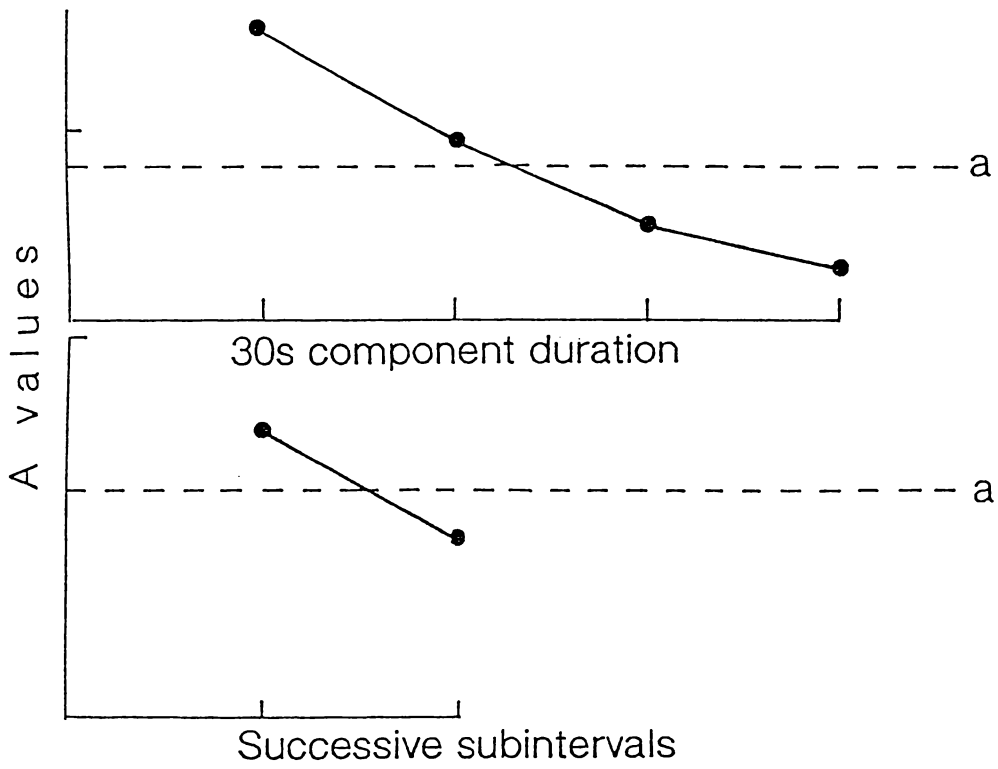
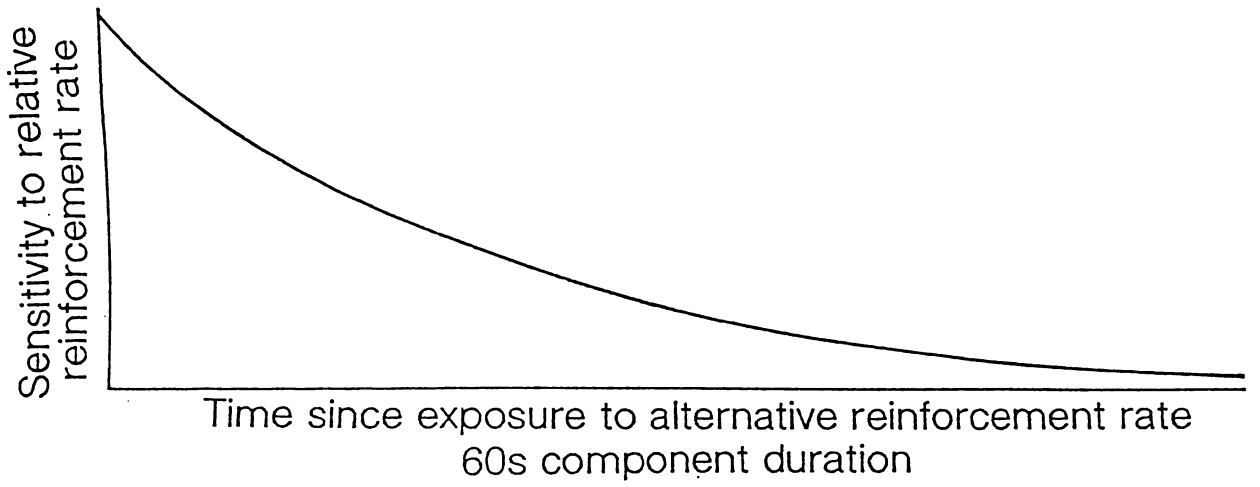
discriminative stimuli on the response key may be larger than contrast with stimuli off the key (Hearst & Gormley, 1976).

In addition to their inconsistency, two other factors make the interpretation of findings relating to the effects of species or stimulus location difficult. Firstly, as discussed above, variables influencing the magnitude of contrast may not necessarily influence values of  $a$ . However, McSweeney, et al. (1986) reported in their review that the median  $a$  value from studies examined which used a signal key procedure (i.e., the discriminative stimuli were located away from the response key) was smaller than the median  $a$  value for all studies included. Secondly, many of the above studies' results may have been confounded as they typically differed with respect to more than one variable. For example studies which used rats as subjects often also used stimuli remote from the response key (Dougan, Farmer-Dougan & McSweeney, 1989). Thus differences between these studies and others which used pigeons and stimuli on the response key may have resulted from either or both of these differences. It is also possible that the apparent effects of species or stimulus location may relate to the already discussed effects of stimulus discriminability. That is discriminative performance may be reduced and hence the magnitude of contrast smaller if the discriminative stimuli are remote from the response key on which attention is focussed (see also Williams, 1983). Apparent effects of species may also be related to discrimination as different species have different sensory capacities. For example, rats' ability to discriminate visual stimuli used may be more limited than pigeons.

Another variable which may influence animals' sensitivity to relative reinforcement rate is the frequency with which an animal experiences alternatives. The effect of reinforcements available for other behaviours on a particular behaviour may be expected to decline as a function of time since exposure to the alternative (Herrnstein, 1970). Such an effect is clearly demonstrated in the changes in animals' performance when experimental conditions change. That is, when behaviour changes following a change in the conditions of reinforcement, it may be argued that reinforcement rates previously operating have minimal effect on current performance. As behaviour typically changes over a period of days following a

FIGURE 0.1

Hypothetical changes in  $a$  that may occur if sensitivity of behaviour to relative reinforcement rates declined as a function of time since exposure to the alternative component. The top panel shows the hypothetical decline in sensitivity to relative reinforcement rate as a function of time since exposure to the alternative source of reinforcement. The second and third panels show the values of  $uau$  that would be obtained for successive subintervals of components. Each of these two panels show  $uau$  values that would be obtained with a different component duration. Also shown, as the dashed horizontal lines, are the approximate values of  $uau$  for overall responding that would be obtained for each component duration.



the alternative source of reinforcement. The second and third panels show the values of  $a$  that would be obtained for successive subintervals of components of multiple schedules given that performance conformed to the underlying monotonic function described in the top panel. Each of these two panels show  $a$  values that would be obtained with a different component duration. Also shown, as the dashed horizontal lines, are the values of  $a$  for overall responding that would be obtained for each component duration. As shown in this figure, if behaviour could be described in terms of the function depicted in the top panel, regardless of the component duration, then the values of  $a$  obtained for the two subintervals where component duration was 30 s would be the same as those obtained for the first two subintervals of a 60-s component. Overall  $a$  values would, however, increase as component duration was decreased.

Although the within-component and component-duration effects described have been reported in a number of studies, others have failed to find one or other of these effects (e.g., Buck, Rothstein & Williams, 1975; Charman & Davison, 1982). Nevertheless the influence of temporal proximity in multiple schedules may be seen as having particular importance as this variable may affect multiple-schedule but not concurrent-schedule performance.

On concurrent schedules animals tend to change over from one schedule to another at a faster rate than component durations in multiple schedules typically allow. Thus on concurrent schedules animals sample the two reinforcement rates more regularly and the maximum period of time since exposure to the alternative reinforcement rate tends to be shorter. It may therefore be argued that temporal proximity of alternate reinforcement rates is relevant to both types of procedures and that the higher  $a$  values obtained for concurrent-schedule performance may result from the shorter period of time between schedule alternations.

The results of an experiment by Silberberg and Schrot (1974), however, suggest that temporal proximity does not influence performance on the two schedules in the same way. This experiment used a procedure where a multiple schedule was yoked to a concurrent VI VI schedule such that components of the multiple schedule changed

when birds working on the concurrent schedule switched between one schedule and another. In the first phase animals on the concurrent schedule changed from one schedule to another relatively quickly. Thus in the multiple schedule, component duration was short and  $a$  values obtained were close to 1.0. In the second phase of this experiment a change-over-delay operating in the concurrent schedule was increased leading to a reduction in the frequency with which animals changed from one schedule to another. Component duration on the multiple schedule was thus increased. As expected  $a$  values obtained for the multiple-schedule performance decreased but  $a$  values obtained for data from the master subjects (i.e., those working on the concurrent schedule) did not. These results suggest that unlike the effect of stimulus discriminability, temporal proximity of alternative reinforcement sources may affect performance on multiple schedules but not on concurrent schedules. Thus the validity of describing behaviour under the two types of schedule with reference to the same equation, the GML, may be questioned.

As stated, the results of studies examining the effects of temporal proximity of reinforcement rates on multiple schedules are not entirely consistent and further experimentation may be regarded as necessary. Furthermore simply finding that sensitivity to relative reinforcement rates decreases with increases in component duration or as a direct function of time within a component, does not provide proof that the relevant variable is time *per se* since exposure to the alternative reinforcement rate. That is, increases in  $a$  observed on short components may result from the maximum period of time since exposure to the alternative reinforcement rate being reduced. Alternatively the increased  $a$  values with short components may be the result of the duration of time a schedule is available being reduced. Similarly, the changes in  $a$  values obtained for successive periods of a component may relate to the increase in time since exposure to the alternative reinforcement rate, but could equally relate to the increase in time since the actual transition from one component to another or stimulus onset (White et al., 1984).

The aim of this thesis was to examine further the effect of temporal proximity of alternative reinforcement rates on multiple-schedule

performance. The first experiment addressed the effect of reducing component duration. The second experiment examined an alternative method of increasing the time between exposure to alternative sources of reinforcement. In both experiments, within-component changes in  $a$  were also assessed. In particular the hypothesis, that sensitivity to relative reinforcement rate decreases as a monotonic function of time since exposure to the alternative reinforcement rate, was assessed.

## EXPERIMENT 1

The data from the first two conditions of this experiment were also presented as part of an unpublished masters thesis by this author: Hunt, M.J. (1985) Multiple schedule performance: The effects of changing component duration. Unpublished masters thesis: University of Waikato.

### The Short-Component Effect

The first experiment which demonstrated increased sensitivity to relative reinforcement rates with shortening component duration in multiple schedules was carried out by Shimp and Wheatley (1971). Shimp and Wheatley found that the ratio of responses made became closer to the ratio of reinforcements obtained as component duration was decreased from 180 s through 60 s, 30 s and 10 s to 5 s. When component duration was further reduced to 2 s the difference between response and reinforcer ratios increased slightly for two of the three birds used. McSweeney et al. (1986) reanalysed the data from this experiment to obtain values for the parameters of Equation 2. Mean  $a$  values (Equation 2) ranged from 0.46 when component duration was 180 s to 0.91 when component duration was 5 s. The mean  $a$  value was 0.82 when component duration was 2 s. Shimp and Wheatley concluded from these results that shortening component duration of multiple schedules produced behaviour similar to that found in concurrent schedules. That is matching between relative response and relative reinforcement rates could obtain.

Several other studies provide support for Shimp & Wheatley's conclusion. These include Merigan, Miller and Gollub, with a two key procedure (1975), Silberberg and Schrot (1974), Todorov (1972), and Williams (1989). In all these experiments relative response rates approximated relative reinforcement rates when component duration was short (< 30 s), and discrepancies between these two measures, typical of multiple schedule performance, were noted when component duration was relatively long (> 30s). One other study (de Villiers, 1974) reported a similar effect when negative reinforcement was employed.

Other studies have similarly demonstrated that values of the parameter  $a$ , at shorter component durations were higher than  $a$  values obtained with longer component durations, but the values of  $a$  found in these studies, at the shortest component durations, were still considerably less than 1.0 (Hunt, 1985; Charman & Davison, Exp 4, 1982).

Still further support for Shimp & Wheatley's findings can be found in studies which examined the effect of reducing component duration on the magnitude of contrast. Several investigators (e.g., Green & Rachlin, 1975; McSweeney, 1982; Spealman, 1976; Williams, 1979; 1983; 1989) have reported that the magnitude of contrast increased when the duration of equal-length components was reduced. However, in a study using rats as subjects, McSweeney (1982) found no difference in the magnitude of contrast obtained when component duration in both components was 30 s compared with conditions where component duration was 90 s in both components. This study does not seriously challenge the findings of others as only two component durations were examined and the shorter of these was longer than that found in several studies to be associated with increases in the magnitude of contrast.

Considerable evidence currently available on the effects of varying component duration on multiple-schedule performance is thus in favour of the hypothesis that shortening component duration will increase  $a$  values obtained. Furthermore the results of some experiments suggest that  $a$  values obtained for multiple-schedule performance can approximate those associated with concurrent schedules.

Two other studies, however, have found that shortening component duration had no effect on values of  $a$  obtained. Charman and Davison (Exp 1, 1982) found that, when the durations of the components of a multiple schedule were unequal, values of  $a$  did not change consistently when component duration was reduced. Similar results have been reported in some studies examining the effects of component duration on behavioural contrast when the duration of only one component was changed (Williams, 1983). Results of early studies suggest that the magnitude of contrast increases if the component duration of a rich component is reduced (e.g., Ettinger &

Staddon, 1982; Hinson & Malone, 1980; Hinson, Malone, McNally & Rowe, 1978). While, if the component duration of a component associated with a lower rate of reinforcement is reduced, the magnitude of contrast will decrease (e.g., Coelho de Rose, 1986; Hinson & Staddon, 1981; Taus & Hearst 1970; Wilton & Clements, 1971). However, Ettinger and Staddon (1982) found that the magnitude of contrast was not affected when the duration of the lean component was reduced. A later study (Williams, 1989) found that when the duration of a varied component was decreased the magnitude of contrast was reduced, while if the duration of a constant component was decreased, the magnitude of contrast was increased regardless of the relative richness or leanness of the components. Thus the variable which determines whether increases or decreases in contrast might be expected with reductions in the duration of one component may not necessarily be the reinforcement rate in that component.

These results may be a reflection of confounding between the effects of reducing component duration and the effects of having unequal component durations. Some evidence exists which suggests that, other things being equal, relative component duration influences relative response rates. For example, Hinson et al. (1978) found that response rates in short and long components of multiple schedules varied as a function of the relative length of the preceding schedule even when reinforcement rates in the two components considered were equal. Conceivably the effects of unequal component durations may reflect a different process from that involved when the duration of components of equal length is reduced.

A more serious threat to the validity of the short-component effect comes from an experiment by Charman and Davison (Exp. 2, 1982) where the duration of components were equal and short (5 s). The values of the exponent  $\alpha$  obtained when data from this study were described by the GML, were within the range of those typically found for multiple-schedule performance with longer component durations and were not greater than those found with the same birds at longer component durations. Charman and Davison (1982) suggested that the discrepancy between their results and the results of others outlined above may be due to procedural variables. They noted that in most

of the studies including Shimp & Wheatley's, which reported the short-component effect, few, if any schedule reversals were carried out, whereas their experiment involved several schedule reversals.

In a further experiment Charman and Davison (Exp 4, 1982) found that increases in the value of  $a$  could be obtained if component duration was systematically reduced while the VI schedules in effect remained unequal but constant. However the higher values of  $a$  obtained were not maintained following a schedule reversal. Thus they concluded that the short-component effect was fragile and possibly more the result of a hysteresis-produced bias than of increased schedule interaction. That is, with continued exposure to conditions where the richer reinforcement rate was consistently associated with one stimulus, animals may have developed a bias toward responding more during that stimulus.

Their conclusion may be hasty given that Shimp and Wheatley (1971) did reverse the reinforcement rates associated with the component schedules at the two shortest component durations examined. Furthermore the low  $a$  values which described performance obtained in the first condition of Shimp and Wheatley's experiment, where component duration was 180 s, were generally replicated when that condition was repeated subsequent to conditions with shorter component durations. Similarly Hunt (1985) found that  $a$  values increased as component duration was systematically reduced, but that  $a$  values then decreased as component duration was systematically increased. These recoveries of low  $a$  values with increasing component duration are not easily explained as hysteresis. Hysteresis-produced bias would predict that  $a$  values for conditions with longer component durations conducted subsequent to systematically reducing component duration would remain high.

Todorov's (1972) results also appear incompatible with Charman and Davison's suggestion. Although Todorov's study did not involve any schedule reversals, conditions with the shorter component durations (5 s and 10 s) were presented early in a series of conditions and were also replicated subsequent to conditions with longer component durations. In general response rates on the component schedules in the replicated conditions were similar to those obtained on the first determination. Where differences were noted, deviations from

matching were greater in the second condition. Furthermore a more recent study by Williams (1989) evidenced the short-component effect even though several schedule pairs were employed.

An alternative explanation of the discrepancy between Charman and Davison's results and those of Shimp and Wheatley (1971), Todorov (1972), Hunt (1985), Williams (1989) and others is that hysteresis effects in Charman and Davison's experiments led to their failure to obtain a short-component effect. In their Experiment 4 the reduction in the values of  $a$  obtained following the schedule reversal when component duration was 6 s, may have been a reflection of response bias due to the higher reinforcement rate, in the previous five conditions, having been correlated with the same stimulus.

Hysteresis may also have influenced results in Experiment 2 of Charman and Davison's (1982) study. As noted by Williams (1983), in many instances response rates in that experiment did not entirely reverse when reinforcement rates were reversed. It is also notable that when reinforcement rates in the two components were equal, the ratios of response rates were often considerably different from 1.0. Results similar to these may be expected if animals' responding is influenced by a consistent bias. However in the conditions of Charman & Davison's study, which employed a single key, very little bias as measured by  $\log c$  was evident. Similar hysteresis problems, where previous reinforcement conditions exert control over behaviour in later conditions, have been noted in multiple schedules before (Williams, 1983 and others). Indeed, if hysteresis occurs consistently, it may contribute to the lower  $a$  values typical of multiple-schedule performance. Thus it could be argued that the insensitivity of behaviour on multiple schedules, to relative reinforcement rates, is the result of hysteresis as much as it is the result of any decreased interaction between schedules. If the effects of hysteresis are compounded across conditions this possibility may be seen as consistent with the finding of McSweeney et al. (1986) that the values obtained for the parameter  $a$  were inversely related to the number of reinforcement ratios employed.

Charman and Davison's failure to obtain the short-component effect may be regarded as an instance where hysteresis may have confounded

other effects. However, data from a study by White, Pipe, McLean and Redman (1985) which did not clearly evidence hysteresis, provide support for their findings. This study also examined the effects of component duration on sensitivity to relative reinforcement rates and involved several schedule reversals at each of the two component durations examined. White et al. report that sensitivity to relative reinforcement as measured by the parameter  $a$  did not change consistently across subjects when component duration was reduced from 60 s to 15 s. The results of this experiment appear to be conclusive evidence against the generality of the short-component effect. However several features of the study question such a conclusion. Only two component durations were examined, the shortest of which was 15 s. Some other studies which have demonstrated the short-component effect have found that increases in  $a$  values across all subjects were observed only at durations shorter than this. For example Hunt (1985) found that for two hens' data (out of the six hens used) increases in  $a$  values were not observed when component duration was reduced to 15 s. When component duration was further reduced increases in  $a$  values for these two hens' data were noted. A similar effect was observed in Shimp and Wheatley's study. In that study consistent increases in  $a$  values were not noted in all pigeons' data until component duration was reduced to 10 s. The values of  $a$  obtained by White et al. when component duration was 15 s were higher than those obtained when component duration was 60 s for two birds' data. It is possible that if component duration had been further reduced, increased sensitivity would also have been noted in the other three birds' data.

Other features of the data from White et al.'s (1985) study are of interest. Noticeable increases in response bias as a function of reduced component duration were observed in the data from two of the three birds which did not demonstrate increases in the value of  $a$ . In both cases this bias was in the direction of the stimulus associated with the higher reinforcement rate in the first condition where component duration was reduced from 60 s to 15 s. Furthermore for these two birds the response differentials in the first two conditions with a 15 s component duration were much greater than those observed in the last two conditions with this component duration. However the reinforcement ratios in these two sets of

conditions were the same. Thus for these two birds relative response rates more closely approximated relative reinforcement rates in earlier conditions than later conditions. It is therefore possible that some kind of hysteresis effect may have influenced the resultant  $a$  values.

Williams' (1989) study suggests a further explanation of their result. In the first five conditions of his study component duration was maintained at 5 s while the reinforcement rates in the two components used were varied such that the reinforcement ratios changed from 1/15 to 15/1 over five conditions (the descending series) but no condition involved reinforcement rates in the component schedules being reversed. In a further five conditions (the ascending series) the reinforcement ratios were changed from 15/1 to 1/15. No hysteresis effect, as assessed by comparing the ascending and descending series, was found. Williams then repeated the same sequence of conditions. The values of  $a$  obtained for the first series were higher than those obtained for the second series for all subjects. Williams thus concluded that increasing the number of conditions examined may decrease sensitivity to reinforcement independently of hysteresis effects as they are generally understood.

Although in their study White et al. (1985) used only seven conditions when component duration was 15 s, these conditions were carried out subsequent to five conditions with 60 s component duration. Therefore it is possible that  $a$  values obtained for the later conditions where component duration was 15 s were lower than might be expected due to decreased sensitivity resulting from exposure to previous conditions. The results obtained for these conditions could thus be seen as the product of two independent variables, reduced component duration (which would increase sensitivity) and increased number of antecedent conditions (which would decrease sensitivity).

#### Within-Component Changes in Sensitivity

A number of studies have reported that response rates changed within components of a multiple schedule. Typically response rates at the beginning of a rich schedule were high and then decreased as a

function of time since component alternation, while response rates in a lean component were initially low and then increased as a function of time since component alternation (Arnett, 1973; Blough, 1983; Boneaux & Axelrod, 1962; Catania & Gill, 1964; Green & Rachlin, 1975; Innis, 1978; McLean & White, 1981; Nevin & Shettleworth, 1966; Wilton & Clements, 1971 and others). These within-component response rate changes have been termed positive and negative local contrast respectively. However the appearance of these phenomena in multiple-schedule performance is inconsistent. Under some conditions in a number of studies it was present in some birds' data but not in others (e.g., Nevin & Shettleworth, 1966) and in many cases local positive and local negative contrast were not found together (e.g., Blough, 1983; Hunt, 1985; Nevin & Shettleworth, 1966; McLean & White, 1981). In general local negative contrast appears to occur more consistently than local positive contrast (Blough, 1983; Hunt, 1985; McLean & White, 1981 and others).

A further threat to the generality of local contrast is that in many studies where the phenomenon was observed it appeared early in discrimination training and then disappeared (e.g., Boneau & Axelrod, 1962; Mackintosh, Little & Lord, 1972; Williams, 1981). In some instances a different pattern of within-component responding emerged after local contrast, as defined here, was eliminated (e.g., Nevin & Shettleworth, 1966; Buck, Rothstein & Williams, 1975; Williams, 1982). For example Buck et al. report that while local positive contrast occurred early in training, after around 30 sessions response rates on a VI schedule of a MULT VI EXT schedule increased as a function of time since component alternation. However Blough (1983), Malone (1976) and Malone and Staddon (1973) found that if discriminative stimuli were difficult to discriminate, or variable, local contrast could persist in steady-state behaviour. Other studies have also reported that local contrast can persist even where stimuli are clearly discriminable (e.g., Arnett, 1973; Catania & Gill, 1964; Hunt, 1985; McLean & White, 1981). Of the two phenomena however, local negative contrast appears more robust (e.g., Blough, 1983; Nevin & Shettleworth, 1966).

If measured in terms of the generalised matching law, changes within components appear more consistent. In two studies examined in

McSweeney et al.' (1986) review (White & Redman, 1983; White, Pipe & McLean, 1984) values of the exponent  $a$  consistently decreased as a function of time since component alternation. A similar effect was also found by Hunt (1985), McLean and White (1981) and White et al. (1985). However Hunt (1985) found that  $a$  values obtained did not change consistently across successive 15 s subintervals of longer components (>30 s) for one subject. For this hen decreases in  $a$  across successive 5 s and 3 s subintervals were noted at the shorter component durations.

#### The Relation Between the Short-Component Effect and Within-Component Changes in Behaviour.

Consistent with the proposition outlined in the general introduction, McLean and White (1981) argued that local contrast in steady-state behaviour could contribute to the magnitude of overall contrast and values of  $a$  obtained for overall responding. In particular they suggested that the short-component effect both in relation to the magnitude of contrast and high  $a$  values observed may be a result of shortening component duration, if doing so is equivalent to sampling only the early part of longer components. An experiment carried out to test this hypothesis (McLean & White, 1981) provided only tentative support. Local contrast was found in many instances. However, in general, the local contrast observed occurred in the changed component and thus did not influence the magnitude of behavioural contrast, a phenomenon measured in terms of response rate changes in the constant component only. Thus it can be argued that the presence of local contrast may be independent of the magnitude of behavioural contrast in short components.

This finding is consistent with earlier studies which found local contrast in the absence of behavioural contrast (e.g., Arnett, 1973; Williams, 1981), and behavioural contrast in the absence of local contrast (e.g., Nevin & Shettleworth, 1966; Williams, 1981). However McLean and White's (1981) study did not preclude the possibility that the changes in  $a$ , as a function of time since component alternation, may contribute to the high  $a$  values found with short components if these  $a$  values result more from response rate changes in a changed rather than constant component. That is, as  $a$  values incorporate response rates in both changed and

unchanged components, within-component changes in an altered component will affect values of  $a$ . Three studies have direct bearing on this issue.

Spealman (1976) reported that the response rates during the first 3 s of a long VI component of a MULT VI EXT schedule were not consistently different from response rates obtained when the component duration was 3 s. A study by Hunt (1985), which examined the relation between  $a$  values when component duration was reduced and within-component changes in  $a$ , also provided some further support for a relation between the two. Changes in values of  $a$  as a function of time since component alternation were evident in the subjects' (hens) data. These changes were more consistent and the change was greatest across successive 5-s and 3-s subintervals of shorter components than across successive 15-s subintervals of longer components. Increases in the values of  $a$  obtained for overall responding with reductions in component duration were also more consistent across the shorter component durations (< 20 s). These findings suggest that the appearance of the short-component effect may be dependent on the occurrence of within-component changes in sensitivity. However the values of  $a$  for the initial 15-s, 5-s, and 3-s periods of longer components found by Hunt (1985) tended to be higher than  $a$  values for overall responding when component durations were 15 s, 5 s, and 3 s respectively. This later finding was also observed by White et al. (1985). In their study the  $a$  values for the first 15 s of 60-s components were higher than  $a$  values obtained when component duration was 15 s. Thus it appears that in some circumstances the short-component effect may not be explained simply as the result of sampling the more reinforcement-sensitive period of longer components. However Mackintosh et al. (1972) found that although behavioural contrast was maintained in the absence of local contrast, behavioural contrast developed only in conditions where local contrast was initially evident. This finding therefore supports the suggestion that the two phenomena are related in some way. It is also notable that in another study (White et al., 1984) within-component effects and changes in sensitivity for overall behaviour were influenced similarly by stimulus discriminability.

In summary, experimental results relating to both the short-component effect and its possible relation to the within-component decreases in  $a$  values observed in several studies are equivocal. However the failure of some studies to demonstrate the short-component effect may be related to other phenomena in their data or simply that the range of component durations studied were insufficient. A more serious threat to the proposition that sensitivity to relative reinforcement rates is a monotonic function of time since exposure to the alternative reinforcement rate, is the apparent independence of the within-component effects and the short-component effect evident in two previous studies. However as few studies have examined this relation and the results of one of these (White et al., 1985) were also atypical (in that the short-component effect was not found) further study of the two phenomena is warranted.

The aim of this experiment was to examine the effects of changing component duration in a two-component multiple schedule while frequently reversing the reinforcement ratios of the component schedules. Two reinforcement ratios only were examined at each of five component durations. Five component durations were used as other studies suggest that the component durations at which changes in  $a$  may be observed varies across animals such that several component durations may need to be examined. Two reinforcement ratios were examined in order to assess the effects of reducing component duration on the parameter  $a$  in the GML independently from changes in  $\log c$ . Although the use of more than two reinforcement ratios may lead to better estimates of these parameters, employing a number of reinforcement ratios may also confound results obtained by increasing the number of conditions.

In addition to examining the effects of reducing component duration on  $a$  values obtained for overall responding, within-component changes in  $a$  and local contrast were examined in order to further examine the relation between these. Of particular interest was the hypothesis that sensitivity to relative reinforcement rates is mediated by the time between exposure to the alternative rates.

## METHOD

### Subjects

Four domestic hens (numbered 51 to 54) maintained at  $80 \pm 10\%$  of their free-feeding bodyweight were used. All hens had been subjects in an undergraduate laboratory class where they had experience with several simple schedules. Water was continuously available in their home cages and grit was occasionally provided.

### Apparatus

Three translucent response keys, each 30mm in diameter, were set on one wall of an experimental chamber with internal dimensions of 410mm x 574mm x 625mm. Two of these keys were sited 200mm apart and 380 mm from the grid floor. The third key was centrally situated between these two keys. This key could be illuminated from behind by either an orange (S1) or yellow light (S2). Pecks, of at least 0.20 N to this key when illuminated, caused both the keylight to darken and a tone to sound, both for 0.35ms. An aperture 70mm x100 mm centrally located 90 mm above the floor in the same wall gave access to the food hopper. The food hopper could be raised and illuminated by a 1 W white light to allow 3-s access to whole wheat. Whenever the food hopper was raised the centre key became dark and inoperative. The two side keys remained dark and inoperative throughout the experiment. A ventilation fan located in the wall opposite the response keys provided masking noise.

Solid-state programming equipment, which scheduled and recorded all experimental events, was located remote from the experimental chamber.

### Procedure

Training. At the start of the experiment all hens were exposed to a Fixed Ratio 1 schedule. Training on this was continued until all hens were pecking reliably. Subjects were then exposed to a MULT VI 15-s VI 15-s schedule. This schedule was changed gradually to a MULT VI 60-s VI 60-s schedule over thirty days. The duration of

both components was 120 s. After this training the first experimental condition was introduced.

Experimental Procedure. In the first condition the duration of both components was 120 s and reinforcement was delivered according to a VI 30-s schedule during one component (S1) and a VI 120-s schedule during the other (S2). Each VI schedule was derived from an arithmetic progression of the form  $i, i+d, i+2d, \text{etc.}$ , where  $i$  was the smallest interval, for example 2.5 s in a VI 30-s schedule, and  $d = 2i$ . Each schedule was comprised of 15 randomised intervals. In the second condition the reinforcement schedules in the components were reversed but component duration was maintained at 120 s. In the third condition the reinforcement ratios remained unchanged but component duration was reduced to 60 s. In every second condition subsequent to this component duration was further reduced. In every alternate condition reinforcement ratios were reversed. Five component durations were examined. These were in order of presentation 120 s, 60 s, 30 s, 15 s, and 6 s. Table 1.1 gives the reinforcement schedules, component duration and number of training sessions in each condition.

Experimental conditions were changed when the behaviour of all subjects was stable. Behaviour was considered stable when the median of the relative response rates in S1 over five sessions was within 0.05 of the median of the previous five, on five, not necessarily consecutive, occasions. Sessions were terminated after 28 minutes in Conditions 1 to 8 and after 20 minutes in Conditions 9 and 10.

The number of responses made and the number of reinforcers obtained in each component and the time each component was available were recorded. In addition responses made within successive subintervals of each component were recorded. The lengths of the subintervals varied across conditions and were 15 s for Conditions 1 to 4, 5 s for Conditions 5 to 8, and 3 s for Conditions 9 and 10.

TABLE 1.1 The variable-interval schedules (in seconds) in each component, component durations, number of component alternations and number of sessions in each condition in the order the conditions were presented.

Condition	VI Schedules		Component Duration (in seconds)	No. of Alternations	No. of Sessions
	Orange	Green			
1	30	120	120	7	35
2	120	30	120	7	27
3	120	30	60	14	22
4	30	120	60	14	47
5	30	120	30	28	60
6	120	30	30	28	30
7	120	30	15	56	20
8	30	120	15	56	28
9	30	120	6	99	23
10	120	30	6	99	21

## RESULTS

The total number of responses made and reinforcers obtained in each component, the total time in each component and the number of responses made in each subinterval of each component for all birds in the last five days of each condition are given in Appendix 1.1 All the following analyses were based on these data.

### Behaviour Across Components

#### Response Rates

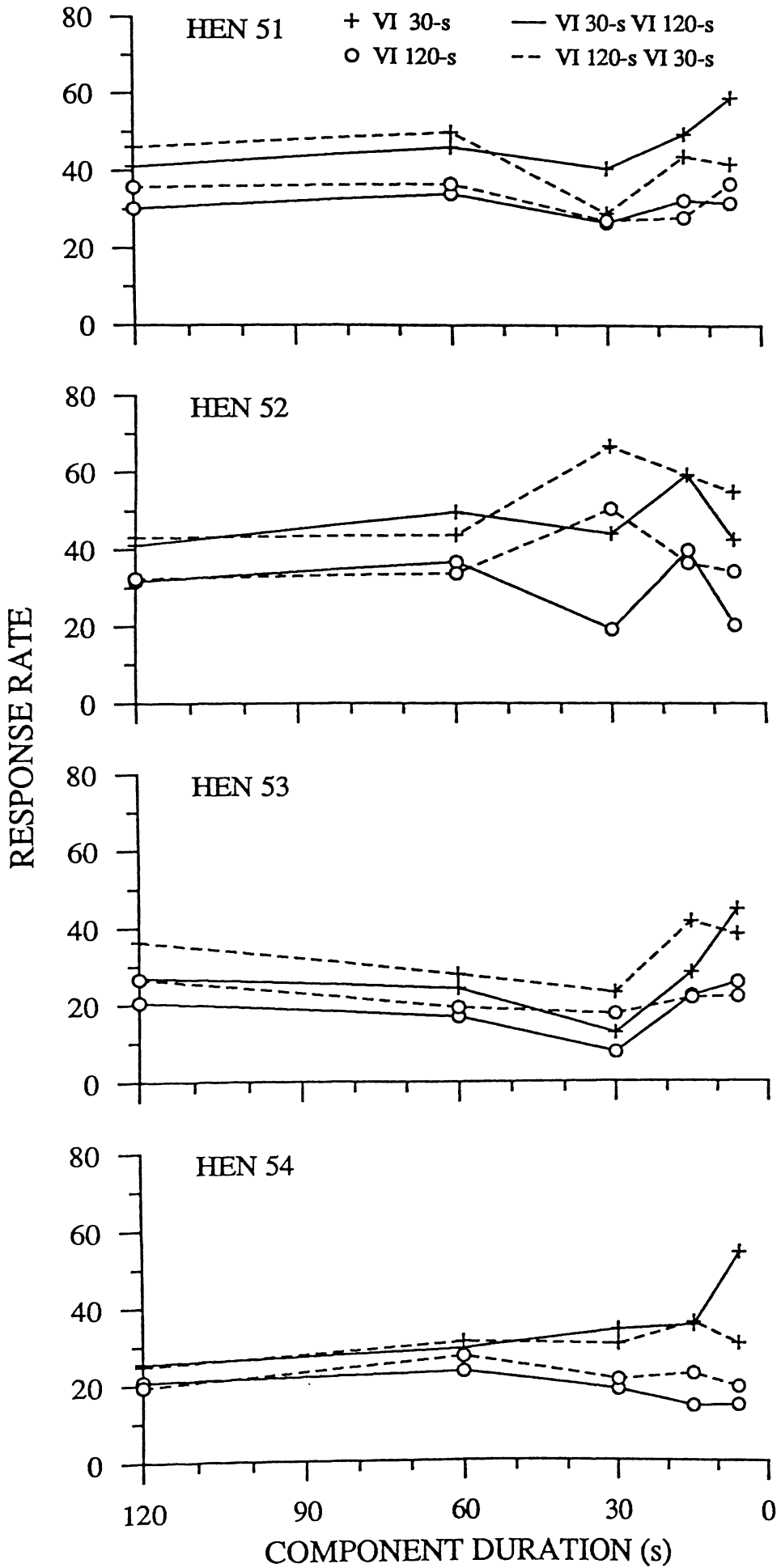
Response rates in each component were calculated by dividing the number of responses in a component by the total time the component was available with reinforcement time excluded. Response rates were then converted to responses per minute.

Figure 1.1 shows response rates in S1 and S2 plotted against component duration for all hens. In all instances the plusses represent response rate on the VI 30-s schedule and the circles represent response rate on the VI 120-s schedule. Points connected with a solid line indicate data obtained when a MULT VI 30-s VI 120-s schedule was in effect and points connected with a dashed line represent data obtained when the schedule in effect was a MULT VI 120-s VI 30-s. For 51's and 54's data response rates on the rich component (plusses) were always higher than response rates on the lean component (circles). Hen 52's and 53's response rates on the VI 30-s component were always higher than response rates obtained on the VI 120-s component within conditions but not across conditions where schedules were reversed. For both these birds' data response rates on the VI 30-s component of Condition 5 (MULT VI 30-s VI 120-s with 30-s component duration) were lower than the response rates on the VI 120-s component of Condition 6 (MULT VI 120-s VI 30-s with 30-s component duration).

Response rates changed as a function of component duration but these changes were not consistent across birds. Generally response rates on the lean schedule (circles) decreased as component duration decreased from 120 s to 30 s. As component duration was further

FIGURE 1.1

Response rates in S1 and S2 plotted against component duration for all birds. In all instances the plusses represent response rate on the VI 30-s schedule and the circles represent response rate on the VI 120-s schedule. Points connected with a solid line indicate data obtained when a MULT VI 30-s VI 120-s schedule was in effect and points connected with a dashed line represent data obtained when the schedule in effect was a MULT VI 120-s VI 30-s.



reduced, response rates for Hens 51 and 53 increased, for Hen 54 decreased further and for Hen 52 stayed (on average) at the same level. For Hen 52 response rates on the VI 120-s component were variable across the two conditions at each component duration.

Response rates in the rich schedule (plusses) tended to be variable across the two conditions at each component duration. That is, there was often a difference of over 10 responses per minute between response rate on the VI 30-s of a MULT VI 30-s VI 120-s schedule and the VI 30-s of a MULT VI 120-s VI 30-s schedule. Given these differences, response rates on the rich schedule varied as a function of reducing component duration but these changes were also inconsistent across birds. For Hen 54 response rates, on average, increased as a function of reducing component duration. For Hen 53 response rates decreased when component duration was decreased from 120 s to 30 s but then increased as component duration was further reduced. The converse effect was present in Hen 52's data. For this bird response rates, on average, increased as component duration was reduced to 30 s and then decreased as component duration was further reduced. Hen 51's response rates in the rich schedule initially increased when component duration was reduced but then decreased before again increasing as component duration was further reduced.

In order to assess whether any hysteresis effects were present in the data the difference between response rates on the two component schedules, in the two conditions carried out at each component duration, were examined. If the reinforcement schedules operating in the previous condition influenced responding during the next condition then the differential between response rates should decrease following a schedule reversal. That is, if hysteresis is present, response rate on the rich schedule would be lower if, in the previous condition, the lean schedule was associated with the stimulus now associated with the rich schedule. Similarly response rate on a lean schedule would be higher if, in the previous condition, the stimulus now associated with the lean schedule had been associated with the rich schedule. Thus, if the preceding condition influences behaviour, differences between response rates should be diminished following a schedule reversal. The differences between response rates on the rich and lean schedules for all hens

are given in Table 1.2. For all hens the first column gives the response differential for the first condition at each component duration and the second column gives the response differential for the second condition at each component duration. These differences, between response rates on the rich and lean schedules, were variable across the two conditions run at each component duration. For Hen 51's data the difference between response rates tended to be greater for the first condition than for the second condition at each component duration. This trend was also evident in Hen 52's and 53's data at shorter component durations. Thus hysteresis was evident in the data from these three hens. In general, for all hens' data the response differentials increased as a function of reducing component duration.

#### Generalised Matching Law Analysis

Regression lines were fitted by the method of least squares to the data obtained from the two conditions at each component duration to determine estimates of the parameters  $a$  and  $\log c$  of Equation 4 given below.  $Br$  represents response rate (calculated as above),  $R$  the number of reinforcers obtained and the subscripts 1 and 2 the components in which they occurred.

$$\frac{Br_1}{Br_2} = a \log \left[ \frac{R_1}{R_2} \right] + \log c \quad (4)$$

This equation is a form of the Generalised Matching Law (as expressed in Equation 3) which takes into account the differences in the times component schedules of a multiple schedule are available due to differences in the number of reinforcers obtained in each component. Figure 1.2 shows line estimates of the parameter  $a$  in Equation 4 plotted as a function of component duration. It can be seen that values of the parameter  $a$  varied as a function of component duration such that  $a$  values tended to increase as component duration decreased. This trend was not, however, evident until component duration was decreased from 60 s to 30 s for 52 and 54 and from 30 s to 15 s for Hen 51. The highest and lowest  $a$  values obtained for each bird's data and component durations at which they occurred are given in Table 1.3. The highest  $a$  values were obtained when component duration was 15 s for two birds (Hen 51 and Hen 53) and 6 s for Hens 52 and 54. The lowest  $a$  values

TABLE 1.2 The difference between response rates on the rich and lean schedules for the two conditions at each component duration. For all hens the first column gives the response differential for the first condition at each component duration and the second column the response differential for the second condition where the reinforcement schedules in the components were reversed.

Comp Duration(s)	Hen 51		Hen 52		Hen 53		Hen 54	
	Cond	Order	Cond	Order	Cond	Order	Cond	Order
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
120	10.65	10.28	9.29	10.66	6.46	9.71	4.67	5.42
60	13.24	11.98	10.05	12.98	8.60	7.33	3.90	5.99
30	13.93	2.95	24.95	16.18	5.17	5.50	15.43	9.06
15	15.81	16.99	27.80	19.59	19.94	6.06	13.30	20.82
6	27.41	5.06	22.13	20.53	19.03	16.37	39.34	17.26

FIGURE 1.2

Estimates of the parameter  $\alpha$  in Equation 4 plotted as a function of component duration.

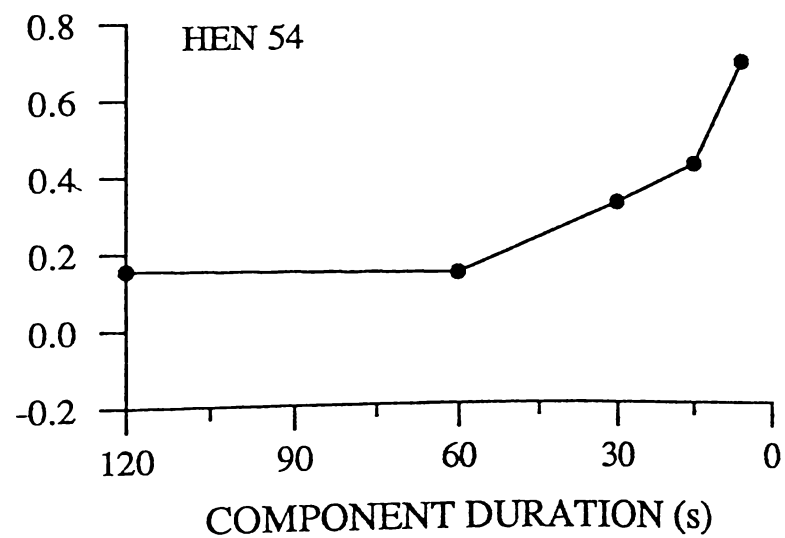
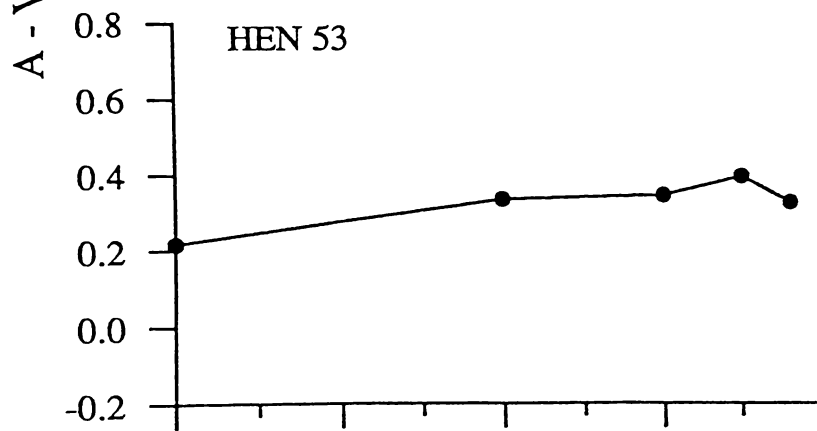
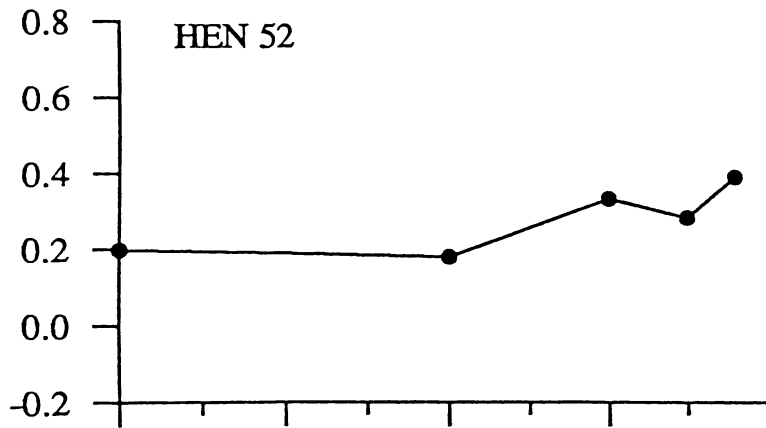
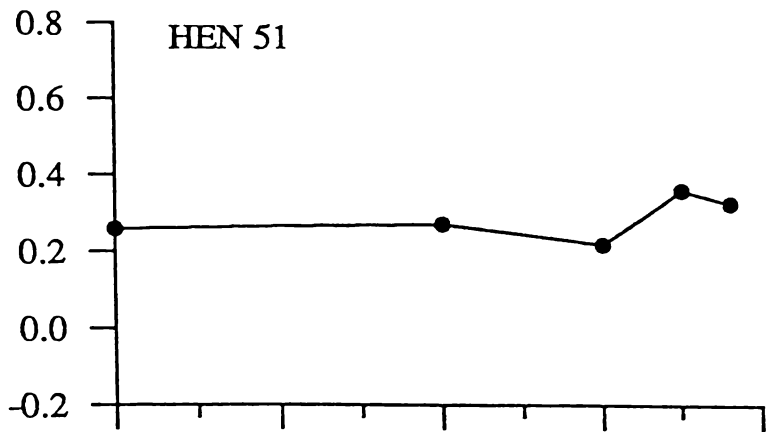


TABLE 1.3 The highest and lowest  $\alpha$ -values obtained for each hen's data and the component duration at which these values were obtained.

Hen	Highest $\alpha$ Obtained	Component Duration	Lowest $\alpha$ Obtained	Component Duration
51	0.36	15	0.22	30
52	0.39	6	0.18	60
53	0.40	15	0.21	120
54	0.69	6	0.14	60

obtained occurred when component duration was 30 s for Hen 51, 60 s for Hens 52 and 54, and 120 s for Hen 53. Estimates of  $a$  when component duration was 120 s ranged from 0.16 (Hen 54) to 0.26 (Hen 51) and from 0.33 (Hen 51) to 0.69 (Hen 54) when component duration was 6 s.

Figure 1.3 shows the estimates of the parameter  $\log c$  in Equation 4 plotted against component duration. The value of  $\log c$  for Hen 54's data increased as component duration decreased indicating an increasing bias toward S1. This increase was from -0.01 when component duration was 120 s to 0.16 when component duration was 6 s. Changes in biases were noted in the data for the remaining three hens but the direction of these bias changes was different at each component duration. For all three birds the direction of bias changed toward S1 when component duration was 30 s, toward S2 when component duration was 15 s and toward S1 in when component duration was 6 s.

#### Behaviour Within Components

The response rate for each subinterval of each component were calculated using Equation 5 given below

$$\text{Response rate in subinterval } i = \frac{R_i}{\frac{T_j - (R_j \times 3)}{N}} \quad (5)$$

In this equation  $B_i$  is the number of responses in the subinterval  $i$ .  $T_j$  and  $R_j$  are the total time in seconds, with reinforcement time excluded, and the total number of reinforcements obtained respectively in the component of which  $i$  is a subinterval and  $N$  is the number of subintervals.

Figure 1.4 shows response rates for each successive subinterval of each component for all hens in all conditions. The first two panels show response rates in each successive 15-s subinterval for the conditions where component duration was 120 s and 60 s. The third and fourth panels show response rates in each successive 5-s subinterval when component duration was 30 s and 15 s respectively and the righthand panel shows response rates in successive 3 s subintervals when component duration was 6 s. In all instances the

FIGURE 1.3

Estimates of the parameter  $\log c$  in Equation 4 plotted against component duration.

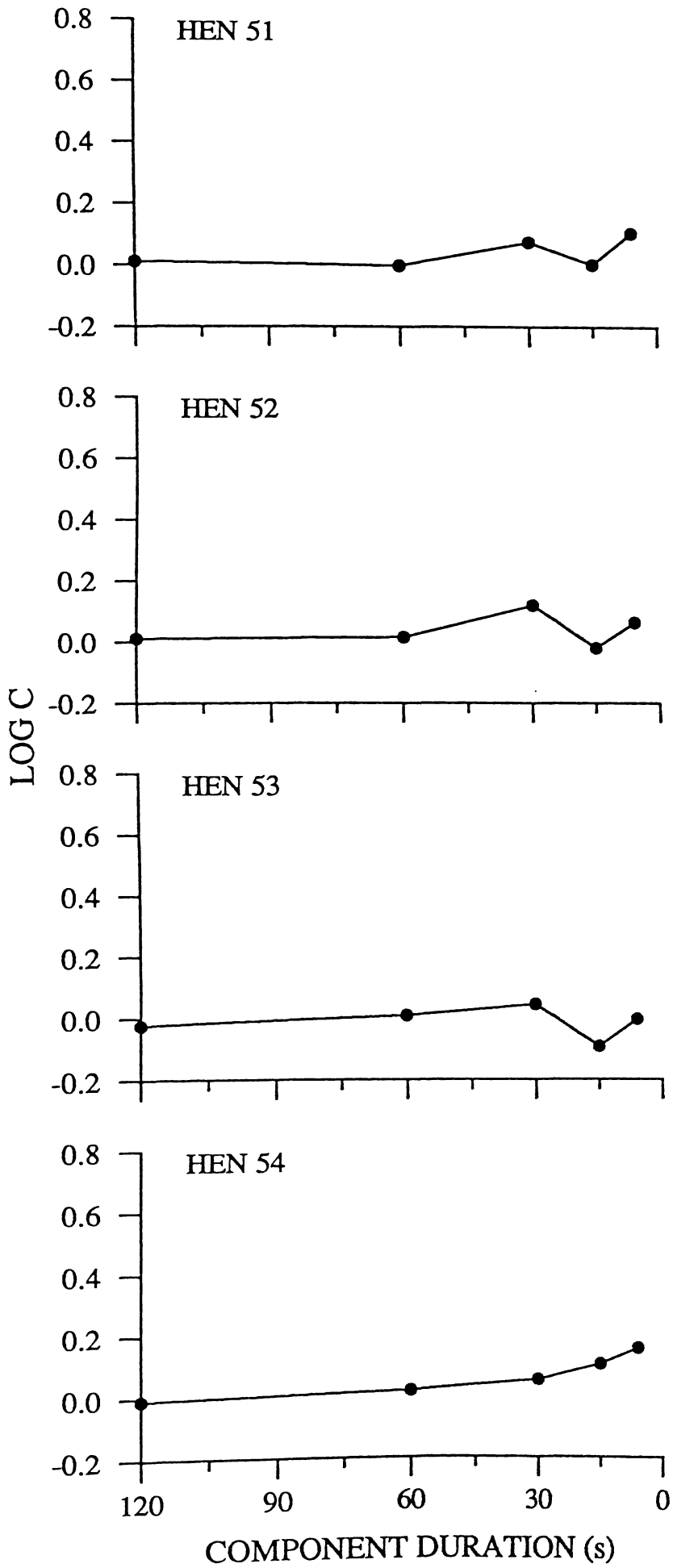
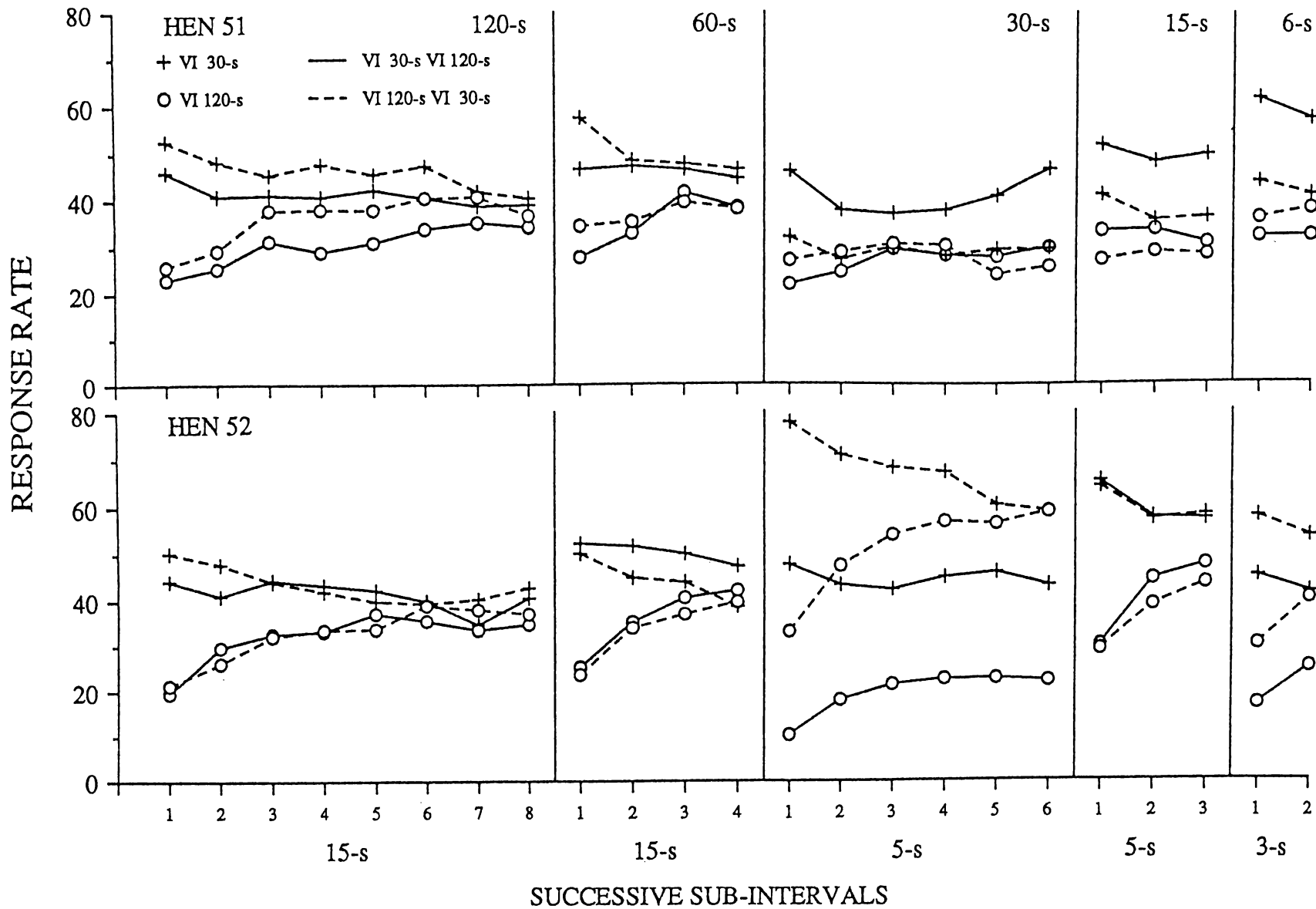
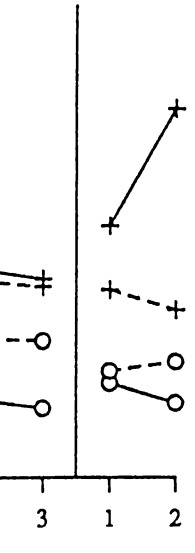
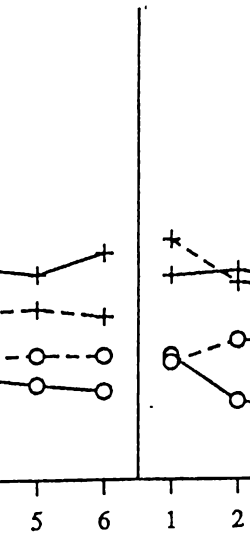
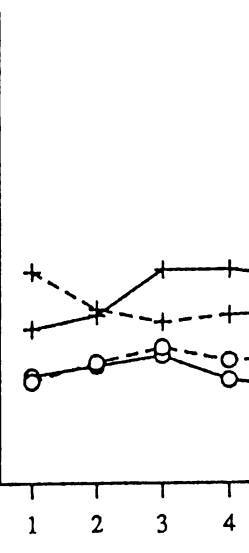
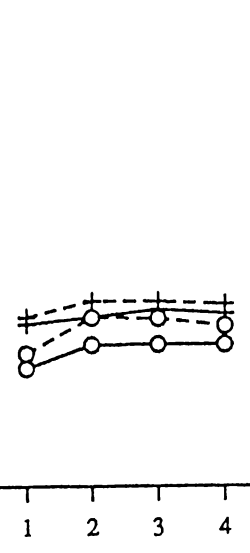
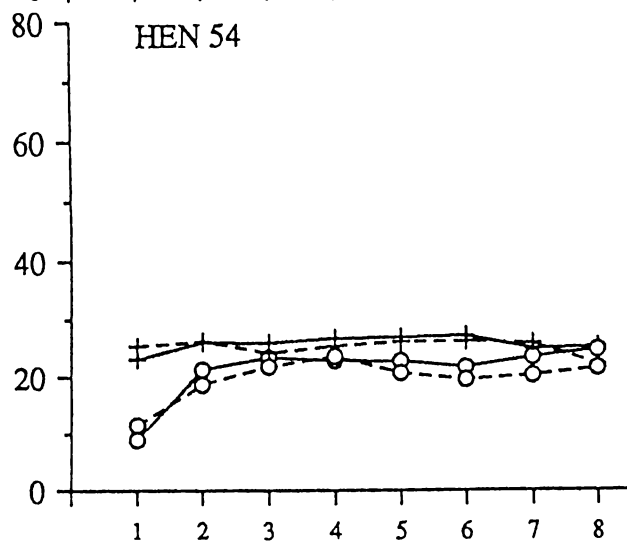
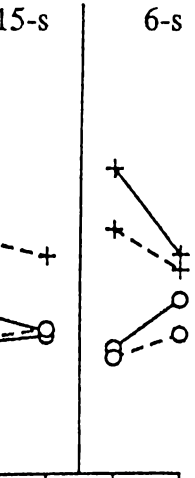
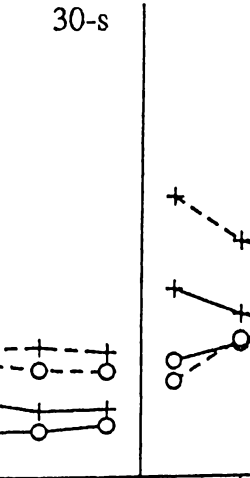
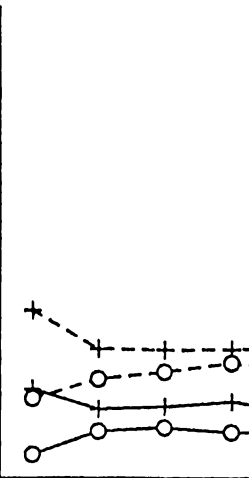
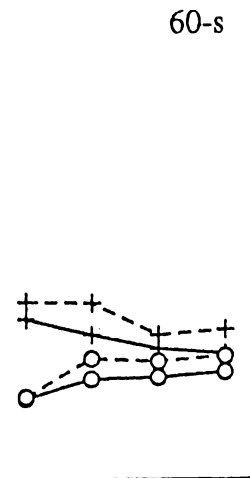
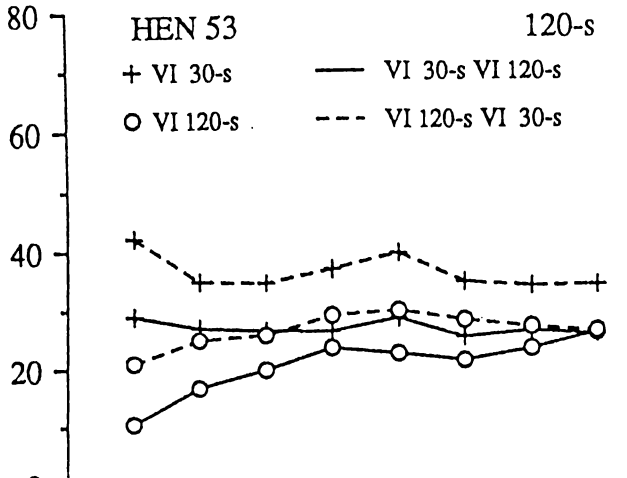
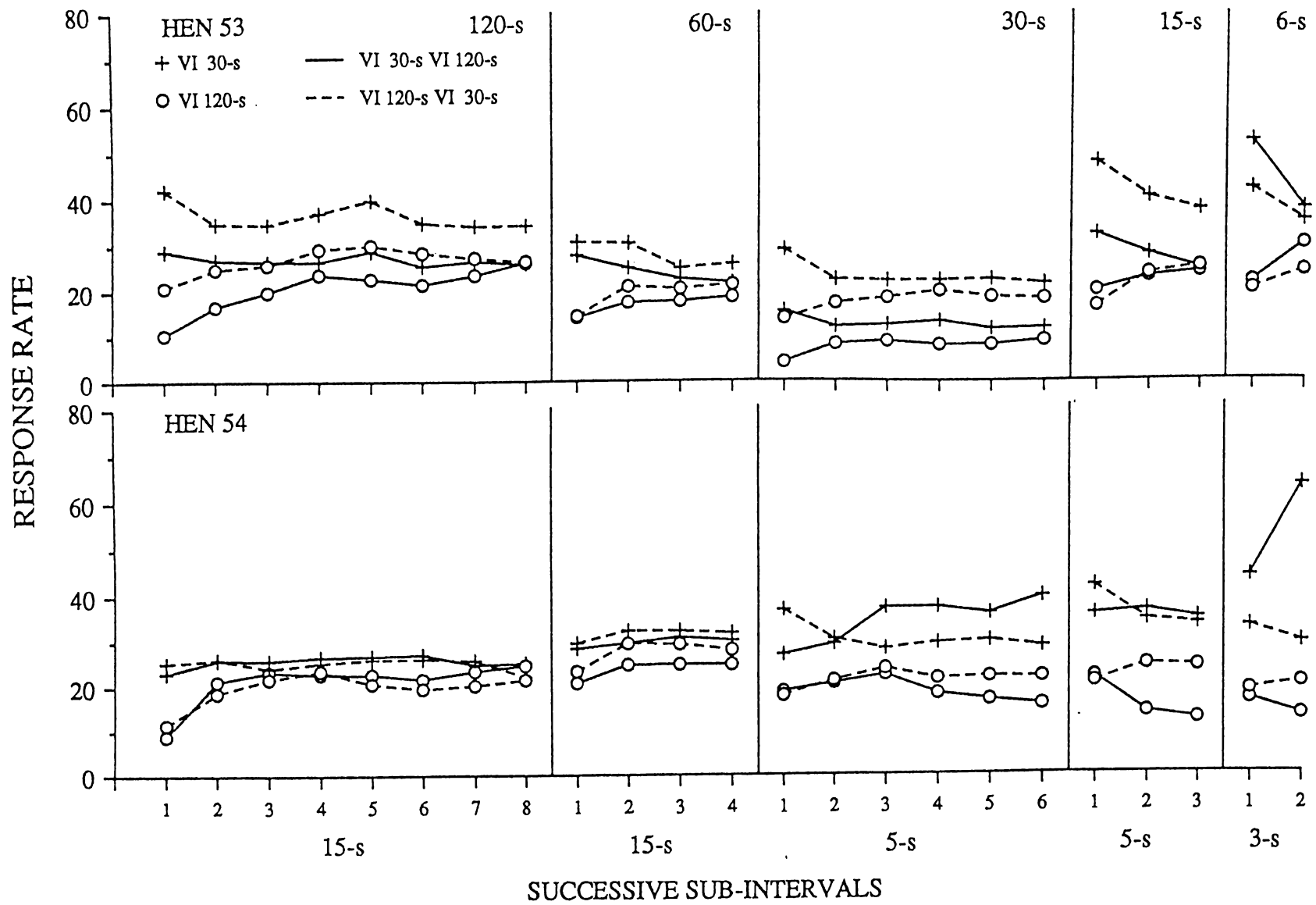


FIGURE 1.4

Response rates for each successive subinterval of each component for all hens in all conditions. Each panel shows response rates in each successive subinterval for the two conditions at one component duration. For the first two panels show response rates in each successive 15-s subinterval when component duration was 120 s and 60 s, the third and fourth panels show response rates in each successive 5-s subinterval when component duration was 30 s and 15 s respectively and in the right hand panel shows response rates in successive 3-s subintervals when component duration was 6 s. In all instances the plusses (+) represent response rate on the VI 30-s component and the filled circles represent response rate on the VI 120-s component. Points connected with a solid line indicate data obtained when a MULT VI 30-s VI 120-s schedule was in effect and points connected with a dashed line represent data obtained when the schedule in effect was a MULT VI 120-s VI 30-s.





plusses (+) represent response rate on the VI 30-s schedule and the circles represent response rate on the VI 120-s schedule. Points connected with a solid line indicate data obtained when a MULT VI 30-s VI 120-s schedule was in effect and points connected with a dashed line represent data obtained when the schedule in effect was a MULT VI 120-s VI 30-s. For all hens response rates on the lean schedule (open circles) tended to increase as a function of time since component alternation. This effect occurred for all hens in both conditions when component duration was 120 s and 60 s (the two left most panels of Figure 1.4) and for Hens 52 and 53 in all conditions. For the Hens 51 and 54 response rates, on the lean component, tended to remain constant, or occasionally decrease, as a function of time since component alternation when component duration was 30s or less. In total, negative local contrast was observed in 33 out of 40 possible instances.

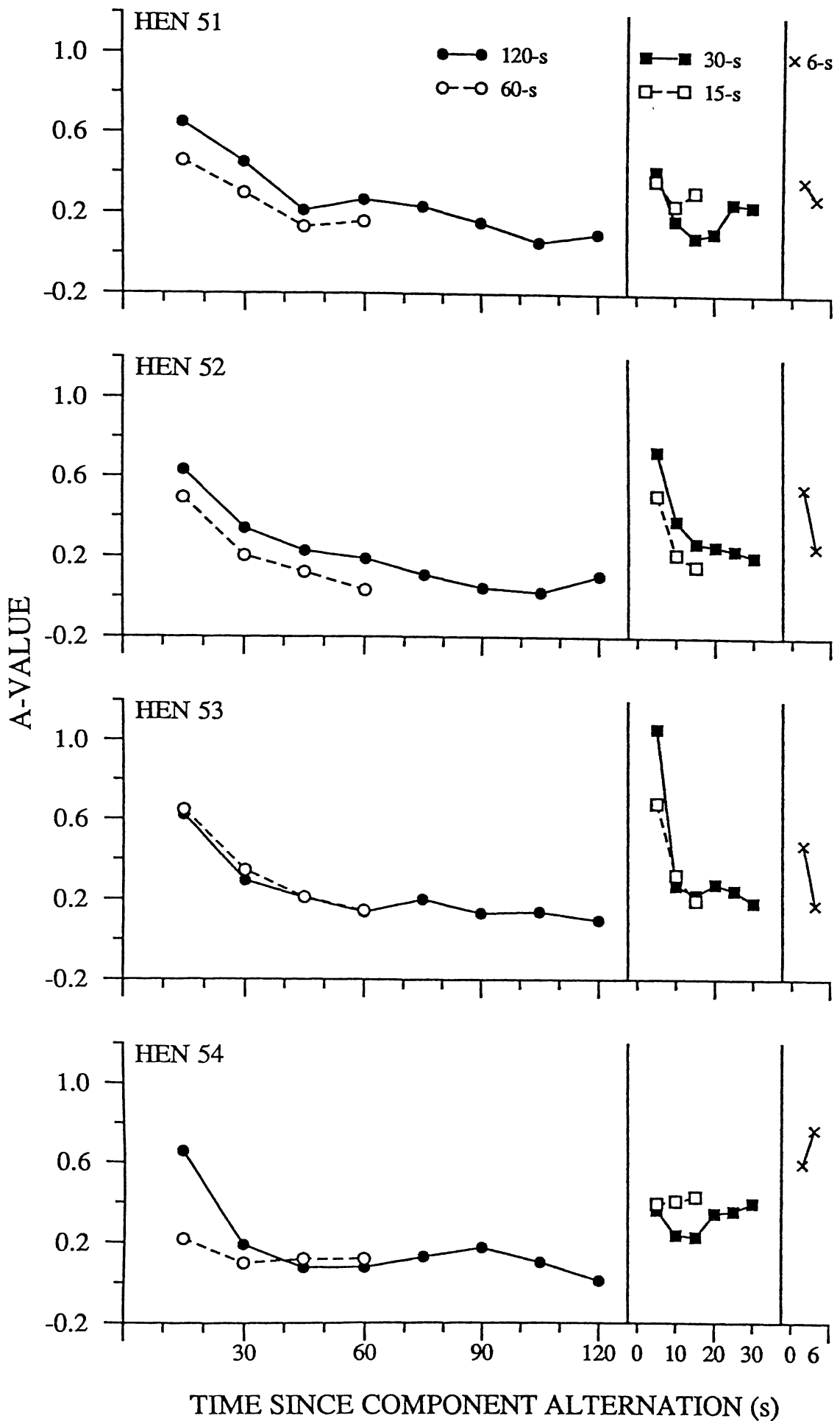
Response rate during the component with the higher reinforcement density tended to decrease as a function of time since component alternation for three of the four hens (51, 52, and 53). For these three hens the effect was present in the data, to some extent, at all component durations. However when component duration was 30 s, this effect was only marginally present for Hen 53 and ambiguous for Hen 51. When the MULT VI 30-s VI 120-s was in effect response rates for Hen 51 decreased immediately after component alternation, but then increased again as time since component alternation increased. This decrease in response rates on the rich schedule as a function of time since component alternation noted in 51's, 52's and 53's data, was not clearly evident in 54's data. For this bird response rate did not vary consistently within components when component duration was 120 s and 60 s and was variable across the two conditions at each of the remaining three component durations. In total, positive local contrast was observed in 32 out of 40 possible instances.

#### Generalised Matching Law Analysis

Figure 1.5 shows the slopes of least square regression lines (the exponent  $\alpha$  in Equation 4) for responding in each successive subinterval on all conditions for all birds plotted against time

FIGURE 1.5

The slopes of least square regression lines (the exponent  $a$  in Equation 4) for responding in each successive subinterval on all conditions for all birds plotted against time since component alternation. The left panel shows values of  $a$  obtained in successive subintervals when component duration was 120 s (filled circles) and 60 s (open circles). The centre panel shows  $a$  values obtained for each successive 5-s subinterval when component duration was 30 s (filled squares) and 15 s (open squares). The right panel shows values of  $a$  obtained in each successive 3-s subinterval when component duration was 6 s.

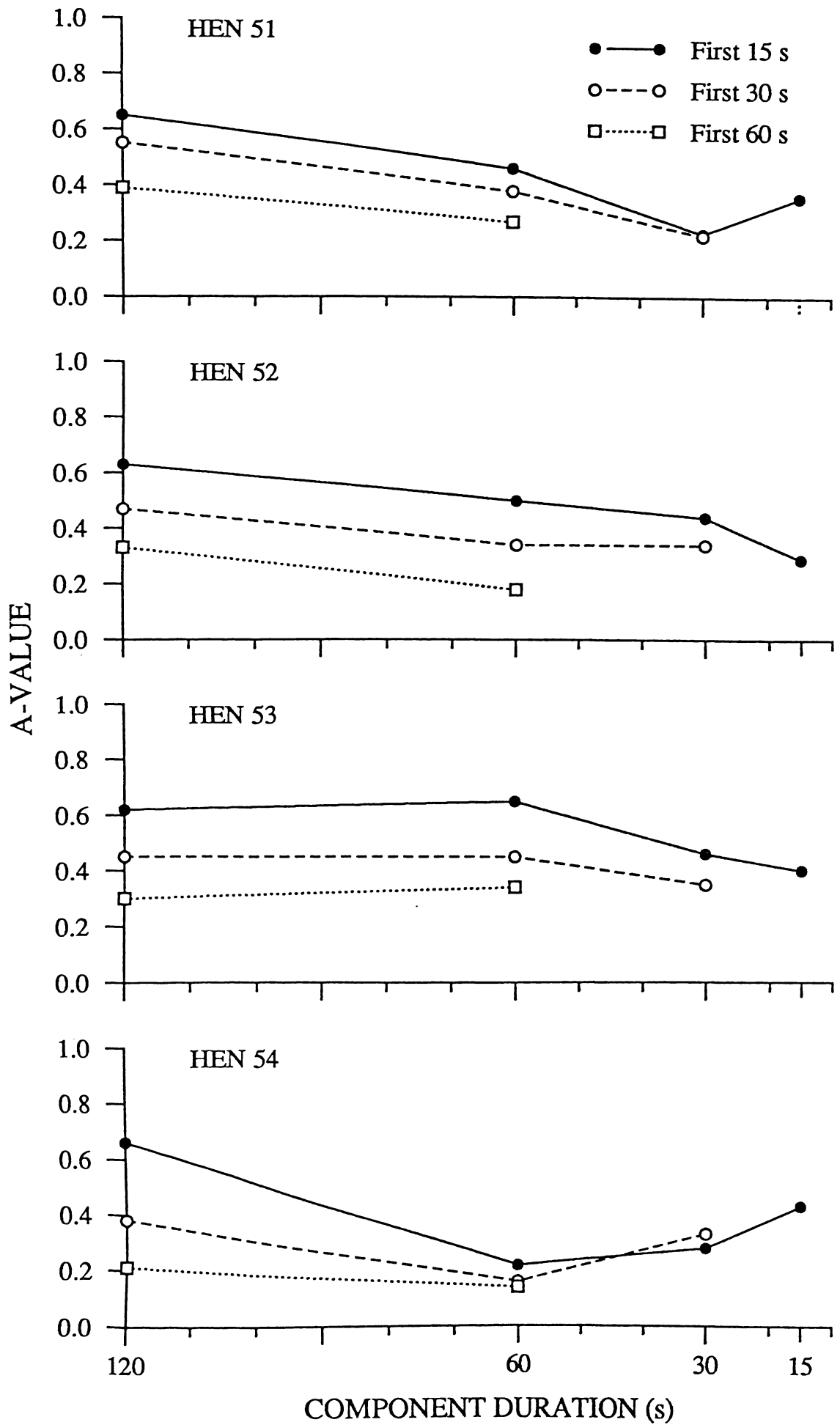


since component alternation. The left panel shows values of  $a$  obtained in successive subintervals when component duration was 120 s (filled circles) and 60 s (open circles). The centre panel shows  $a$  values obtained for each successive 5-s subinterval when component duration was 30 s (filled squares) and 15 s (open squares). The right panel shows values of  $a$  obtained in each successive 3-s subinterval when component duration was 6 s. Generally there was a decrease in the value obtained for the exponent  $a$  as a function of time since component alternation. This effect can be seen in all birds' data when component duration was 120 s and 60 s and to some extent in the data from all conditions for Hens 51, 52 and 53. Values of  $a$  obtained for 54's data increased as a function of time since component alternation when component duration was 6 s and 15 s and first decreased, and then increased, as a function of time since component alternation when component duration was 30 s. This decrease followed by an increase in  $a$  values obtained was also noticeable in Hen 51's data when component duration was 30 s and 15 s. The subsequent increase in this hen's data, relative to the initial decrease, was smaller than that seen in 54's data. Where decreases in  $a$  as a function of time since component alternation occurred, they tended to occur over the first few intervals with the greatest decrease in  $a$  occurring between the first and second subintervals regardless of their length.

Figure 1.6 shows estimates of  $a$  for responding during the first 15 s, 30 s and 60 s of components where component duration was greater than or equal to these values, plotted against component duration. Filled circles represent  $a$  values for the first 15 s of components, open circles the first 30 s and squares the first 60 s. Generally estimates of  $a$  obtained for early portions of longer components were greater than the  $a$  values obtained for total responding when component durations were equal to those portions. For example  $a$  values obtained for responding in the first 15 s, 30 s and 60 s of a 120 s component were generally higher than  $a$  values obtained when component duration was 15 s, 30 s and 60 s respectively. In most instances values of  $a$  obtained for responding during early portions of longer components decreased as component duration decreased. That is values of  $a$  for the first 15 s of a 120 s component were higher than those obtained for a comparable

FIGURE 1.6

Estimates of  $a$  for responding during the first 15 s, 30 s and 60 s of components where component duration was greater than or equal to these values, plotted against component duration.

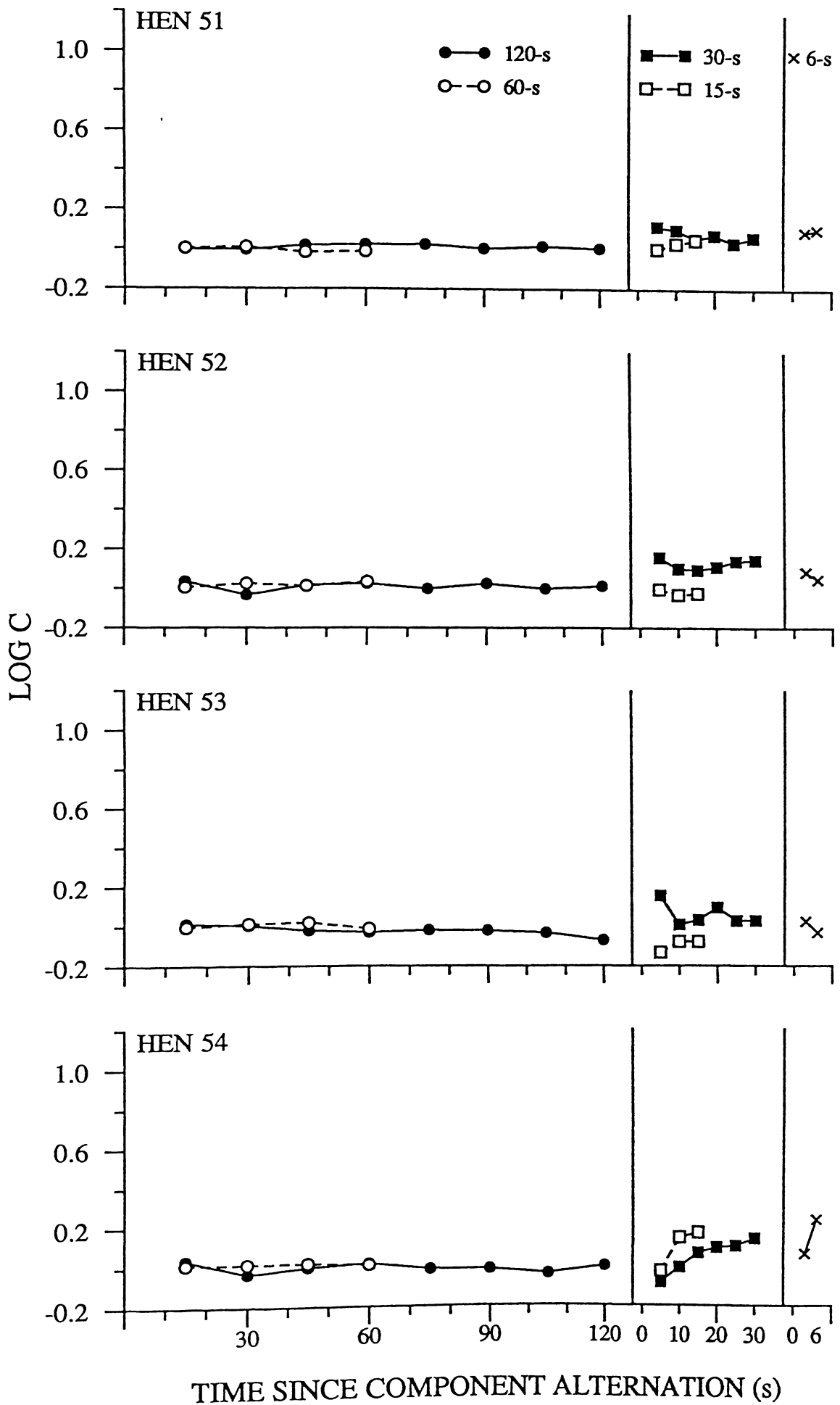


period of a 60 s component which in turn were higher than  $a$ 's obtained for the first 15 s of a 30 s component. These effects are clearest in the data from Hens 51, 52 and 53. For Hen 54's data  $a$  values obtained for early portions of components, when component duration was 120 s, were higher than those obtained when component duration was equal to the duration of these portions. For conditions where component duration was less than 120 s the opposite pattern occurred. As component duration was reduced from 60 s  $a$  values obtained for early portions of equal duration increased. For example, the  $a$  value obtained for the first 15 s of components when component duration was 60 s, was lower than that obtained for the same period when component duration was 30 s, which in turn was lower than that obtained when component duration was 15 s.

Figure 1.7 shows estimates of the parameter  $\log c$  in Equation 4 for all hens' data plotted as a function of time since component alternation. The left panel shows values of  $\log c$  obtained when component duration was 120 s (filled circles) and 60 s (open circles). The centre panel shows  $\log c$  values when component duration was 30 s (filled squares) and 15 s (open squares). The right panel shows values of  $\log c$  obtained when component duration was 6 s. There were no consistent changes in  $\log c$  across birds and in only one bird's data were changes in bias, as a function of time since component alternation, consistent across conditions. For Hen 54's data, bias towards S1 increased as a function of time since component alternation when component duration was 30 s, 15 s and 6 s.

FIGURE 1.7

Estimates of the parameter  $\log c$  for successive subintervals of components plotted as a function of time since component alternation. The left panel shows values of  $\log c$  obtained when component duration was 120 s (filled circles) and 60 s (open circles). The centre panel shows  $\log c$  values when component duration was 30 s (filled squares) and 15 s (open squares). The right panel shows values of  $\log c$  obtained when component duration was 6 s.



## DISCUSSION

The aim of this experiment was firstly to determine whether the short-component effect reported by Shimp and Wheatley (1971) and others was replicable when reinforcement rates in the component schedules were reversed frequently. In addition the contribution of within-component changes in relative response rates, to the phenomenon were investigated.

### The Short-Component Effect

The results of this experiment were similar in form to those reported by de Villiers (1974), Merigan et al. (1975), Silberberg and Schrot (1974), Shimp and Wheatley (1971), Todorov (1972) and Williams (1989). They are also consistent with other studies where increases in the magnitude of behavioural contrast were reported when component duration was reduced (e.g., McSweeney et al., 1986; McSweeney, 1982; Williams, 1982).

Several features of the data are of particular interest. For all birds, values of  $a$  increased as component duration was reduced but this increase was not a constant function of decreasing component duration. For two hens' data  $a$  values did not increase until component duration was reduced to 30 s. In the data from another hen, Hen 51, there was no increase in  $a$  until component duration was reduced from 30 s to 15 s. This finding is similar to those reported by Hunt (1985) and Shimp and Wheatley (1971). Hunt found that for all subjects (hens) initial reductions in component duration did not affect point estimates of  $a$  consistently. Similarly examination of the data from Shimp and Wheatley's (1971) study suggests that values of  $a$  did not change consistently as a function of component duration. In particular when component duration was decreased from 60 s to 30 s  $a$  values increased for only one bird and decreased for the other two subjects. It may therefore be argued that reducing component duration does not increase sensitivity to reinforcement ratios until some critical component duration is reached.

Given that Shimp and Wheatley and Hunt found that the low  $a$  values typical of longer components were recoverable when component

duration was increased this effect may be re-stated in terms of increasing component duration. That is, it appears that increasing component duration decreases animals' sensitivity to relative reinforcement rates until some asymptotic level of  $a$  is reached. Increasing component duration beyond this level has no further consistent effect. Thus it appears that the short-component effect is limited at one extreme, although the component duration at which asymptotically low  $a$  values are reached varies across subjects.

The short-component effect also appears to be limited at the other extreme. For two birds in this study the highest  $a$  values were obtained when component duration was 15 s with values of  $a$  decreasing for these birds when component duration was further reduced. Similar results were reported by Shimp and Wheatley (1971), and Todorov (1972). The highest  $a$  values were obtained when component duration was between 5 s and 10 s in Shimp and Wheatley's study and 10 s in Todorov's study. One possible explanation for this effect is that, at short component durations, reinforcement time is more likely to carry over across schedule alternations. Thus the stimulus present when a reinforcer is obtained may be different from the stimulus present when the reinforcement duration is complete. In such situations the stimulus immediately following, as well as the stimulus immediately preceding reinforcement delivery, may come to have some control over behaviour. If this were so, some reinforcers for behaviour in one component may reinforce behaviour in the other and thus  $a$  values would decline. However the highest  $a$  values from some birds' data in this and others' studies (Hunt, 1985; Shimp & Wheatley, 1971) were found at the shortest component durations examined. Thus increases in sensitivity to relative reinforcement rates appear to occur across a limited range of component durations and this range varies across subjects.

Although in form the results of the current experiment support the findings of Shimp and Wheatley (1971), the values of  $a$  obtained differ. In Shimp and Wheatley's study  $a$  values ranged from 0.16 to 0.91 while in this study values of  $a$  obtained ranged from 0.16 to 0.68 with a median of 0.39. Thus, while values of  $a$  obtained at short component durations by Shimp and Wheatley may be described as similar to those typical of concurrent-schedule performance,

considerably more undermatching was evident in this study than typically found with concurrent schedules.

Three procedural variables may have contributed to the relatively greater undermatching evident in this experiment. Firstly this experiment used hens as subjects while most other studies demonstrating the short-component effect used pigeons. Hunt (1985) also examined the effects of component duration on multiple-schedule performance with hens as subjects and found that  $a$  values at short component durations were considerably less than 1.0 in most instances. As previously discussed, some other studies have also reported that multiple-schedule performance varies with the species used (e.g., Weiss, 1971). However it is notable that concurrent-schedule performance with hens as subjects is not characterised by lower  $a$  values than found in other species (DeMello, 1984; Scown, 1983). Thus if the undermatching evident here is related to species differences it would appear that this variable also influences multiple and concurrent-schedule performance differently.

A second factor which may have contributed to the comparative insensitivity of relative response rates to relative reinforcement rates noted in this study and in that of Hunt (1985), is that the stimuli employed in these two studies may have been more difficult to discriminate. As stated, several studies have shown that the decreased discriminability of stimuli will decrease  $a$  values obtained for concurrent-schedule (Bourland & Miller, 1981; Miller et al., 1980) and multiple-schedule performance (White et al., 1983, 1984). Data from experiments using a delayed-matching-to-sample task have shown that hens can discriminate colours (Breen, 1987; Carroll, 1989 and Jones, 1988) but the colour differential used in those experiments were greater than those used in this study. However as no experiments have assessed the discriminability of the stimuli used here it is only possible to speculate that this variable may have contributed to the low  $a$  values found.

Finally the schedule reversals carried out at each component duration may have attenuated the short-component effect. In this study hens tended to respond less on the VI 30-s schedule and more on the VI 120-s following a schedule reversal. That is when

reinforcement rates associated with the component schedules were reversed response rates did not reverse to the same extent. This effect is demonstrated in three hens' data by the reduced response differential noted between the first and second condition at various component durations (Table 1.2) and is reflected in the changes in the direction of bias in the data from Hens 51, 52 and 53 (Figure 1.3). For example, when component duration was reduced from 15 s to 6 s the component schedules in effect were kept constant and response rate was highest on the VI 30-s schedule associated with S1. In the following condition reinforcement rates in the component schedules were reversed, and although response rates were higher on S2 (associated with the VI 30-s schedule) than on S1 (associated with the VI 120-s schedule), response rates on S2 were lower than response rates on S1 in the previous condition. When such data are analysed using the GML equation the value of  $\log c$  will differ from zero. Given that the direction of bias ( $\log c$ ) changed according to which stimulus was associated with the rich schedule in the first of the two conditions at each component duration, bias, in these instances, does not reflect bias toward a particular stimuli so much as the influence of previous conditions, or hysteresis.

As a result of the previous schedule influencing behaviour, apparent sensitivity to current reinforcement rates will decrease when reinforcement rates associated with the component schedules are reversed. The lower  $a$  values found in this experiment may well be the result of this hysteresis although their similarity to the results of Hunt's (1985) study, which did not involve schedule reversals, suggest that difficulties in discrimination or species-related variables may also contribute.

The results of this study are contrary to those obtained by Charman and Davison (Exp 2, 1982) and White et al. (1985). However, as previously discussed, it is arguably the case that aspects of their procedures may have contributed to their failure to find the short-component effect. The results of this study add further support to this hypothesis. Firstly, it was suggested that the study by White et al. may have failed to demonstrate the short-component effect consistently across birds because they did not examine a sufficient range of component durations. As found in previous studies, in this experiment the effect of reducing

component duration was consistent across subjects in that values of  $a$  for all hens' data increased at shorter component durations but increases in  $a$  did not occur across all component durations. It is clearly possible that studies which examine few component durations may not demonstrate the short-component effect purely because they have not used a component duration at which it would be evidenced for their particular subjects. However, while Charman and Davison examined only one component duration, 5 s, this duration is sufficiently small, given the component durations found by others to be associated with increased sensitivity, to expect relatively high values of  $a$  to be found.

As already suggested, Charman and Davison's study may have failed to show the short-component effect because of hysteresis present in their data. However, similar hysteresis effects were present in the data from this experiment and the short-component effect was still evident. Although it is not clear why the influence of previous conditions might have been sufficient to eliminate any effects of employing a short component duration in Charman and Davison's results but not in the present study, or why hysteresis was not evident in Williams' (1989) study, procedural differences in the studies may have contributed. Specifically, it is possible that both the use of frequent schedule reversals and a large number of conditions may contribute to the development of hysteresis.

Williams used several reinforcement ratios but the order of conditions was such that no condition was followed by a condition where the reinforcement rates were reversed. In this study, and in Charman and Davison's study, reinforcement conditions in adjacent conditions were often reversed. Thus abrupt schedule changes may be a necessary condition for hysteresis to obtain.

The difference between Charman and Davison's result and those obtained in this study may be predicted if, with each schedule reversal, response differentials decrease such that response rate becomes increasingly insensitive to current reinforcement ratios. In Charman and Davison's study two schedule reversals were carried out when component duration was 5 s but in the current study only one schedule reversal was carried out at each component duration. If the actual number of schedule reversals was relevant then it

would be predicted that hysteresis would increase over successive schedule reversals. The results of this study suggest that this may be the case as the failure of response rate to reverse completely following reinforcement rate reversals was more consistent in later conditions. However, if simply increasing the number of schedule reversals was sufficient to allow the influence of previous conditions to outweigh any effect of component duration, then the short-component effect would not be expected in this experiment. That is  $a$  values in this experiment were found to increase more in the later conditions, even when hysteresis was observed more consistently.

An alternative explanation of the difference between the results reported here and those of Charman and Davison (1982) relates not to the number of schedule reversals but to the number of conditions employed. As stated, Williams found that values of  $a$  decreased as a function of the number of conditions carried out. In total ten conditions were examined in the present experiment and the only previous experience the hens had was on a small series of single schedule experiments for an undergraduate laboratory class. Charman and Davison's pigeons had previously been exposed to 23 experimental conditions in another experiment. White et al.'s (1985) data may also have been influenced by the number of conditions arranged. It may therefore be concluded that the short-component effect can be reduced by two other effects both of which could relate to previous conditions affecting performance.

The first, which will be referred to here as short-term hysteresis, may be defined as the immediately preceding condition influencing performance. That is, the first may be seen as a tendency for response rates in a particular condition to be more similar to response rates in the previous condition than the reinforcement ratio in effect would predict. This form of hysteresis appears to occur more consistently when the procedure employed involves abrupt changes in reinforcement ratios.

The second form of hysteresis, which will be termed long-term hysteresis, may be defined as a decrease in sensitivity to current reinforcement conditions as a function of the number of previous conditions. This latter form of hysteresis may well result from all

previous conditions influencing performance. That is, this phenomenon may occur as a result of animals' behaviour becoming influenced by the average rate of reinforcement associated with a particular stimulus for all the previous conditions, as the number of previous conditions increase. If animals respond in this manner, and the previous conditions involved changes in reinforcement rates such that in some conditions higher rates were associated with one component but in other conditions higher rates were associated with the other component, then response rates on the component schedules would become similar. It is notable that long-term hysteresis has been observed in concurrent-schedule performance as well (Todorov, Castro, Hanna, Bittencourt de Sa & Barreto, 1983) and thus its appearance in multiple-schedule performance provides some support for the notion that performance on the two types of schedules is controlled by similar processes.

The presence of hysteresis in the data is of interest and may be seen as worthy of further examination. Indeed, if the effects of hysteresis outweigh the effects of reducing component duration, it may be argued that an investigation of hysteresis is of greater importance. However, hysteresis effects do not appear to outweigh the effects of reducing component duration consistently. In the present experiment the short-component effect was observed in all subjects' data including data from those that evidenced instances of short-term hysteresis. Furthermore hysteresis was not evident in all hens' data. Williams (1989) found that the  $a$  values obtained from a second series of conditions with a short component duration were higher than  $a$  values typically obtained when longer durations were used even though long-term hysteresis was evident. Of the two studies which did not obtain the short-component effect the results of one, White et al (1985), may be regarded as an instance where insufficient component durations were examined. Thus only one study currently reported clearly indicates that hysteresis effects may outweigh any effect of reducing component duration. It is also worth noting that in subsequent experiments carried out by Charman and Davison (Experiments 3 & 4, 1982) with the same birds limited evidence of a short-component effect was obtained.

If behaviour across components is considered, the results of this experiment are consistent with the hypothesis that temporal

proximity of alternative reinforcement rates influence the values of  $\alpha$  in the GML.

#### Within-Component Changes in Behaviour

Changes in behaviour within components as a function of time since component alternation, whether assessed in terms of response rate changes or as changes in  $\alpha$ , were observed. However changes observed were not consistent across conditions or birds.

Either local negative contrast or local positive contrast was observed in all birds' data in at least one condition but was observed in only one bird's data in all conditions. The two phenomena were not symmetrical in that in some conditions local positive contrast occurred where local negative contrast did not and in other conditions the opposite was true. Furthermore in some conditions local contrast was observed in some birds' data but not in others. Similar findings have been reported by Blough (1983), Nevin and Shettleworth (1966), McLean and White (1981) and others. For one bird's data the form of within-component changes in response rates changed as a function of decreasing component duration. For this bird (Hen 54) local contrast was observed at longer component durations and either little change in response rates or local induction occurred at shorter component durations. A number of previous studies also report instances where local induction occurred for some birds under conditions where other birds' data evidenced local contrast (e.g., McLean & White, 1981; Nevin and Shettleworth, 1966). In general, changes in response rates were greatest across the first few subintervals of a component regardless of their length as was also found by Hunt (1985), McLean & White (1981), Nevin and Shettleworth (1966) and White et al. (1984). Thus in many respects the changes in response rates within components observed in this study were similar to those reported in previous studies. However several differences between the results of other studies and those observed in this experiment were evident.

Unlike the findings of some other studies (Boneau & Axelrod, 1962; Buck et al., 1975; Williams, 1981) both local positive and local negative contrast were found in steady-state behaviour. In general the two phenomena occurred most reliably at longer component

durations when subintervals were 15 s in duration. This result was therefore different from that found by Hunt (1985). Unlike the results of many previous experiments (e.g., Blough, 1983; Hunt, 1985; McLean & White, 1981; Nevin & Shettleworth, 1966) local negative contrast was not found more reliably than local positive contrast. However, the magnitude of local negative contrast was generally greater than the magnitude of local positive contrast.

The results of this study, taken with the results of others, suggest that, although some aspects of within-component response rate changes may be common across subjects, in general the phenomena may best be described as idiosyncratic. This general lack of consistency across conditions and subjects and the lack of symmetry between local positive and negative contrast observed make these phenomena difficult to explain.

The inherent problems can be easily seen if one theory which has been proposed to explain local contrast is examined. A group of researchers have suggested that behavioural contrast may be explained in terms of Pavlovian stimulus-reinforcer relations which occur when different stimuli are associated with different schedules of reinforcement (Rachlin, 1973; Schwartz & Gamzu, 1977). This theory, termed additivity theory, states that a stimulus associated with a schedule with relatively high reinforcement frequency will become a conditioned stimulus which elicits responding while a stimulus associated with a leaner schedule will inhibit responding. These Pavlovian stimulus-reinforcer responses interact with operant responses, controlled by the response-reinforcer contingency, such that, in a standard contrast experiment response rates in a constant component increase or decrease as a result of the stimulus-reinforcer relation inhibiting or enhancing responding. According to this theory the stimulus-reinforcer relation will be strongest immediately after a transition from one stimulus to another and hence local contrast is predicted. The observed response rate on a rich schedule would be predicted to be highest immediately after a schedule transition, given that more elicited responding would occur at that time.

This theory readily accounts for the local contrast that was observed, although no direct evidence that the observed responses

included elicited responding is available. However this theory cannot explain why local contrast occurred in some conditions but not others where the same stimulus-reinforcer relations were in effect. Nor can this theory easily accommodate the local induction observed in Hen 54's data and in other experiments (e.g., Buck et al, 1975) where response rate in a rich component was highest later in a component when the stimulus-reinforcer relation is supposedly weakest.

Other explanations of local contrast tend to invoke schedule transitions as the relevant variable underlying within-component changes in response rate. For example, it has been suggested that the transition from a lower-valued state to a higher-valued state, or vice versa, may acquire reinforcing or punishing properties, with consequent changes in response rates close to transition periods (Hinson et al., 1978). Alternatively response rates may be inflated or reduced as a rebound effect from conditions operating in the previous component schedule. For example, response rates may be inflated in the rich schedule following a lean schedule due to some emotional reaction to the release from the less desirable state (Terrace, 1966). All these propositions may predict one of the possible patterns of local response rates but have difficulty explaining all the variations commonly observed.

McSweeney, Ettinger & Norman (1981) suggested that the understanding of behavioural contrast may require recourse to more than one theory. It may be similarly argued that local contrast may be not be explained in terms of one process. That is all within-component response rate changes may be explicable if different processes are invoked to explain each particular response pattern observed. However, it may be argued that the variability in response rates observed is simply a reflection of the idiosyncrasy of that measure in general. As stated in the general introduction, animals' response rates on single schedules, while exhibiting some common features across subjects, also vary across subjects.

In this experiment, and in experiments by Hunt (1985), McLean & White (1981) and others, more consistent patterns of behaviour were apparent if changes in behaviour within components were described in terms of the parameters of the GML. This finding supports the idea

that relative reinforcement rate controls behaviour even though the ways animals distribute their responses may differ. For example, in the current study, animals' behaviour in the first subintervals of a component was generally described by higher  $a$  values than behaviour later in a component. This effect may be observed as a result of an animal changing its rate of responding on either component schedule or on both schedules.

Although changes in behaviour within components were more consistent if examined in terms of values of  $a$ , data from this experiment were still somewhat variable across birds. In this respect the findings of the present experiment differ from those of McLean and White (1981), White et al. (1984) and White et al. (1985). In all of these experiments  $a$  values decreased as a function of time since component alternation for all birds in all conditions in which they were examined. In the current experiment, for three of the birds' data, values of  $a$  obtained decreased between the first and last subinterval of components regardless of the component duration. These decreases in  $a$  tended to be greatest over the first few subintervals. For one bird (Hen 54), however, the degree of change in values of  $a$  as a function of time since component alternation, diminished as component duration was initially reduced. For this bird, in the last three conditions, values of  $a$  obtained tended to increase as a function of time since component alternation (Figure 1.5).

It is notable that this bird's data also demonstrated other effects which were not apparent in the other birds' data. In terms of overall responding, this bird did not demonstrate any hysteresis as measured by the response differentials but did show an increase in bias as a function of reducing component duration. Changes in bias as a function of time since component alternation were also evident and these were in the same direction as changes in bias as a function of component duration. However, there is no obvious relation between these bias changes and the different pattern of  $a$  values found for this bird.

It could be argued that the bias toward responding to one stimulus indicated that, that stimulus was more 'valued'. Behaviour under that stimulus may therefore become more like behaviour on a rich

schedule and behaviour under the other stimulus more like behaviour on a lean schedule. Certainly it has been found that differential responding can be maintained by altering stimuli rather than relative reinforcement rates (Blue, Sherman & Pierrel, 1971; Raslear, 1981; Starr & Staddon, 1982). If this were so then response rates might start high and decrease during a component associated with the more 'valued' stimulus (i.e., the stimulus towards which an animal's behaviour is biased) regardless of the reinforcement rate. Similarly response rates might start low and then increase as a function of time since component alternation during a component associated with the less 'valued' stimulus. If such stimulus preference outweighed the effects of differential reinforcement rates then, as a result of the reinforcement schedules in the component being reversed, response rates would decrease as a function of time since component alternation in both the lean schedule and the rich schedule when each was associated with the favoured stimulus. That is local induction would apparently be present in one condition and local contrast in the other. In this instance, local induction would be expected to occur when the lean schedule was associated with the more 'valued' stimulus, S1 (i.e., on the schedule associated with S1 response rate would start high and decrease as if the schedule was the richer of the pair and on S2 response rate would start low and increase). Increases in  $a$  over successive subintervals, where  $a$  is calculated on the basis of both conditions, would occur if the magnitude of the induction was greater than the magnitude of the contrast.

To some extent this pattern of responding was evident in Hen 54's data in conditions with short components. Local induction was present in the data from one of the conditions at each component duration while local contrast was present in the other and the magnitude of induction was greater than the local contrast. Unfortunately local induction occurred in conditions where the more 'valued' stimulus, S1, was associated with the richer schedule (e.g., Condition 9) and contrast occurred in conditions where the favoured stimulus was associated with the leaner schedule (e.g., Condition 10). That is, response rates at the beginning of a component associated with S1 started low and increased regardless of the schedule in effect and response rates at the beginning of the component associated with S2 started high and decreased as a

function of time since component alternation. Thus, if a favoured stimulus does act in a similar way to a rich schedule of reinforcement, the data from this bird demonstrates the opposite effect to that observed in other birds' data to an even greater extent. That is, if  $a$  values were calculated in relation to the relative 'value' of a stimulus, the increase in  $a$  values as a function of time since component alternation would be even clearer. It is also worth note that similar patterns of within-component changes in responding to those observed for Hen 54 have been reported as occurring consistently in some other studies (Buck et al., 1975; Williams, 1982). These findings suggest that, at least under some circumstances, sensitivity to relative reinforcement rates does not decrease as a function of time since exposure to the alternative reinforcement rate.

The results discussed above threaten the generality of the finding that values of  $a$  decrease as a function of time since component alternation reported by others. However, it may still be possible that where within-component decreases in  $a$  do occur, the relevant variable is the time since exposure to the alternative reinforcement rate.

Firstly, it is reasonable to assume that the effect of time since exposure to alternative reinforcement rates on the influence of relative reinforcement rate may be bounded at either extreme. That is, after a certain time since exposure to another schedule has elapsed, the salience of relative reinforcement may be diminished to the point where it is no longer relevant. Any further increases in within-component time would have no further effect. Data from this experiment clearly support this proposition. Changes in  $a$  tended to be greatest over the first few subintervals of components and little, if any, change occurred later in the components. It is also interesting to note that  $a$  values obtained for later subintervals of the longest component were close to 0.0 in all cases suggesting that relative reinforcement rate was not controlling behaviour.

It is also reasonable to predict that the decrease in salience of alternative reinforcement rates would not begin until some minimal period since exposure to them had elapsed. It could therefore be predicted that shortening component duration beyond some minimal

period would have no further effect on the values of  $a$ . The data from this study offer little support for such a proposal. For three of the hens' data (Hens 51, 52 and 53) values of  $a$  decreased over the first few subintervals, even when the duration of the subintervals was 3 s. For the fourth hen's data (Hen 54)  $a$  values did not consistently decrease over the first few intervals. However, as already stated, values of  $a$  for this bird increased as a function of time since component alternation at the shortest component durations. If the salience of alternative reinforcements remained static across an initial period no change, rather than an increase, in values of  $a$  would be expected at the shorter component durations. The data from this experiment thus support the intuitive idea that the salience of alternative reinforcers may diminish over time such that no further decreases in  $a$  would be obtained after a certain time since component alternation was reached. The data do not, however, suggest that there is a minimal period of time before decreases in salience of alternative reinforcers might begin.

The initial hypothesis of this dissertation was that sensitivity to relative reinforcement rates on multiple schedules is a monotonic function of time since exposure to the alternative reinforcement rate. One of the hen's data clearly did not support this proposition. On the other hand the within-component changes in sensitivity observed for the other three birds' data appear consistent with this. However, if this was the case then values of  $a$  for the same period of time since component alternation would be similar regardless of the component duration. As shown in Figure 1.6, values of  $a$  obtained for subintervals of components representing the same period of time since component alternation varied with changes in component duration. Thus examination of the data in terms of changes within components provides little support for this hypothesis.

#### The Relation Between Within-component Changes in $a$ and the Short-component Effect.

One of the aims of this study was to determine if there was a relation between within-component changes in responding and the short-component effect. As discussed above the short-component effect was present in all birds' data, which is consistent with the

notion that behaviour on multiple schedules can be explained in terms of an underlying monotonic function relating sensitivity to relative reinforcement rates to time since exposure to alternative reinforcement rates. However, while consistent with such a proposition, simply obtaining the short-component effect does not provide proof as to its source. Alternatively, examination of within-component effects while changing component duration does allow some assessment of the validity of this proposition. As discussed, some aspects of the data suggest that the within-component changes in  $a$  observed in this experiment are inconsistent with the existence of an underlying function relating  $a$  values to time since component alternation independent of component duration. Further support for this conclusion is gained if changes in values of  $a$  obtained for overall responding as a function of reducing component duration are compared with the within-component changes in responding. As seen in Figure 1.6, the  $a$  values obtained for responding at short component durations were not equal to the  $a$  values obtained for subintervals of longer components equal to that duration. In general  $a$  values for the subintervals of longer components tended to be higher than  $a$  values obtained when component duration was equal to those subintervals. Thus reducing component duration was not equivalent to sampling early portions of longer components.

These results suggest clearly that the two phenomena examined, the within-component decrease in sensitivity and the short-component effect, could not be described simply in terms of sampling various portions of an underlying function. The results of this experiment also indicate that the phenomena may be independent. That is, the occurrence of one phenomenon is not conditional on the occurrence of the other. If these phenomena were dependent then the short-component effect should not be present where responding during latter portions of a longer component were not characterised by decreased sensitivity to reinforcement rates. As stated, for one bird's data,  $a$  values did not decrease as a function of the time since component alternation during the conditions with the three shortest component durations. However the short-component effect was clearest in this bird's data. In this experiment the appearance of the short-component effect, in the absence of the expected within-component effect, was evident in only one bird's data.

White et al. (1985), however, provide further support for the independence of the two phenomena. As previously noted they found consistent decreases in  $a$  as a function of time since component alternation in the absence of the short-component effect.

Although there was no obvious relation between the short-component effect and a particular pattern of changes in behaviour within components,  $a$  values obtained for overall responding were obviously related to within-component changes in  $a$  in as far as total responding is the sum of those changes. A greater understanding of the effects of reducing component duration may be obtained if the within-component  $a$  values are examined in terms of their contribution to overall  $a$  values. As already discussed two distinct patterns of behaviour are clear in the data. One for Hens 51, 52 and 53 and another for Hen 54.

Firstly for the data from Hens 51, 52 and 53, the decrement in  $a$  values as a function of time since component alternation, when component duration was 60 s, appear similar to the decrement seen when component duration was 120 s. However, lower overall  $a$  values arose when component duration was 120 s because a larger portion of the component was associated with behaviour described by lower  $a$  values. This finding is consistent with the idea that shortening component duration is similar to sampling early portions of longer components. However, for two of these hens' data, the value of  $a$  for each subinterval was lower during the 60-s components than during the 120-s components. This suggests that reducing component duration influenced behaviour in some way in addition to removing the less sensitive period of responding. This suggestion is confirmed if changes in behaviour for the same three hens, when component duration was further reduced, are examined.

Firstly  $a$  values obtained for both the first 15 s of components, where component duration was 30 s, and for total responding, when component duration was 15 s, were lower than those obtained for the first 15 s when component duration was 60 s. Thus the trend evident in two birds' data when component duration was reduced from 120 s to 60 s was continued for these birds and was also present in the third bird's data. Although direct comparison is not possible, it is reasonable to assume that this trend continued when component

duration was further reduced. That is, the  $a$  values obtained for overall responding when component duration was 6 s were lower than the  $a$  values obtained for the first 5 s of longer components. Indeed the  $a$  values obtained for the first 3 s of the 6-s components were lower than the first 5 s of longer components for two of the birds' data.

Secondly the drop in  $a$  values at the shortest component duration appeared to occur at a faster rate. That is the drop between the  $a$  values obtained for the first 3 s and last 3 s of the 6-s components is similar to the drop in  $a$  values between the first 5 s and second 5 s when component duration was 15 s or 30 s. Therefore as component duration was decreased the  $a$  values obtained for each successive subinterval became generally lower and the rate of decrease in  $a$  as a function of time since component alternation increased.

These two findings indicate that decreases in  $a$  values as a function of reducing component duration might have been expected rather than the increases actually observed. The higher  $a$  values obtained for overall responding still occur, however, as the  $a$  values obtained for the last subintervals of shorter components do not reach the asymptotically low values obtained for the last few subintervals of longer components. Thus, although not readily apparent, some evidence in the data suggests that the short-component effect occurred for these three birds as a result of eliminating the insensitive period of responding evident within later portions of longer components. This effect is, however, overshadowed by a second effect of reducing component duration. That is shortening component duration actually appeared to decrease sensitivity to relative reinforcement rates throughout a component and to increase the rate of decrement in sensitivity.

This finding also makes apparent an alternative explanation to those already offered for the disparity between the findings of this experiment and those of Charman and Davison (1982) and White et al. (1985). The subjects in their experiments may have behaved in a similar way to Hens 51, 52 and 53. If this were so, but the increase in the rate of decrement in  $a$  values was sufficiently large or the initial  $a$  values were sufficiently low under conditions with

short components, then  $a$  values similar to those found with long components might be expected.

In general, it appears that increasing the time since exposure to an alternative reinforcement rate can lead to decreases in  $a$  values so that after some period of time has elapsed  $a$  values will become close to 0.0. This finding is consistent with the initial hypothesis, that sensitivity to relative reinforcement rates will decrease as a function of time since exposure to the alternative reinforcement rate. However, it also appears that the shape of such a function may be influenced by component duration. That is, the decrease in sensitivity observed within components is mediated by the time a component is available.

Throughout this later discussion the data from Hen 54 has been ignored. As stated, the data from this bird were different from those of the other birds and are not easily explained in terms of the same processes. The expected decrease in  $a$  values as a function of time since exposure to alternative reinforcement rate was demonstrated clearly only at the longest component duration. Thus, if this hen's data were influenced by the decreases in component duration in the same way as the other hens' data, then for this hen decreases in  $a$  values as a function of component duration might be expected. That is, two effects were noted in the data from Hens 51, 52, and 53; one that shortening component duration decreased the sensitivity of responding to relative reinforcement rates throughout the component and two, that shortening component duration eliminated the less sensitive period of responding observed in later portions of components. If there was no relatively insensitive period to eliminate then the only effect expected would be the decrease in sensitivity. This was not evident in Hen 54's data. Rather, for this bird, decreasing component duration appeared to increase the  $a$  values obtained for the initial and subsequent subintervals of components. Thus, for this bird, reducing component duration had effectively the opposite effect from that observed for the other hens.

One possible explanation of the the difference between Hen 54's data and that of the others relates to a set of experiments by Williams (1981; 1989 and others). In these experiments

pigeons were exposed to a multiple schedule with three components so that any differential effects, on behaviour in a particular component, of the schedules in operation in the components preceding and following it could be examined. Williams reported that, in general, the schedule following a component exerted more influence on behaviour than the schedule preceding it. As in the current experiment the schedule in the following component was the same as the schedule in the preceding component, the relative influence of these cannot be determined. However, if the following schedule did exert greater influence on behaviour then it may be argued that behaviour at the start of a component would be less influenced by relative reinforcement rate than behaviour later in a component. Increases in the values of  $a$  as a function of decreasing component duration may still be expected if reducing component duration was equivalent to sampling the later part of longer components. Examination of Figure 1.5 reveals that this explanation of behaviour seems unlikely if Hens 51, 52 and 53's data are examined.

However the idea may have some merit with reference to Hen 54's data in later conditions. For example, the values of  $a$  obtained for this birds' data for successive 5-s subintervals when component duration was 15 s may be seen as similar, although slightly higher, to the  $a$  values obtained for the last three 5-s subintervals when component duration was 30 s. A similar effect is apparent if the  $a$  values obtained for this bird's data across successive 15-s subintervals, when component duration was 60 s, are compared to  $a$  values obtained for the last 60 s of the 120-s components. Although the  $a$  values obtained for Hen 54's data, when component duration was 6 s, were considerably higher than  $a$  values obtained in either the first or last 5-s subintervals when component duration was 15 s or 30 s, the increase in  $a$  values over the two 3-s subintervals is consistent with the increase observed in previous conditions.

Thus it is possible that, for all hens, reducing component duration may have removed the less reinforcement sensitive period of responding, but the period of a component associated with more sensitive responding may have varied across hens. That is, it may be argued that sensitivity to reinforcement rates may decrease as a function of time either since or before exposure to the alternative reinforcement rate depending upon the relative influence of the

preceding versus the following schedule. Such a possibility may also explain the 'U-shaped' function evident in the  $a$  values obtained for successive subintervals of components for some birds' data at some component durations (e.g., Hen 51's data when component duration was 30 s and 15 s). That is, in such situations, a hens' behaviour may have been influenced by both the preceding and following schedule such that sensitivity to relative reinforcement rates declined as a function of time since exposure to the preceding schedule but then increased as the time to exposure to the following schedule decreased.

As an explanation of the results of this experiment this analysis has some limitations. Firstly, as stated, it is not possible to determine the relative influence of the following and preceding schedules on behaviour in this experiment. Thus it can only be speculated that Hen 54's behaviour in later conditions was influenced by the following schedule and that the other hens' behaviour was more influenced by the preceding schedule.

Secondly, it is not clear why Hen 54's behaviour would be influenced by the following schedule in later conditions but not in conditions with 120-s component duration. Nor is it clear why other hens' behaviour might on some conditions be influenced by both the following and preceding schedules but not on others (e.g., Hen 51 on conditions with 30-s and 15-s component durations vs conditions with 120-s, 60-s and 6-s components). Williams (1981) reports instances where initially the preceding schedule appeared to have the greater influence while later the following schedule had the strongest influence on responding. However where such effects were noted they occurred within a single condition.

Thirdly, although Williams' studies suggest that overall responding is influenced by the following schedule in some instances, within-component changes in responding remained similar to those commonly observed. That is response rate on a lean component increased as a function of time since component alternation as observed in Hens 51, 52 and 53 s' data. Thus the relative influence of preceding and following schedules on overall responding was not necessarily reflected in a particular pattern of within-component responding. Therefore, although it is possible that the difference

between the pattern of within-component responding observed in Hen 54's data and that observed in the other hens' data may relate to differences in the relative influence on responding of the preceding and following schedules, such an explanation must remain speculative. The only means of assessing the relative influence of these schedules in this experiment is through the within-component effects themselves. This would appear to be an unreliable measure of such effects and furthermore as the explanation is being offered to explain differences in these effects, the argument becomes tautologous. This explanation of behaviour also does not explain the second difference noted between 51's to 53's data and that of Hen 54 adequately. As discussed, for Hens 51, 52 and 53, reducing component duration appeared to decrease sensitivity to relative reinforcement rates in general. For Hen 54 this effect of reducing component duration was not apparent even if  $a$  values obtained with shorter component durations are compared to the later part of longer components. The results of Williams' studies does however provide further evidence that effects observed in overall responding do not necessarily relate to particular patterns of within-component responding.

### Conclusion

While this experiment has enabled the contribution of within-component changes in  $a$  on the short-component effect to be examined further, the results are not conclusive. The data from three of the hens used suggest that the short-component effect can occur apparently as a result of the less reinforcement-sensitive period of responding at the end of long components being eliminated. This result is consistent with the hypothesis that sensitivity to relative reinforcement rates decrease as a monotonic function of time since exposure of the alternative reinforcement rate. However other aspects of the results suggest this explanation is inadequate.

For one bird the short-component effect was present where sensitivity to reinforcement increased as a function of time since component alternation. It was postulated that this effect may be expected if for this bird the following schedule had more influence on behaviour than the preceding schedule. However as an explanation of the data this suggestion is at best speculative. Furthermore the

results of studies by Williams (1981; 1989 and others) related to this explanation provide further evidence that specific within-component changes in responding are not necessarily related to effects noted in overall responding. For the other birds shortening component duration actually reduced  $a$  values obtained for responding at the same time since exposure to the alternative reinforcement rate.

Given these findings the only conclusion possible at this point is that the short-component effect is a replicable phenomenon that can occur when schedules are reversed. However the effect is also limited in several ways. It may be reduced if hysteresis is present in the data and thus may be less robust than some other phenomena. Where the effect is present, results of this and other studies suggest that altering component duration affects sensitivity to relative reinforcement within only a limited range of component durations and this range varies across subjects. Any explanation of the effect should find such limitations predictable.

The increases in  $a$  found appear independent of any particular pattern of within-component responding. In general it appears that just as changes in  $a$  values within components may result from various within-component changes in absolute response rates, changes in overall sensitivity may result from various patterns of within-component changes in sensitivity. Thus examination of two phenomena which might be expected to reflect changes relating to the temporal proximity of alternative reinforcement rates yield somewhat different results. Explanations of either phenomenon in terms of a monotonic function relating sensitivity to relative reinforcement rates to time since exposure to alternative rates may, therefore, have doubtful validity. Nevertheless, with longer component durations decreased  $a$  values as a function of time since component alternation were noted in all birds' data. Only when component duration was 30 s or less were inconsistencies noted. It might therefore be argued that temporal proximity to alternative sources of reinforcement does influence responding but that this effect is eliminated or confounded by changing the period of time a component is available. The effects of time since exposure to alternative reinforcement sources may therefore become clearer if the temporal proximity of schedules is increased or decreased while the duration of time a schedule is available is kept constant.

## EXPERIMENT 2

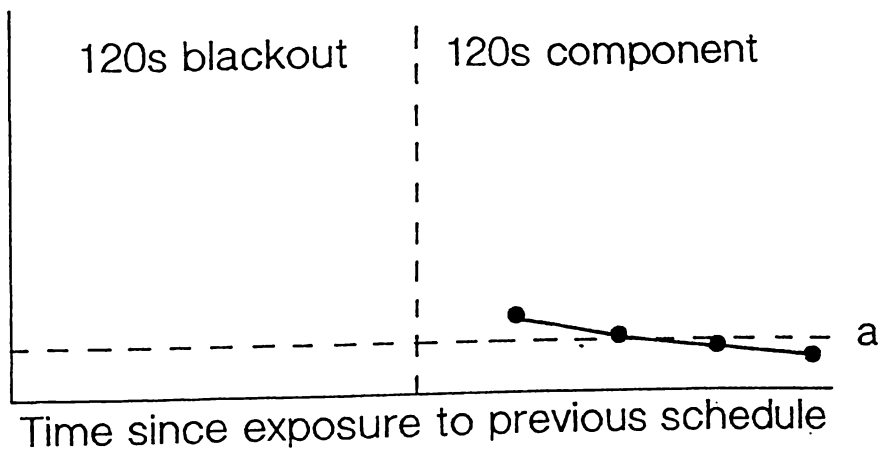
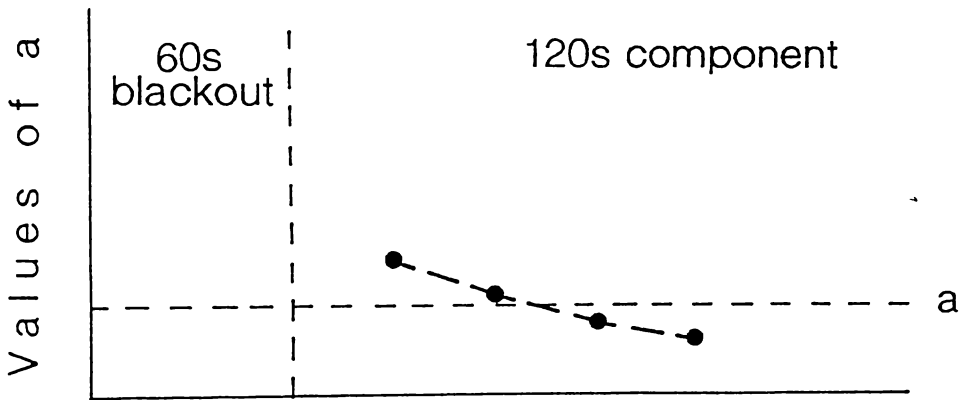
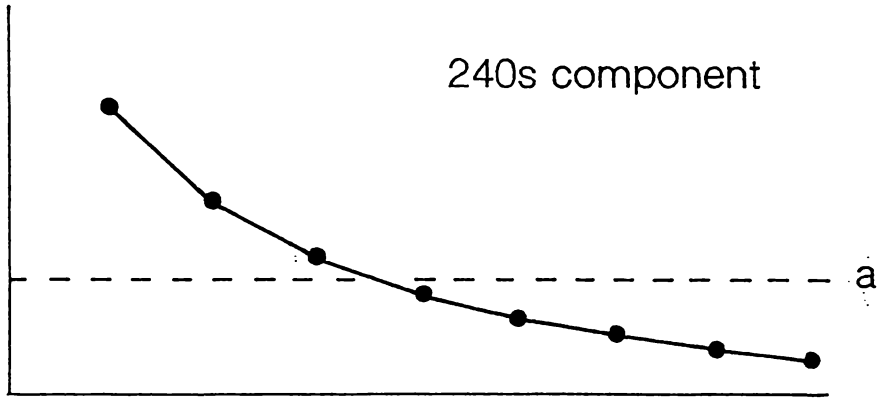
The results of Experiment 1 did not support the initial hypothesis that sensitivity to relative reinforcement rates necessarily declines as a monotonic function of time since exposure to the alternative reinforcement rates. However in that experiment any changes related to the temporal proximity of components were confounded by the length of time a component was available.

Another method of assessing whether the temporal proximity of alternative reinforcement sources influences responding in multiple schedules is to separate multiple-schedule components by incorporating a period of blackout between component alternations. If sensitivity to reinforcement declines as a monotonic function of time since exposure to the alternative, then programming a period of blackout between components, may be equivalent to 'removing' the more reinforcement sensitive period of responding typically observed in early portions of components. Increasing the duration of the blackout may also be equivalent to 'removing' more of this sensitive period of responding from analysis.

This situation is depicted in Figure 2.0. Each panel shows hypothetical  $a$  values for successive subintervals plotted as a function of time since exposure to the previous schedule. The top panel shows  $a$  values that would be observed over a long component. The middle and bottom panels show  $a$  values that would be observed in successive subintervals, where component duration was half that shown in the top panel, but where components were separated by blackout. Each of these two panels show  $a$  values that would be observed, with a different duration of blackout, if behaviour could be described in terms of an underlying function as shown in the top panel. Values of  $a$  for overall responding that would be obtained are also shown as the dashed horizontal lines. As seen in this figure if sensitivity to relative reinforcement rates declines as a function of time since exposure to the alternative rate, then  $a$  values for overall responding would decrease as the duration of an inter-component blackout was increased. Values of  $a$  for subintervals of components representing the same period of time since exposure to the alternative component would be the same. However, the first and subsequent subintervals of components

FIGURE 2.0

Hypothetical  $a$  values for successive subintervals of components plotted as a function of time since exposure to the previous schedule. The top panel shows  $a$  values that would be observed over a long component. The middle and bottom panels show  $a$  values that would be observed in successive subintervals, where component duration was half that shown in the top panel, but where components were separated by blackout. Each of these two panels show  $a$  values that would be observed, with a different duration of blackout, if behaviour could be described in terms of an underlying function as shown in the top panel. Values of  $a$  for overall responding that would be obtained are also shown as the dashed horizontal lines.



separated by the longer blackout duration illustrated represent different periods to the first and subsequent subintervals of components with the smaller inter-component blackout. Thus  $a$  values for successive subintervals of components with the longer blackout would be lower than  $a$  values for successive subintervals of components with the shorter blackout. The limited amount of evidence which is available supports the hypothesis that sensitivity to reinforcement will be reduced by separating components in time.

A number of the studies which examined behavioural contrast have employed a short period of blackout between components (e.g., Farthing, 1974; Halliday & Boakes, 1974; Hearst, 1971; Thomas & Cameron, 1974) and have reported contrast effects similar to those observed in experiments without a blackout. While these experiments suggest that decreased proximity of the component schedules does not affect multiple-schedule performance such a conclusion would be unwise. Comparisons across studies are fraught with difficulties as studies typically vary with respect to more than one procedural variable. For example, studies which have employed a blackout typically present schedules in random order while those without a blackout tend to alternate the component schedules. The order of schedule presentation may itself have an effect on  $a$  values or behavioural contrast. It may be argued that if separating components in time decreases contrast or sensitivity but presenting components in random order increases the magnitude of contrast or sensitivity, then studies which differ with respect to both variables could find similar results.

Two experiments have, however, examined the effects of changing the temporal proximity of components of a multiple schedule. In an experiment using a between-group experimental design by Mackintosh, Little and Lord (1972), the effect of incorporating a period of timeout, where keylights were extinguished, between alternations of VI and EXT schedules on behavioural contrast was assessed. In two conditions a single VI schedule was alternated with a period of timeout (T0). In one of these conditions the T0 was 10 s and in the other 60 s. In a further two conditions the single VI schedules, preceded and followed by periods of T0, were alternated with an extinction schedule. When the period of T0 was 10 s Mackintosh et al. report that response rates were higher on the VI schedule in the

condition which incorporated an EXT component, compared to response rates on the condition without an EXT component. This effect was not evident when the two conditions involving a 60-s TO were compared.

These results could be interpreted as support for the idea that decreasing the temporal proximity by increasing the TO between components (in this case the VI and EXT components) resulted in less interaction between the components and hence no contrast occurred. Unfortunately the results may also have occurred if the response rates on the single VI with the 60 s TO were already at an asymptotically high level. This interpretation is possible as the VI response rates, for the group with the longer TO, were higher than the VI response rates for the group with the smaller TO. However, in two conditions of an experiment by Charman and Davison (1982), the effect of a 5-s period of blackout inserted between components of MULT VI VI schedules was assessed. The reinforcement rates in the two component schedules were varied across these conditions. Charman and Davison reported that the values of  $a$  obtained were generally lower than values of  $a$  obtained for the same subjects in similar conditions in an earlier experiment where no blackout separated the components. The changes in  $a$  were, however, small in some instances. Nevertheless this study suggests that the effect of blackout duration is worth further study and that decreases in sensitivity to relative reinforcement rate consistent with the hypothesis outlined above may be expected. Moreover Mackintosh et al. (1972) report that, in the study discussed above, the development of behavioural contrast appeared to be correlated with the appearance of within-component changes in response rates on the VI schedule. That is, local positive contrast was observed when a 10-s TO separated components and behavioural contrast was evident. When a 60-s TO separated the VI and EXT components, no local or overall contrast was observed.

This experiment assessed the effect of varying the duration of a period of blackout inserted between components of a multiple schedule on both overall and within-component changes in responding.

As previously discussed the results of Experiment 1, and other studies, suggest that multiple-schedule performance can be

influenced by short and/or long-term hysteresis. However the short-component effect and within-component changes in sensitivity can occur in the presence of these other phenomena. It is therefore reasonable to assume that if changes in sensitivity, as a function of separating components of a multiple schedule in time, are related to either within component changes in behaviour or the short-component effect, then they should also be robust against these other effects. However, possible hysteresis effects also need to be examined. Thus the duration of the blackout period was varied across conditions in an ascending and then descending order. At each blackout duration five reinforcement ratios were employed. The order in which particular schedules were used varied across conditions but were such that conditions at each blackout duration included two conditions where reinforcement rates in the component schedules were the reverse of those in the previous condition.

## METHOD

### Subjects

The six naive domestic hens used were maintained at 80 (+/-5)% of their free-feeding bodyweight by supplementary feeding at the end of each experimental session. Water was continuously available in their home cages and grit was occasionally provided. The hens were numbered 61 to 66.

### Apparatus

The apparatus used was similar to that used in Experiment 1 except that the experimental chamber had two rather than three response keys. These keys were situated 200mm apart, 380mm from the grid floor. The left hand key could be illuminated from behind with either a green (S1) or red (S2) light. The right hand key remained dark and inoperative throughout the experiment.

### Procedure

Training. Subjects were trained to feed from the raised hopper and then to peck the lighted key. When all hens were pecking reliably they were exposed to a two component multiple schedule in which pecks were reinforced according to VI 15-s schedule in both S1 and S2. This reinforcement schedule in both components was gradually changed to a VI 60-s schedule over 30 days. A 1-s blackout was then inserted between all schedule alternations so that each component was preceded and followed by a period of blackout. After 20 days hens were introduced to the first experimental condition.

Experimental Conditions. The reinforcement rates in component schedules were varied and the duration of the blackout between component schedules was systematically increased (ascending series) and then decreased (descending series) across conditions. The duration of blackout was 1 s in Conditions 1 to 5, 10 s in Conditions 6 to 10, 30 s in Conditions 11 to 15, 60 s in Conditions 16 to 20, 120 s in Conditions 21 to 25, 180 s in Conditions 26 to 30 and 297 s in Conditions 31 to 35. Blackout duration was then decreased so that it was 30 s in Conditions 36 to 42 and 1 s in Conditions 43 to 47.

The VI schedules in each component were varied across five conditions at each blackout duration so that five different reinforcement ratios were used but overall reinforcement rate remained constant. The schedule pairs used were VI 48-s VI 48-s, VI 120-s VI 30-s, VI 30-s VI 120-s, VI 27-s VI 216-s, and VI 216-s VI 27-s. The order in which schedule pairs were run varied across blackout durations, but in all cases conditions where a MULT VI 120-s VI 30-s was in effect were preceded or followed by a condition where a MULT VI 30-s VI 120-s was in effect. Conditions where a MULT VI 216-s VI 27-s was in effect were always preceded or followed by a condition where the schedule in effect was a MULT VI 27-s VI 216-s.

The number of component alternations per session decreased as blackout duration increased. To assess any effects that this decrease in the number of schedule alternations per session would have, the number of schedule alternations during conditions 36 to 40 where a 30 s blackout was in effect, was kept the same as when blackout duration was 297 s. In conditions 41 and 42 blackout duration was maintained at 30 s but the number of schedule alternations was increased. Only two schedule pairs were examined with the increased number of alternations as analysis of previous conditions demonstrated that  $a$  values obtained, when only two of the schedule pairs were examined, were similar to those obtained with all schedule pairs used in the analysis.

In all conditions component duration was maintained at 105 s. All VI schedules were derived from an arithmetic progression  $i$ ,  $i+d$ ,  $i+2d$ , etc., and comprised of 15 randomised intervals as in Experiment 1. Conditions were not changed until the behaviour of all hens met the stability criterion as defined in Experiment 1.

The reinforcement schedules, blackout duration, number of schedule alternations and number of training days in each condition are given in Table 2.1.

The number of responses made and the number of reinforcers obtained in each component, and the time each component was available were recorded. In addition, responses made within successive 15 s subintervals of each component were recorded.

Table 2.1. The VI schedules (in seconds), blackout duration, number of presentations of components per session and the number of sessions in each condition.

Condition	VI Schedules		Blackout Duration(s)	No. of Presentations	No. of Sessions
	Green	Red			
1	120	30	1	8	33
2	30	120	1	8	25
3	48	48	1	8	16
4	216	27	1	8	24
5	27	216	1	8	36
6	48	48	10	8	17
7	27	216	10	8	23
8	216	27	10	8	28
9	120	30	10	8	17
10	30	120	10	8	18
11	120	30	30	7	19
12	30	120	30	7	22
13	27	216	30	7	17
14	216	27	30	7	22
15	48	48	30	7	68
16	48	48	60	6	24
17	120	30	60	6	21
18	30	120	60	6	29
19	27	216	60	6	25
20	216	27	60	6	26
21	216	27	120	5	27
22	27	216	120	5	21
23	120	30	120	5	19
24	30	120	120	5	20
25	48	48	120	5	34
26	48	48	180	4	18
27	120	30	180	4	21
28	30	120	180	4	20
29	216	27	180	4	22
30	27	216	180	4	21
31	27	216	297	3	26
32	216	27	297	3	25
33	120	30	297	3	20
34	30	120	297	3	28
35	48	48	297	3	107
36	48	48	30	3	28
37	120	30	30	3	23
38	30	120	30	3	22
39	27	216	30	3	28
40	216	27	30	3	29
41	216	27	30	7	19
42	27	216	30	7	23
43	27	216	1	8	29
44	216	27	1	8	25
45	120	30	1	8	17
46	30	120	1	8	22
47	48	48	1	8	17

## RESULTS

The total number of responses made and reinforcers obtained in each component, the total time each component was available and the number of responses made in successive 15-s subintervals of each component for all hens in the last five days of each condition are given in Appendix 2.1. All the following analyses were based on these data. Response rates and estimates of the parameters of the generalised matching law were determined in the same way as in Experiment 1.

### Behaviour Across Components

#### Ascending Series

##### Response Rates

Figure 2.1 shows response rates on each component schedule plotted against blackout duration. Each graph represents response rates on one of the five pairs of schedules used. In all cases, where reinforcement rates on the two components were different, squares indicate response rates on the richer schedule of a pair and circles response rates on the leaner schedule. Response rates on S1 when the schedules in effect were both VI 48-s are shown as squares and response rates on S2 in these conditions are represented by circles.

As the inter-component blackout duration increased, for all hens, response rate on the leaner component of a pair of schedules (circles) showed an initial increase followed by either a decrease or no systematic change. The number of blackout durations over which the response rate increase persisted varied across hens. For some hens the increase in lean schedule response rate persisted until the same blackout duration was reached for all schedule pairs (e.g. 30 s for Hen 65). For others the increase in response rate during the lean schedule of some schedule pairs was still evident across blackout durations where response rate on the lean schedule of other schedule pairs did not increase (e.g. Hen 66).

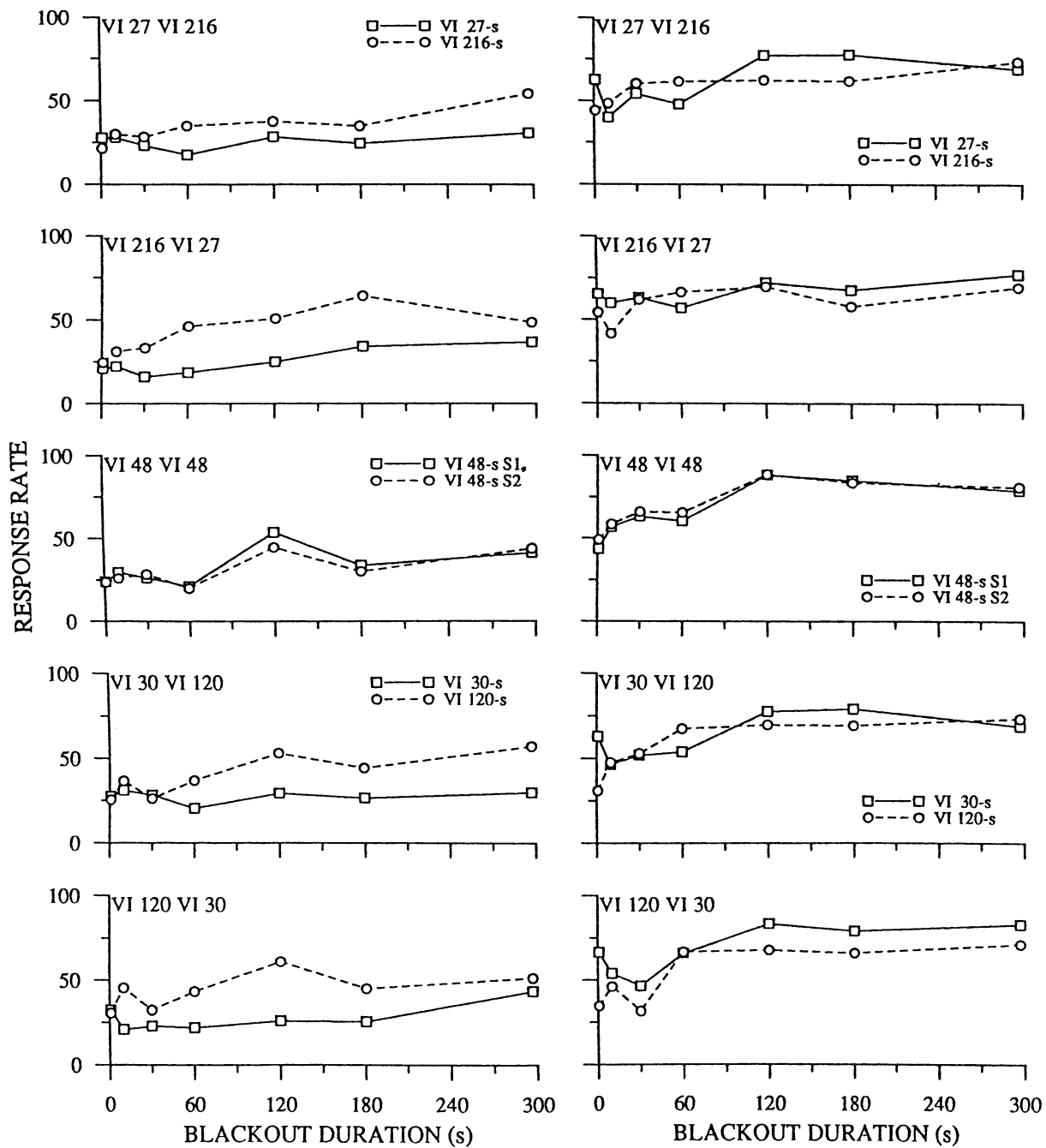
With increases in the duration of blackout, response rates on the rich component of a pair of schedules (squares) initially tended to

FIGURE 2.1

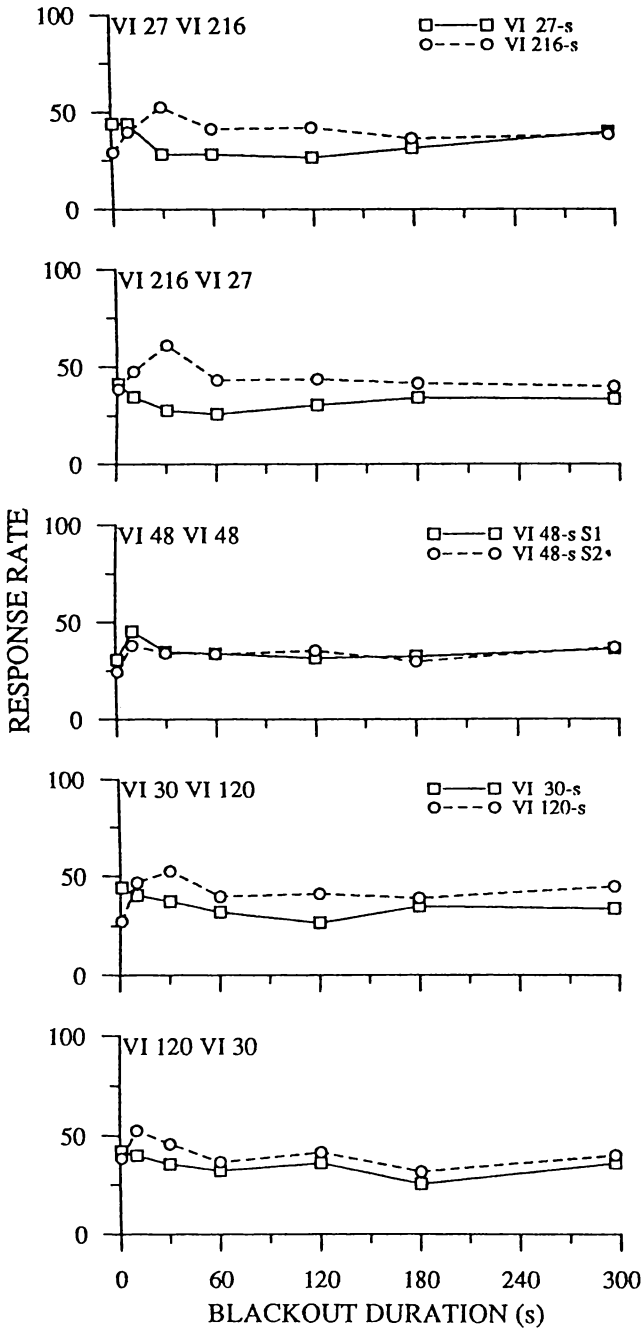
Response rates on each component of all multiple schedules for conditions in the ascending series. Each graph represents response rates on one of the five pairs of schedules used. Circles represent response rates on leaner schedules of the schedule pairs and squares represent response rates on the richer schedules of the schedule pairs. Response rates on S1 of the equal schedule pairs are shown as squares and response rates on S2 as circles.

### HEN 61

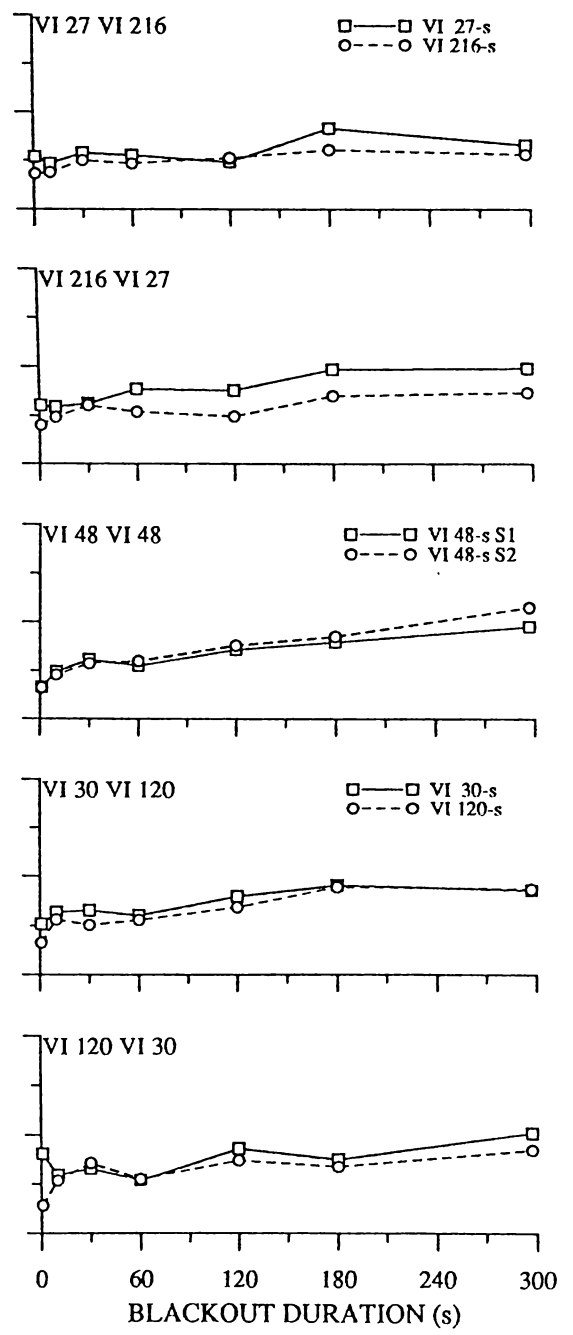
### HEN 62



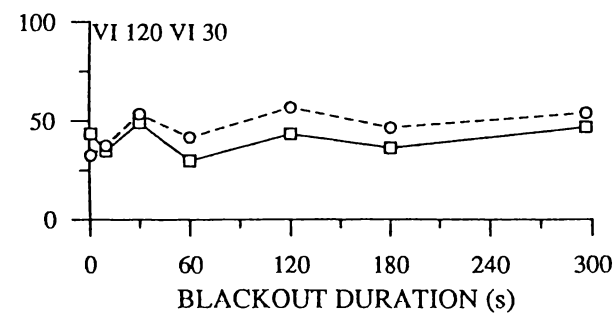
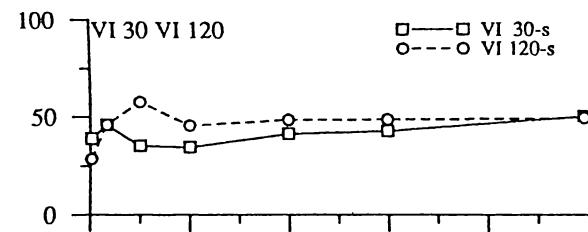
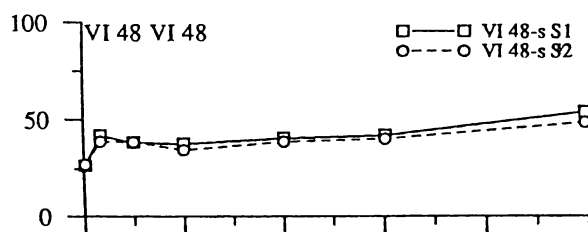
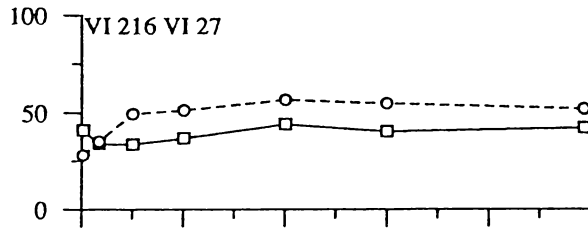
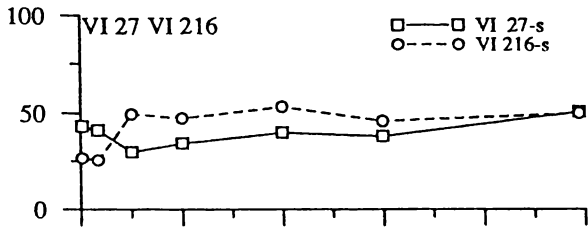
HEN 63



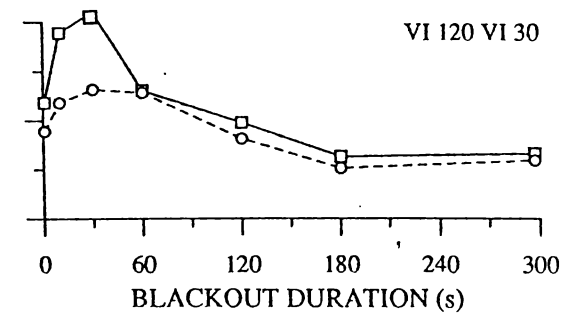
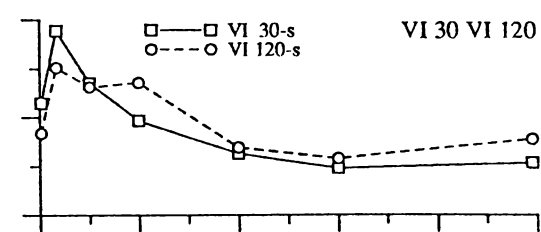
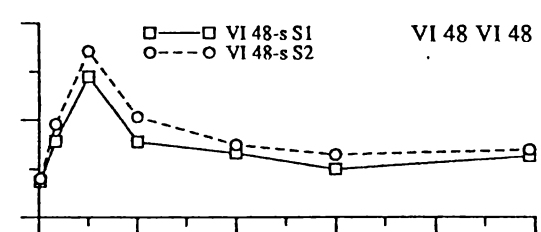
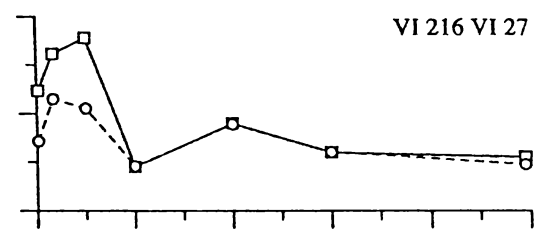
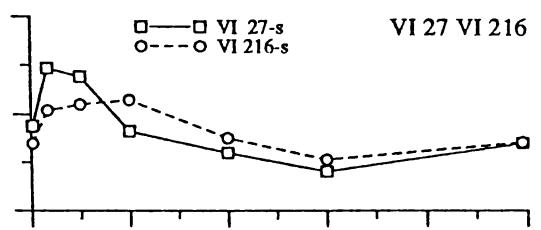
HEN 64



### HEN 65



### HEN 66



decrease and then increased for five of the six hens (Hens 61 to 65). The condition and blackout duration at which the initial decrease stopped varied as for the lean schedule response rate increases. Hen 66's response rates on the rich schedule initially increased and then decreased as a function of blackout duration in a similar way to response rates on the lean schedule. However the magnitude of the increase and subsequent decrease was greater on the rich schedule.

The changes in rich and lean schedule response rates resulted, for five of the six hens, in response rates on the lean schedule becoming higher than response rates on the rich schedule as blackout duration increased. Although the degree of difference between response rates decreased with further increases in the duration of the blackout, the direction of the difference was often maintained over further conditions.

There were two patterns of behaviour on the equal schedules. For three hens (Hens 61, 62 & 64) response rates in both schedules increased as the duration of the inter-component blackout increased. For the other three hens response rate on both schedules initially increased with increases in blackout duration and then decreased again as blackout duration was further lengthened.

In order to examine whether any short term hysteresis, as defined in Experiment 1, was present, the differences between response rates on the component schedules for conditions with differential reinforcement rates were calculated. If the previous schedule did influence responding then the difference between response rates on the second presentation of a schedule pair following a schedule reversal would be expected to be smaller than the response rate differential on the first condition with that schedule pair.

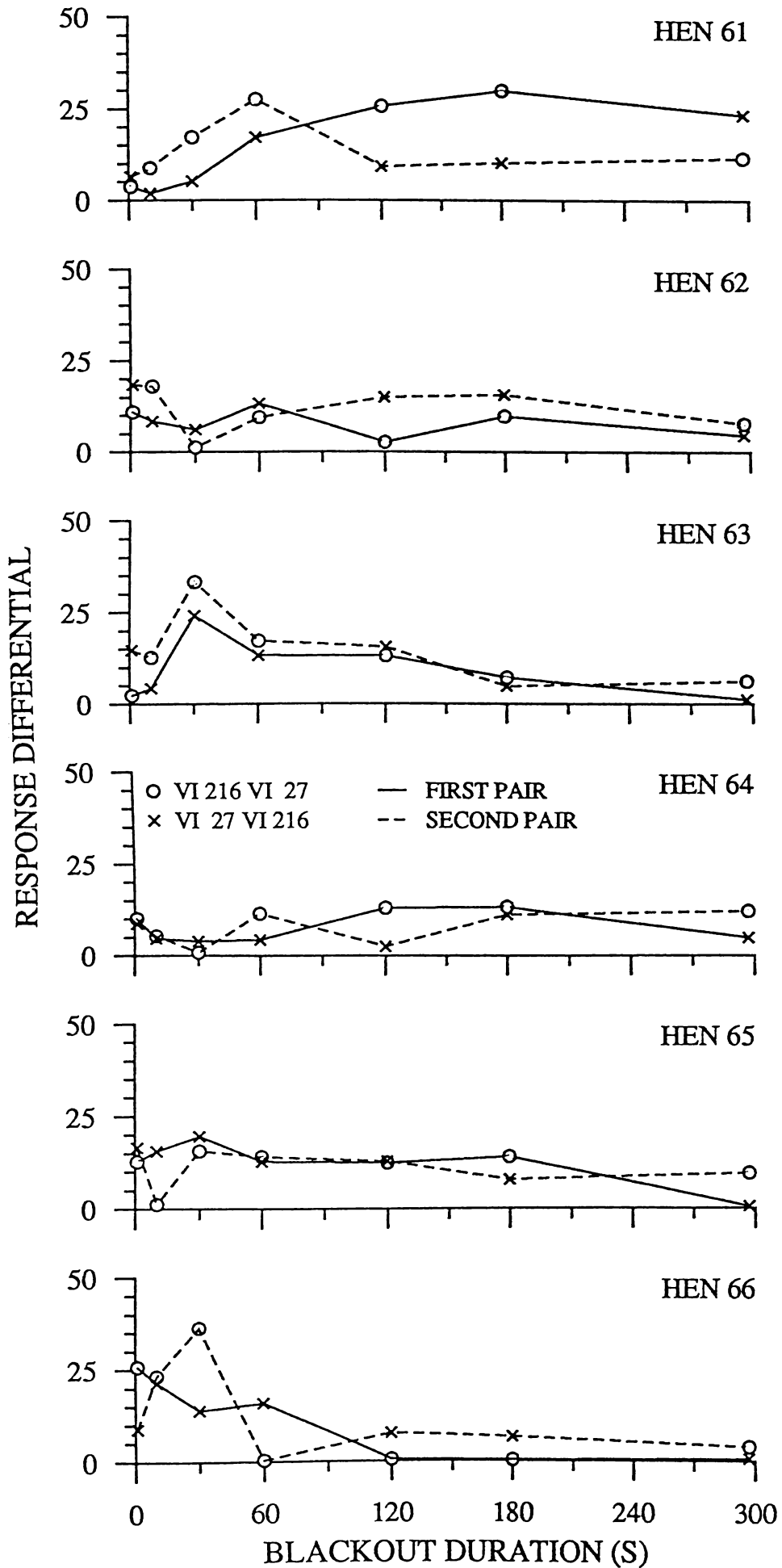
Figure 2.2 shows the absolute difference between response rates on the lean and rich schedules as a function of blackout duration. Figure 2.2.1 shows the difference between response rates on the VI 27-s schedules and the VI 216-s schedules. Figure 2.2.2 shows the difference between response rates on the VI 30-s schedules and the VI 120-s schedules. Points joined by a solid line represent the differential between the rich and lean schedules for the first of

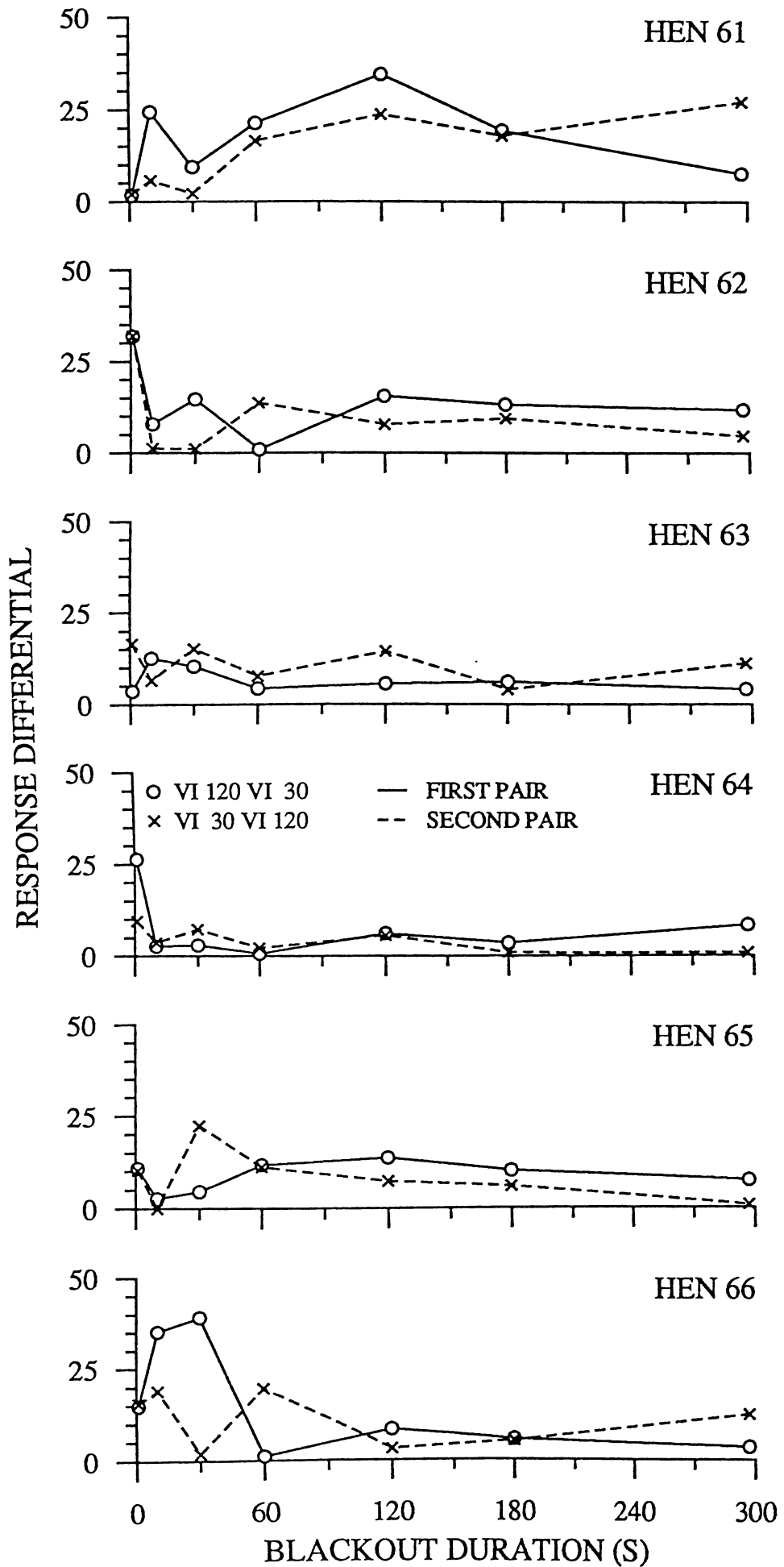
FIGURE 2.2

The absolute difference between response rates on the lean and rich component schedules (the response differentials). Points joined by a solid line represent the differential between the rich and lean schedules for the first, of the two conditions using the pair of schedules. Points joined by a dotted line represent the differential between rich and lean schedules for the second condition where the component schedules were reversed. The difference between response rates when a MULT VI 30-s VI 120-s or MULT VI 27-s VI 216-s was in effect are shown as crosses. The difference between response rates when a MULT VI 120-s VI 30-s or MULT VI 216-s VI 27-s schedule was in effect are shown as circles.

2.2.1 The difference between response rates on the VI 27-s schedules and the VI 216-s schedules.

2.2.2 The difference between response rate on the VI 30-s schedules and the VI 120-s schedules.





the two conditions with a pair of schedules. Points joined by a dotted line represent the differential between response rates on the rich and lean schedules for the second condition where the component schedules were reversed. At all blackout durations the MULT VI 120-s VI 30-s schedule occurred immediately prior to the MULT VI 30-s VI 120-s schedule. At some blackout durations the MULT VI 27-s VI 216-s schedule was immediately prior to the MULT VI 216-s VI 27-s schedule. At other blackout durations the order of these conditions was reversed. The difference between response rates when a MULT VI 30-s VI 120-s or MULT VI 27-s VI 216-s was in effect are shown as crosses. The difference between response rates when a MULT VI 120-s VI 30-s or MULT VI 216-s VI 27-s schedule was in effect are shown as circles.

Examination of Figure 2.2 shows that at each blackout duration the differences between response rates on a VI 120-s schedule and on a VI 30-s schedule or between response rates on a VI 216-s schedule and on a VI 27-s schedule, during the first condition which used either of these schedule pairs, were not consistently greater or smaller across hens than the differences between response rates in the following condition, in which the reinforcement rates in the component schedules were reversed. The lack of any consistent effect on response rate differentials, according to whether a condition was the first or second condition of a pair of reversed schedules, was independent of whether the schedule pairs were always presented in the same order (as with the MULT VI 120-s VI 30-s and MULT VI 30-s VI 120-s schedules) or in different orders.

#### Generalised Matching Law Analysis

Table 2.2 gives, for all hens, the intercepts (the parameter  $\log c$  in Equation 4), the slopes (the parameter  $a$  in Equation 4), the standard errors and percentages of variance accounted for by regression lines fitted by the method of least squares to the daily data obtained from the five schedules pairs at each blackout duration. The variance accounted for by the regression lines ranged from 1.1 (Hen 66 with 297-s blackout) to 94.1 percent (Hen 63 with 60-s blackout) and tended to be smaller when the absolute values of  $a$  obtained were low. The standard errors of estimates ranged from

TABLE 2.2. The intercepts (values of  $\log c$ ), slopes (values of  $a$ ), standard errors (S.E.) and percentage of variance accounted for (VAC) by regression lines fitted by the method of least squares to the daily data obtained from the five multiple schedules at each blackout duration.

Blackout Duration	$\log c$	$a$	S.E	VAC	Blackout Duration	$\log c$	$a$	S.E	VAC
HEN 61					HEN 64				
1	0.04	0.03	0.076	7.0	1	-0.04	0.28	0.130	75.0
10	0.08	-0.17	0.114	54.8	10	0.01	0.09	0.035	78.0
30	0.08	-0.19	0.105	61.3	30	0.05	0.05	0.036	47.6
60	0.00	-0.39	0.087	91.4	60	-0.01	0.10	0.058	60.6
120	0.07	-0.34	0.115	80.3	120	-0.05	0.08	0.067	47.3
180	0.03	-0.27	0.099	80.6	180	-0.01	0.12	0.063	66.2
297	-0.07	-0.22	0.079	81.1	297	-0.05	0.09	0.052	61.0
HEN 62					HEN 65				
1	0.01	0.23	0.123	68.7	1	0.00	0.20	0.048	90.6
10	-0.06	0.05	0.071	18.3	10	0.06	0.07	0.088	24.5
30	-0.05	0.03	0.065	7.0	30	-0.05	-0.22	0.044	92.3
60	-0.03	-0.09	0.039	75.9	60	0.01	-0.17	0.032	94.1
120	0.01	0.07	0.048	55.7	120	0.01	-0.12	0.027	93.2
180	0.00	0.09	0.056	63.3	180	0.02	-0.12	0.033	88.2
297	-0.04	0.01	0.053	1.6	297	0.04	-0.05	0.025	66.0
HEN 63					HEN 66				
1	0.09	0.14	0.062	71.6	1	-0.02	0.17	0.098	65.6
10	0.06	-0.08	0.058	49.2	10	-0.04	0.19	0.055	86.2
30	-0.01	-0.30	0.058	93.1	30	-0.07	0.17	0.048	88.1
60	0.01	-0.18	0.062	82.0	60	-0.10	-0.06	0.109	15.5
120	-0.04	-0.19	0.053	87.7	120	-0.06	-0.02	0.051	10.4
180	0.02	-0.10	0.033	82.6	180	-0.08	-0.04	0.067	15.5
297	0.00	-0.07	0.063	38.0	297	-0.08	-0.02	0.141	1.1

0.025 (Hen 65 with 297-s blackout) to 0.141 (Hen 66 with 297-s blackout) and did not vary consistently across blackout durations or with changes in the variance accounted for.

Figure 2.3 shows the values of the parameters  $a$  (filled circles) and  $\log c$  (open circles) for all hens' data plotted as a function of blackout duration. With the exception of those obtained for Hen 66's data, values of  $a$  decreased with initial increases in blackout duration and then either increased again or showed no systematic change as blackout duration was further increased. For Hen 66's data values of  $a$  increased slightly when blackout duration was increased to 10 s but then decreased when blackout duration was further increased. For five of the six hens the decrease in the values of  $a$  was such that the  $a$  values obtained became negative as blackout duration increased. For only one of these hens' data (Hen 62) did the subsequent increase in  $a$  values as blackout duration was further increased result in  $a$  values becoming positive again. In no instance however was the increase in  $a$  values such that values of  $a$  obtained for conditions with longer inter-component blackouts were higher than values obtained during the first condition.

The duration of the blackout at which  $a$  values became negative and at which the lowest  $a$  values were obtained varied across hens. These are given in Table 2.3 together with the highest  $a$  value obtained for each hen and the blackout duration at which it occurred. The highest values of  $a$  obtained ranged from 0.28 for Hen 64 to 0.03 for Hen 61 and, with the exception of that from Hen 66's data, occurred when the inter-component blackout was 1 s. The highest  $a$  value obtained for Hen 66 occurred when the duration of blackout was 10 s. The lowest  $a$  values obtained ranged from 0.05 for Hen 64 to -0.39 for Hen 61. The duration of the inter-component blackout at which the lowest  $a$  values were obtained was 30 s for Hens 63, 64 and 65 and 60 s for Hens 61, 62, and 66. The blackout duration at which  $a$  values became negative ranged from 10 s for Hens 61 and 63 to 60 s for Hens 66 and 62.

Values of  $\log c$  tended to be close to 0.0 for all hens in all conditions (median = 0.0; range = -0.10 to 0.09) and did not vary consistently across blackout durations.

FIGURE 2.3

The values of the parameters  $a$  (filled circles) and  $\log c$  (open circles) of Equation 4 for all hens' data for conditions in the ascending series.



TABLE 2.3. The highest and lowest  $\alpha$  values obtained, the blackout duration at which they occurred and the blackout duration at which the  $\alpha$  values became negative. Blackout durations are given in seconds.

Hen	Highest $\alpha$ obtained	Blackout Duration	Lowest $\alpha$ obtained	Blackout Duration	Blackout Duration where $\alpha$ became -ve
61	0.03	1	-0.39	60	10
62	0.23	1	-0.09	60	60
63	0.14	1	-0.30	30	10
64	0.28	1	0.05	30	-
65	0.20	1	-0.22	30	30
66	0.19	10	-0.06	60	60

Data were divided into two sets. The first included data obtained from equal schedules, the MULT VI 30-s VI 120-s and its reversal. The second set included equal schedule data and data from the MULT VI 27-s VI 216-s and its reversal. Values of the parameters  $a$  and  $\log c$  were obtained for the two sets of data and no consistent differences in the values of either parameter were found.

#### Conditions 36 to 42

In order to determine whether the number of schedule alternations per session influenced responding, data from Conditions 36 to 40, where components alternated three times per session, were compared to data obtained from Conditions 41 and 42, where components were alternated seven times per session. Only the two extreme schedule pairs were used with the seven alternations given that the analysis reported above yielded no consistent differences in the parameters of the GML if one schedule pair was eliminated from analysis.

#### Response Rates

The response rates on each component for Conditions 41 and 42 together with response rates obtained in Conditions 39 and 40, which used the same schedule pairs but involved fewer schedule alternations per session, are given in Table 2.4. The differences between component response rates in each of these conditions are also provided.

Examination of Table 2.4 reveals that response rates on each of the component schedules were not consistently different on conditions which involved seven component alternations per session (Conditions 41 and 42) compared to conditions involving three component alternations per session (Conditions 39 and 40). That is, for some hens, response rates on the VI 27-s schedule were higher in Conditions 39 and 40 while for others response rates on these schedules were higher in Conditions 41 and 42. Differences in the response rates on the VI 216-s schedule between the two sets of conditions were similarly inconsistent across hens.

For five of the six hens' data (Hens 61, 63, 64, 65 and 66) the directions of the response rate differences found in Conditions 39

TABLE 2.4 Response rates on each component of Conditions 39, 40, 41 and 42 together with the differences between response rates on the component schedules. The VI schedules operating in the component schedules were the same for Conditions 39 and 42 and for Conditions 40 and 41.

Hen	Condition 39			Condition 40			Condition 41			Condition 42		
	VI 27	VI216	Difference	VI 216	VI 27	difference	VI 216	VI 27	difference	VI 27	VI 216	difference
61	30.58	45.73	-15.15	45.55	30.81	14.74	36.25	28.35	7.90	32.66	37.33	-4.67
62	74.44	68.10	6.34	67.87	73.45	-5.58	62.93	56.02	6.91	58.80	61.10	-2.30
63	40.04	43.98	-3.94	45.70	37.60	8.1	49.96	38.80	11.16	46.71	53.36	-6.65
64	50.22	28.72	21.50	28.15	54.73	-26.58	26.05	26.77	-0.72	45.75	33.14	12.61
65	67.71	59.50	8.21	68.01	62.44	5.57	58.17	50.98	8.19	51.07	48.88	2.19
66	20.16	15.70	4.46	34.50	41.59	-7.09	18.40	40.66	-22.26	37.57	27.07	10.50

and 40 were the same as the direction of the differences found in Conditions 41 and 42. Hen 62's response rates were higher during the rich schedules in the conditions involving three component alternations but were higher in the lean schedules in conditions where components alternated seven times per session.

Of the two conditions with seven component alternations per session (Conditions 41 and 42) the response differential was generally smaller in the second condition. That is response rates did not entirely reverse when the reinforcement rates in the component schedules were reversed. This pattern was less evident in the conditions with three component alternations per session.

#### Generalised Matching Law Analysis

The values of the parameters  $a$  and  $\log c$  of Equation 4 obtained for Conditions 36 to 40 and for Conditions 41 and 42 are given in Table 2.5. No consistent differences across hens between the data from the two sets of conditions were found in either the values of  $a$  or  $\log c$  obtained. For two hens' data (63 and 66) values of  $a$  were more extreme (more negative or more positive) in Conditions 41 and 42 while for others the opposite was true. For two hens' data (62 and 65)  $a$  values obtained were negative for conditions with seven alternations per session (Conditions 41 and 42) but positive for conditions with three alternations (Conditions 36 to 40). For these two hens' data values of  $a$  obtained in both sets of conditions were, however, small. For the other four hens' data, the values of  $a$  obtained for the two sets of conditions were either both positive or both negative and generally larger than the  $a$  values obtained for Hen 62's and 65's data. Values of  $\log c$  were generally small and less variable, across the two sets of conditions, than values of  $a$ .

Given the limited differences between data obtained during the two sets of conditions examined with a blackout duration of 30 s, the subsequent comparison of response rates in the ascending and descending series used data from the conditions with three schedule alternations but five reinforcement ratios. The use of these conditions may be seen as preferable as the greater number of schedules used allow better estimates of the fits of the data to Equation 4. However comparable graphs to those presented below but

TABLE 2.5. Values of the parameters  $a$  and  $\log c$  of Equation 4 for the data from Conditions 36 to 40 and Conditions 41 and 42.

HEN	Condition 36 to 40		Conditions 41 and 42	
	$a$	$\log c$	$a$	$\log c$
61	-0.20	0.02	-0.10	0.02
62	0.04	-0.02	-0.04	0.02
63	-0.04	0.00	-0.10	0.03
64	0.24	-0.04	0.10	0.07
65	0.02	0.04	-0.02	0.04
66	0.11	-0.03	0.28	-0.11

which included data from the conditions with seven component alternations were drawn and inspected. Examination of these figures showed that, in general, differences described below between the ascending and descending series when blackout duration was 30 s, were similar to those seen if data from the ascending series were compared to data from conditions 41 and 42.

### Descending Series

#### Response Rates

Figure 2.4 shows response rates on each component schedule plotted as a function of blackout duration on the descending series (decreasing blackout duration) together with response rates obtained with the same blackout durations in the ascending series (increasing blackout duration). Response rates obtained when blackout duration was 297 s are also shown. Response rates on the richer schedule of a schedule pair are shown as squares (ascending series) or plusses (descending series) connected with a solid line and response rates on the leaner schedule as circles (ascending series) and crosses (descending series) connected with a dashed line. For the equal schedule pair response rates on the schedule associated with S1 are shown as squares (ascending series) or plusses (descending series) connected by solid lines and response rates on the schedule associated with S2 as circles (ascending series) and crosses (descending series) connected with dashed lines. Each graph represents responding on one of the five schedule pairs used.

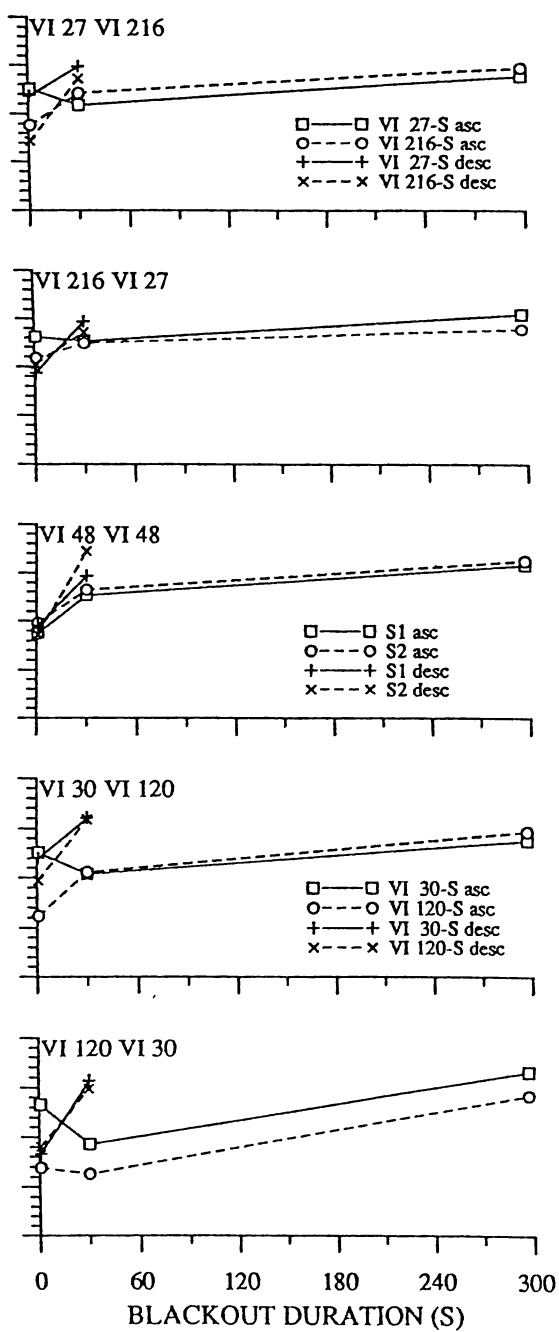
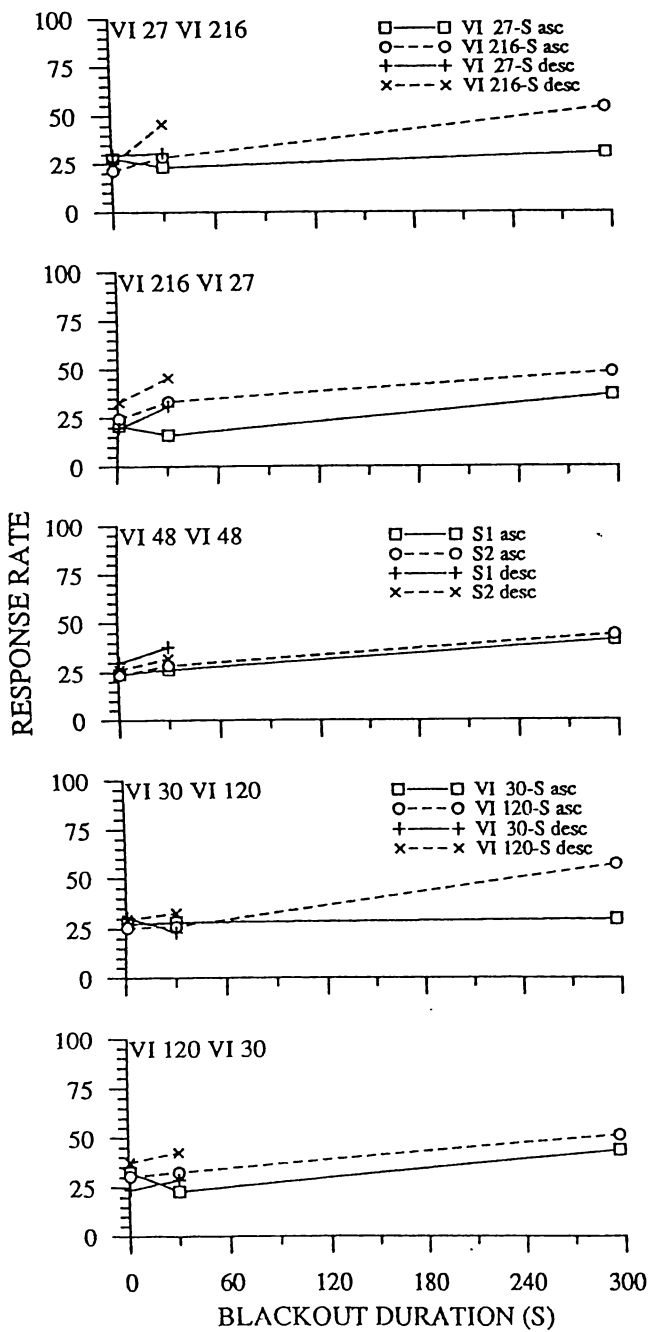
Response rates on component schedules for Hens 61, 62, 64, and 65, for conditions with a 30-s blackout duration, were generally higher on the descending series than response rates on the equivalent component schedules on the ascending series. With 30 s blackout Hen 63's response rates were lower on the leaner schedules and higher on the richer schedules on the descending series than on equivalent schedules in the ascending series. With the same blackout duration Hen 66's response rates on all component schedules were lower on the descending series than on the ascending series. In general response rates with 30 s blackout on the descending series tended to be more similar to response rates obtained on conditions with 297 s blackout than to those where blackout duration

FIGURE 2.4

Response rates on each component schedule plotted as a function of blackout duration on the descending series (decreasing blackout duration) and the ascending series (increasing blackout duration). Response rates obtained when blackout duration was 297 s are also shown. Response rates on the richer schedule of a schedule pair are shown as squares (ascending series) or plusses (descending series) connected with a solid line and response rates on the leaner schedule as circles (ascending series) and crosses (descending series) connected with a dashed line. For the equal schedule pair response rates on the schedule associated with S1 are shown as squares (ascending series) or plusses (descending series) connected by solid lines and response rates on the schedule associated with S2 as circles (ascending series) and crosses (descending series) connected with dashed lines. Each graph represents responding on one of the five schedule pairs used.

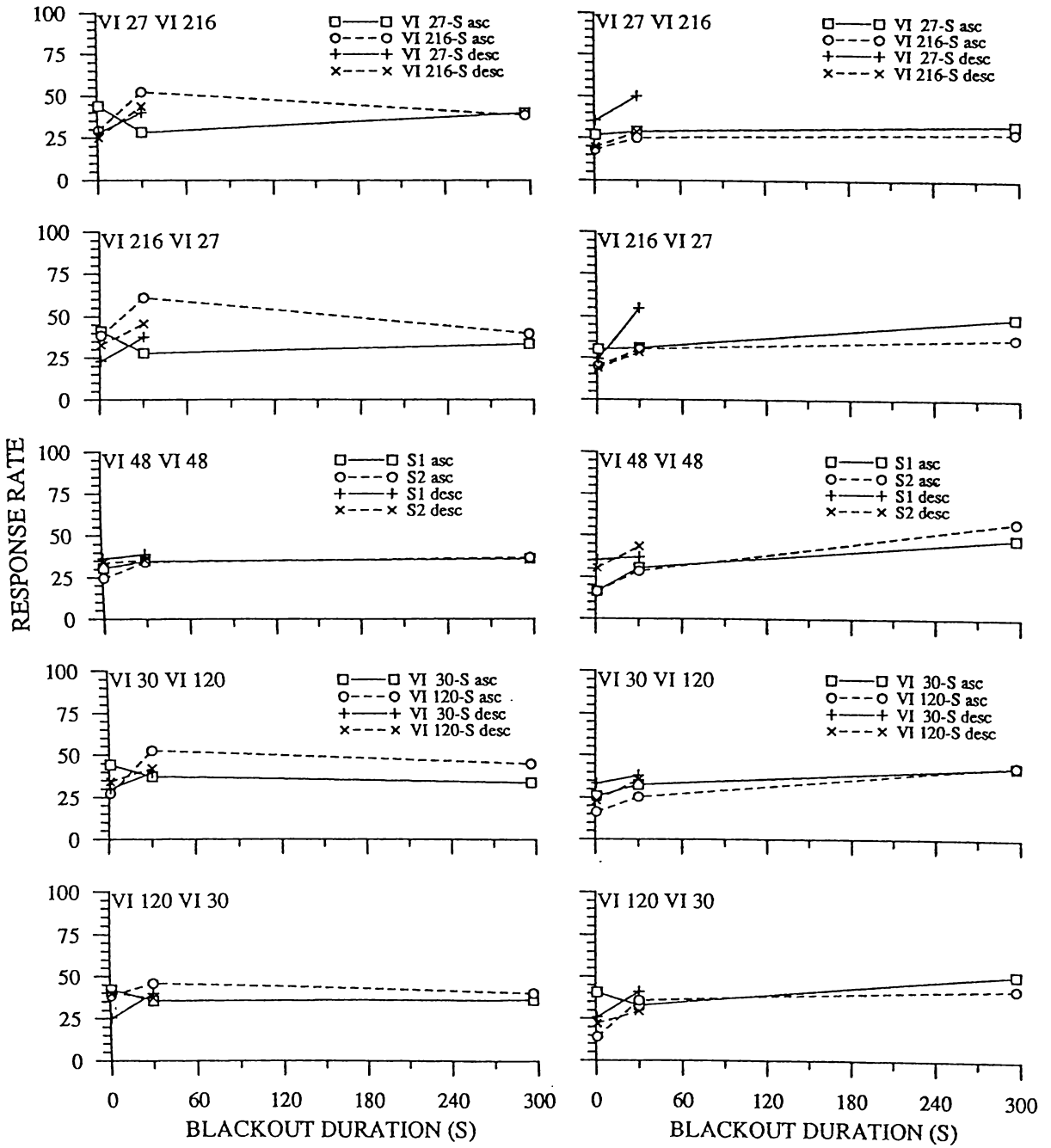
HEN 61

HEN 62

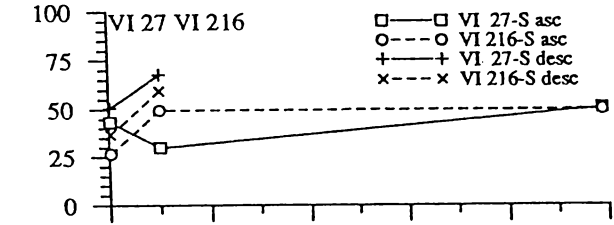


### HEN 63

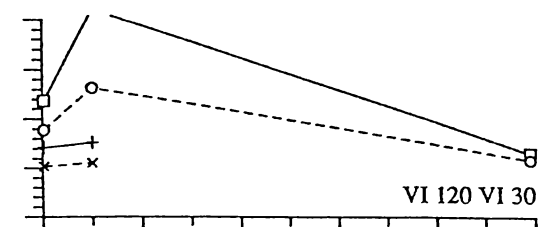
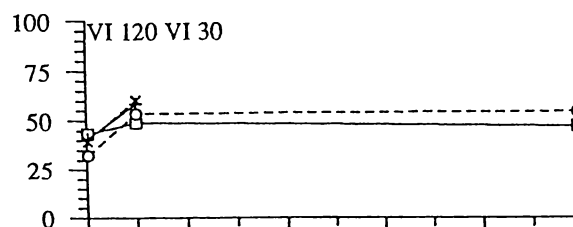
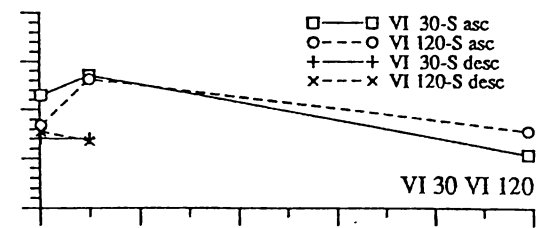
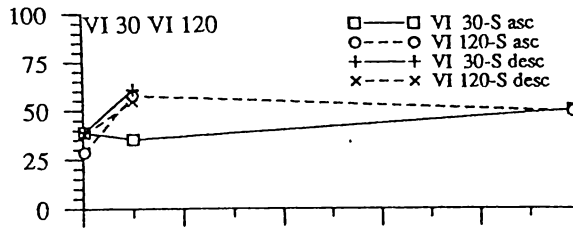
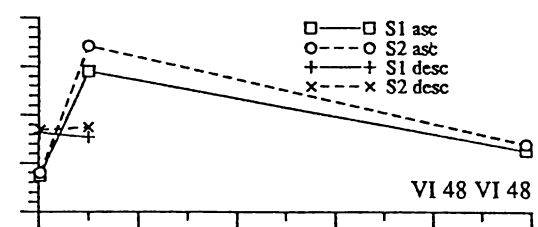
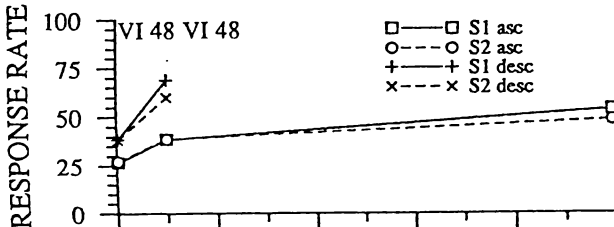
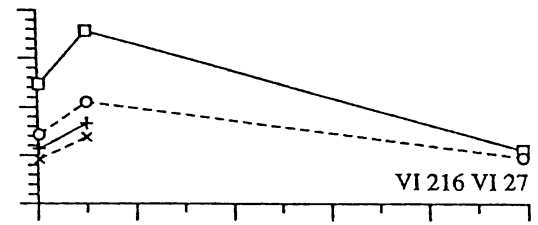
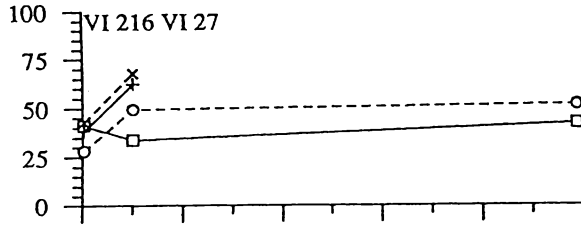
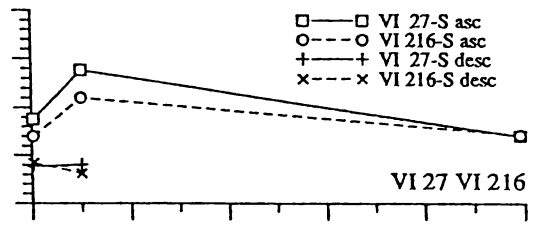
### HEN 64



### HEN 65



### HEN 66



RESPONSE RATE

BLACKOUT DURATION (S)

BLACKOUT DURATION (S)

was 30 s on the ascending series. This pattern is particularly notable in Hen 63's and Hen 66's data.

When blackout duration was reduced from 30 s to 1 s, for all but Hen 66, response rates on all component schedules tended to decrease while Hen 66's response rates generally remained similar. There was no consistent difference across hens between response rates obtained on these conditions compared to those obtained on the ascending series. Hen 61's, 64's and 65's response rates were generally higher while Hen 62's, 63's and 66's response rates tended to be lower, with some exceptions, on the descending series than on equivalent conditions in the ascending series.

The differences between response rates on the rich and lean schedules, of the schedule pairs with differential reinforcement rates, were calculated for all conditions in the descending series and are presented in Table 2.6. For 14 of the 24 comparisons the magnitude of response differentials were greater for the first condition using a particular pair of schedules than in the following condition where the schedules were reversed. However no consistent differences in the response differentials were found across the two sets of conditions as a function of whether the condition was the first or second presented which used the same schedules. For example, although for Hen 64's data the magnitude of the response differential was greater in the first condition using the VI 30-s and VI 120-s schedules than in the second using these conditions, the greater response differential was observed in the second condition using the VI 27-s and VI 216-s schedules.

#### Generalised Matching Law Analysis

Table 2.7 gives the intercepts (values of  $\log c$  in Equation 4), the slopes (values of  $a$  in Equation 4), standard errors and the percentages of variance accounted for by regression lines fitted by the method of least squares to the daily data from the five conditions at each blackout duration in the descending series. Neither the standard errors of, nor the percentage of variance accounted for by the fitted lines, varied consistently across hens as a function of blackout duration and both measures were within the range of those obtained on the descending series.

TABLE 2.6. Differences between response rates on the two components of multiple schedules with differential reinforcement rates in the component schedules. The first two columns give differences between component schedules when the schedule in effect was either a MULT VI 27-s VI 216-s or MULT VI 216-s VI 27-s. The last two columns give response differentials when the schedule in effect was either a MULT VI 30-s VI 120-s or MULT VI 120-s VI 30-s. The first column of each pair gives the response differences for the first condition at each blackout duration which used the specified schedules. The second column gives the response differences for conditions where the reinforcement rates were reversed.

HEN	Blackout Duration (s)	Component Schedules VI 27-s and VI 216-s		Component schedules VI 30-s and VI 120-s	
		First pair	Second pair	First pair	Second pair
61	1	4.56	13.45	13.67	0.95
	30	-15.15	14.74	13.80	-9.59
62	1	23.22	4.57	3.71	11.29
	30	6.33	-5.58	-3.72	0.70
63	1	2.75	9.89	14.42	-4.24
	30	-3.94	8.09	-2.52	-2.56
64	1	15.73	-5.49	-3.70	10.14
	30	21.50	-26.58	-11.45	2.47
65	1	13.80	4.69	-1.59	1.17
	30	8.21	5.57	1.83	6.25
66	1	-2.03	-5.41	-9.63	-3.76
	30	4.47	-7.09	-10.32	1.23

TABLE 2.7. Values of the parameters  $\log c$  and  $a$  of Equation 4 obtained by fitting regression lines by the method of least squares to the daily data from the five multiple schedules employed at each blackout duration in the descending series. The standard errors (S.E), percentages of variance accounted for (VAC) by the fitted lines are also given.

Blackout Duration	$\log c$	$a$	S.E	VAC	Blackout Duration	$\log c$	$a$	S.E	VAC
HEN 61					HEN 62				
1	0.11	-0.11	0.051	69.6	1	0.09	0.08	0.058	52.3
30	0.02	-0.20	0.062	85.9	30	-0.02	0.04	0.055	15.5
HEN 63					HEN 64				
1	0.07	-0.11	0.081	48.9	1	0.06	0.21	0.046	90.5
30	0.01	-0.04	0.056	25.5	30	-0.04	0.24	0.113	71.2
HEN 65					HEN 66				
1	0.04	0.04	0.057	20.8	1	-0.07	0.05	0.051	31.3
30	0.04	0.02	0.036	11.6	30	-0.03	0.11	0.099	39.4

Figure 2.5 shows values of  $a$ , plotted as a function of blackout duration, for data from the descending series (crosses) together with values of  $a$  for data from the ascending series (circles) for conditions with the same blackout duration and with 297 s blackout. Values of  $a$  obtained with 30-s blackout duration in the descending series were not consistently higher or lower across hens than  $a$  values obtained with the same blackout duration in the ascending series, but were more similar to those obtained for the data on conditions with 297 s blackout.

Values of  $a$  did not change consistently across hens as a function of reducing blackout duration from 30 s to 1 s. For three hens' data  $a$  values increased and for the other three  $a$  values decreased. Values of  $a$  obtained were lower than those from the same blackout duration in the ascending series and were generally similar to values obtained for the data on conditions with 297 s blackout. For two hens' data (61 and 63) values of  $a$  remained negative for both sets of conditions on the ascending series.

Figure 2.6 shows the values of  $\log c$  obtained plotted as a function of blackout duration on the descending series (crosses) together with values of  $\log c$  obtained on the ascending series (filled circles) for conditions with the same blackout duration and with 297 s blackout. Values of  $\log c$ , where blackout duration was 30 s, were not consistently different on the descending series from those obtained on the ascending series. For five of the hens' data the absolute values of  $\log c$  increased when blackout duration was decreased from 30 s to 1 s. The value of  $\log c$  obtained for Hen 65's data remained similar to that obtained when blackout duration was 30 s. For Hen 63's data, values of  $\log c$  were similar on the ascending and descending series but, for the other hens' data, the absolute values of  $\log c$  obtained on the descending series, when blackout duration was 1 s, were higher than those obtained for equivalent conditions on the ascending series.

FIGURE 2.5

Values of  $a$  plotted as a function of blackout duration on the descending series (crosses) and the ascending series (circles).

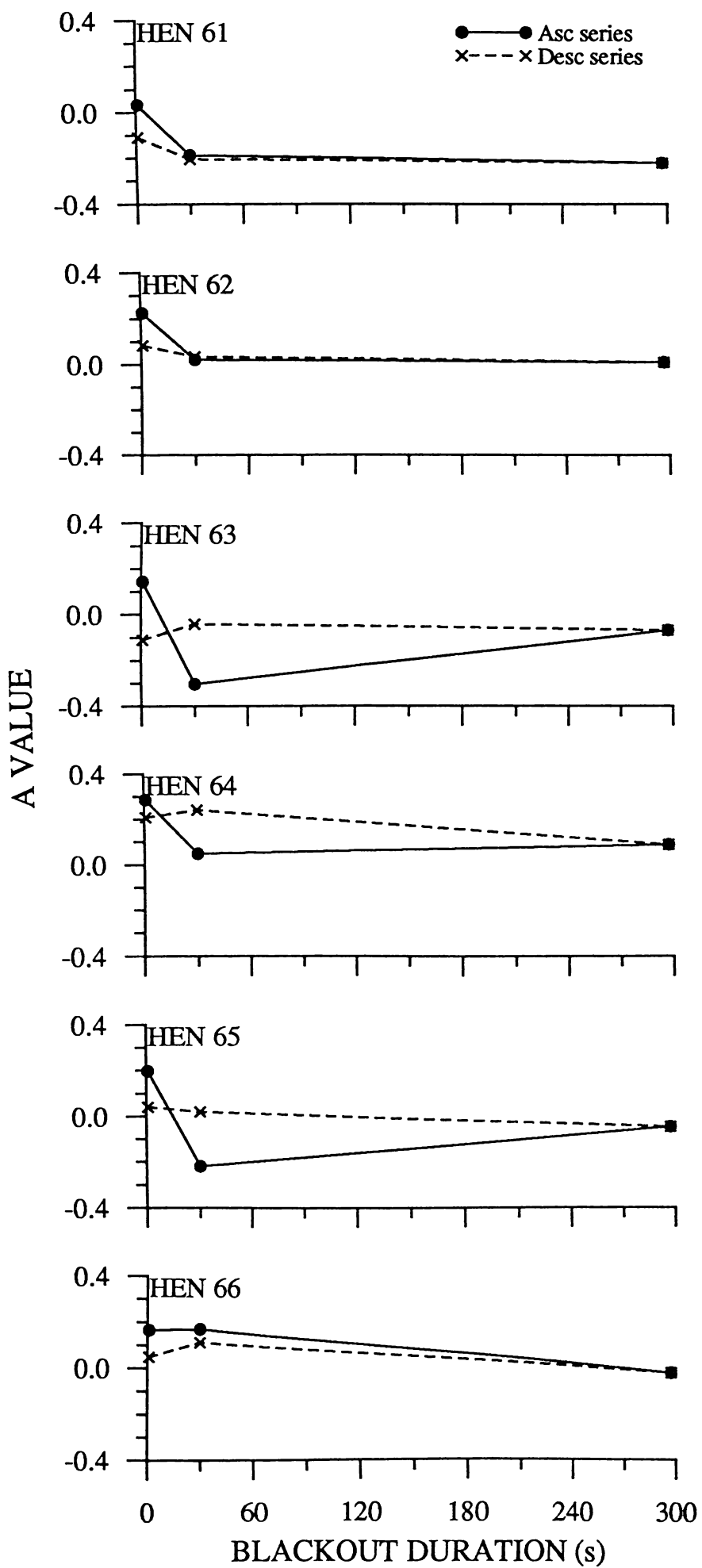
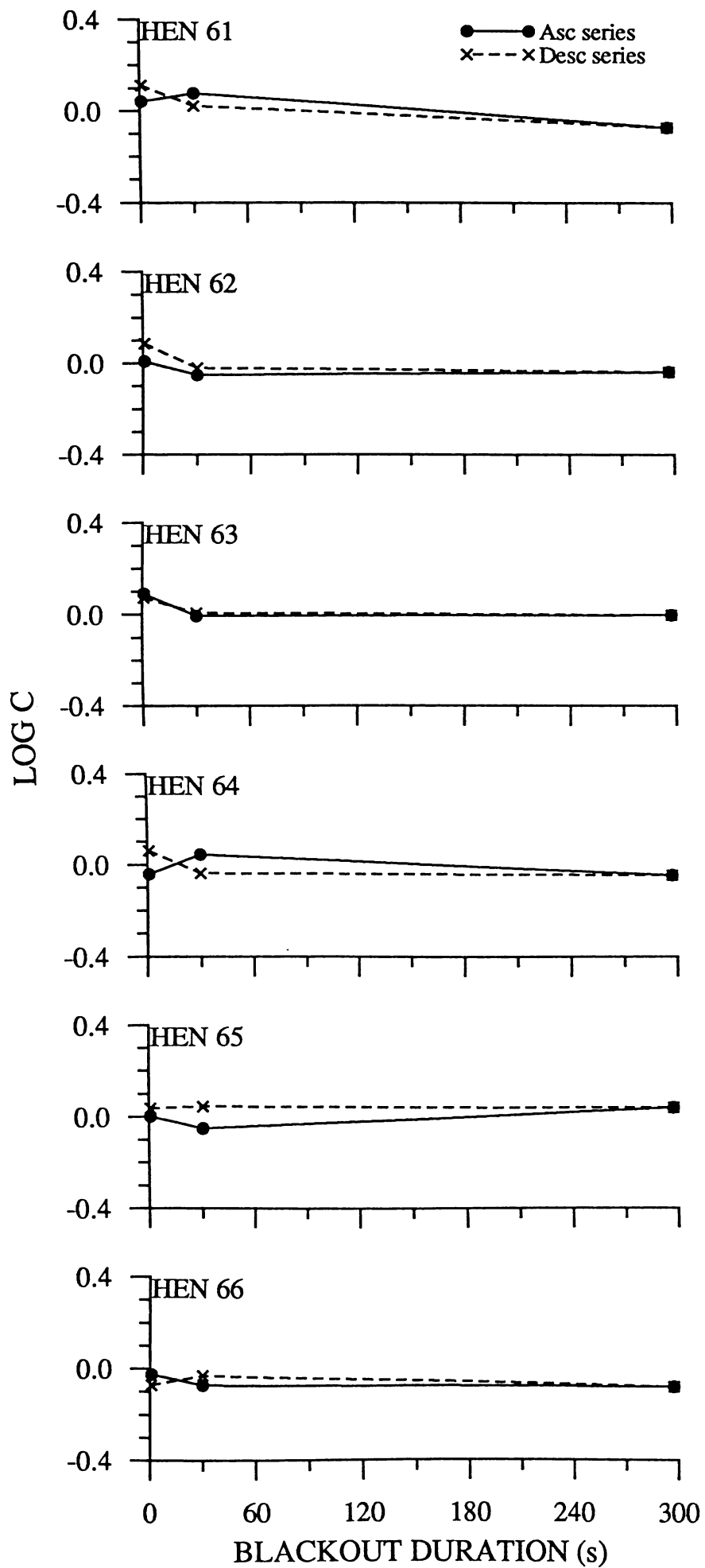


FIGURE 2.6

Values of  $\log c$  plotted as a function of blackout duration on the descending series (crosses) and the ascending series (filled circles).



## Behaviour Within Components

Ascending Series.Response rates

All 210 graphs showing response rates in the component schedules of each schedule pair at each blackout duration, plotted as a function of time since a component became available were drawn and inspected. These are not presented but an alternative measure,  $D$ , was devised. This measure adequately summarised the overall trends seen in the initial graphs and represents the change in response rates between the first and last 15-s subintervals of a component as a percentage of the response rate in the first subinterval. The values of  $D$  were calculated for both components on all conditions using Equation 6.

$$D = \frac{R_{t2} - R_{t1}}{R_{t1}} \quad (6)$$

In this equation  $R_{t1}$  is the average response rate in the first 15 s of a component and  $R_{t2}$  the average response rate in the last 15 s of that component. If response rates increased between the first and last 15 s of a component the  $D$  obtained will be positive. If these decreased then it will be negative. Local negative contrast is evident when values of  $D$  for lean schedule responding are greater than 0.0. Local positive contrast is evident when values of  $D$  for rich schedule behaviour are less than 0.0. Local induction is represented by values of  $D$  of less than 0.0 for lean schedule behaviour or greater than 0.0 for rich schedule behaviour.

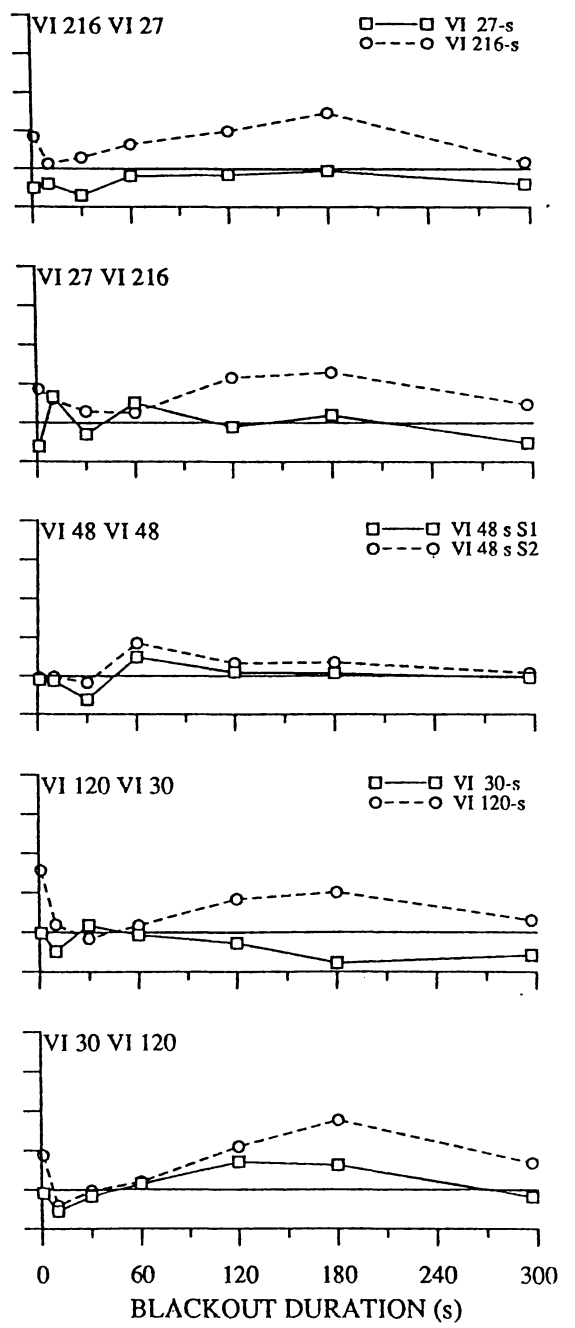
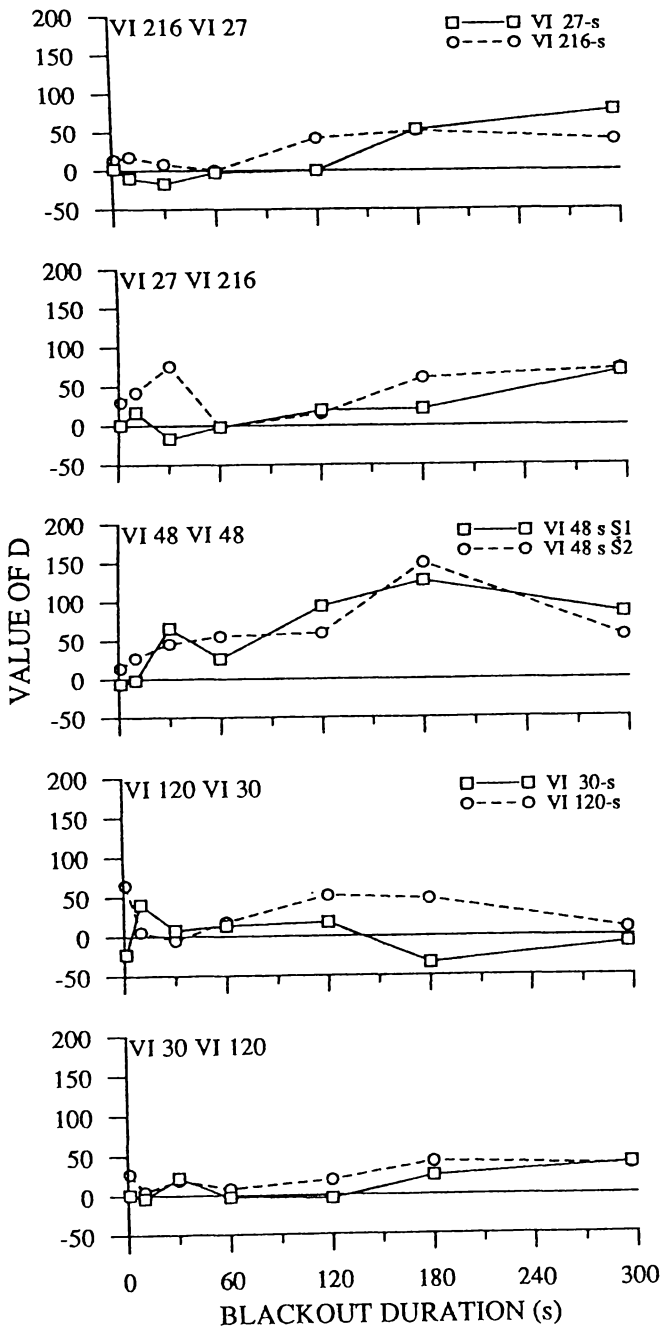
Figure 2.7 shows values of  $D$  for each component of all schedule pairs, plotted as a function of blackout duration, in the ascending series. Each graph shows values of  $D$  obtained in each component of one schedule pair. In all cases  $D$  values for responding on lean schedules are shown as circles and on rich schedules as squares. For the conditions with equal reinforcement schedules  $D$  values for S1 responding are shown as squares and S2 responding as circles. The direction and magnitude of changes in  $D$  as a function of blackout duration varied across hens and across conditions at each blackout duration. In general when the blackout duration was 1 s values of  $D$  for lean schedule responding were positive indicating an

FIGURE 2.7

Values of  $D$  for each component of all schedule pairs plotted as a function of blackout duration in the ascending series. Each graph shows values of  $D$  obtained for each component of one schedule pair. Circles indicate values of  $D$  for the leaner schedule of a schedule pair and squares indicate values of  $D$  for the rich schedule.

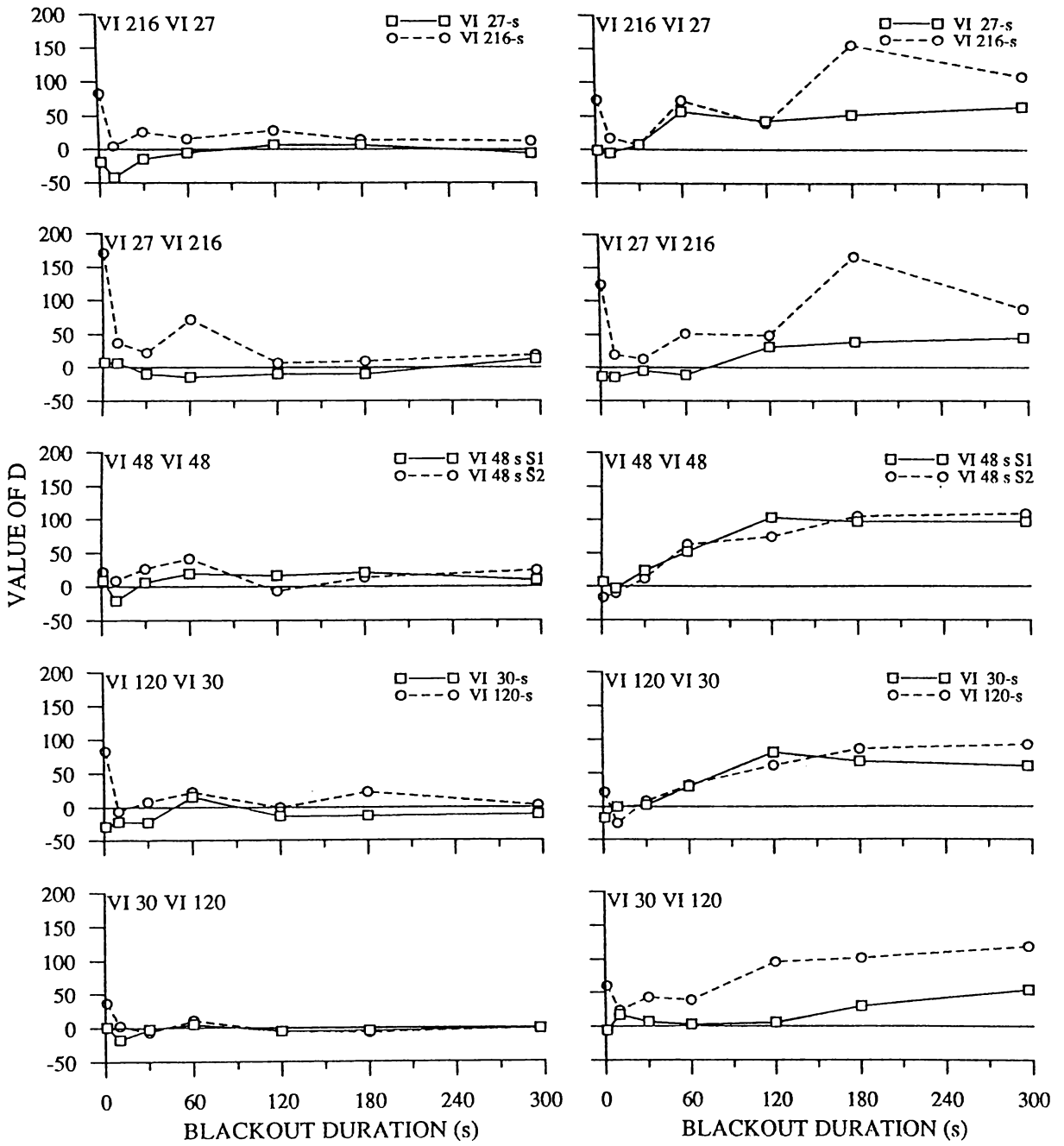
HEN 61

HEN 62



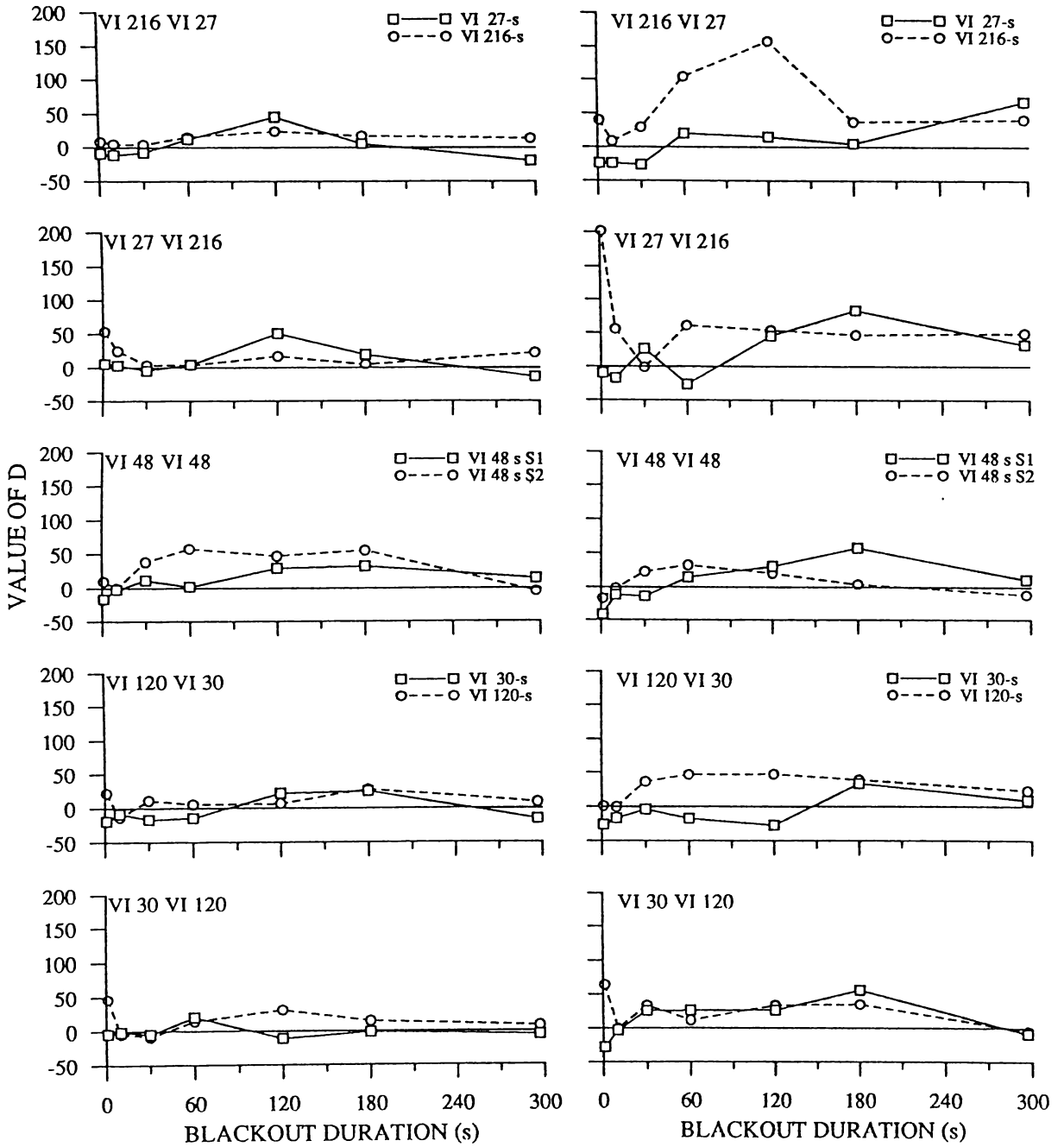
HEN 63

HEN 64



HEN 65

HEN 66



increase in response rate as a function of time since component alternation (local negative contrast). As the duration of the blackout was initially increased values of  $D$  tended to decrease so that for all hens no local negative contrast was observed in some conditions for at least one blackout duration. The blackout duration at which no notable decreases in values of  $D$  occurred varied across birds. For some hens' data, in some conditions, as blackout duration was further increased  $D$  values for the lean schedules again increased.

Generally  $D$  values for responding on the rich schedule, when the inter-component blackout was 1 s, were either negative, indicating local positive contrast, or close to 0.0. As the duration of the blackout increased values of  $D$  obtained for rich schedule responding tended to become less negative. For all hens these values became positive indicating an increase in rich schedule response rates (positive induction) in at least one condition but often over several conditions. The magnitude of any local positive contrast as measured by  $D$  was smaller than the local negative contrast noted at the same blackout durations.

Values of  $D$  obtained for the data from both components of the equal schedule pairs tended to increase when blackout duration was initially increased and then remain at a constant level or decrease again as blackout duration was further increased. The blackout duration at which no notable increase in values of  $D$  occurred varied across hens. These effects were most notable in Hen 61's and 64's data and not apparent in Hen 63's data.

#### Generalised Matching Law Analysis

The intercepts ( $\log c$ ), the slopes ( $a$ ), standard errors and percentages of variance accounted for by regression lines fitted by the method of least squares to the data for each 15-s subinterval for conditions at each blackout duration in the ascending series are given in Appendix 2.2.1 to 2.2.4. The percentages of variance accounted for by the lines (Appendix 2.2.4) ranged between 0.1 and 91.8 and were generally less when the absolute values of  $a$  were smaller. The standard errors of the fits (Appendix 2.2.3) ranged from 0.043 to 0.266 and did not vary consistently across hens as a

function of blackout duration, time since component alternation, or with changes in the percentage of variance accounted for.

Values of  $\log c$  obtained (Appendix 2.2.2) were generally small and did not vary consistently across hens as a function of time since component alternation.

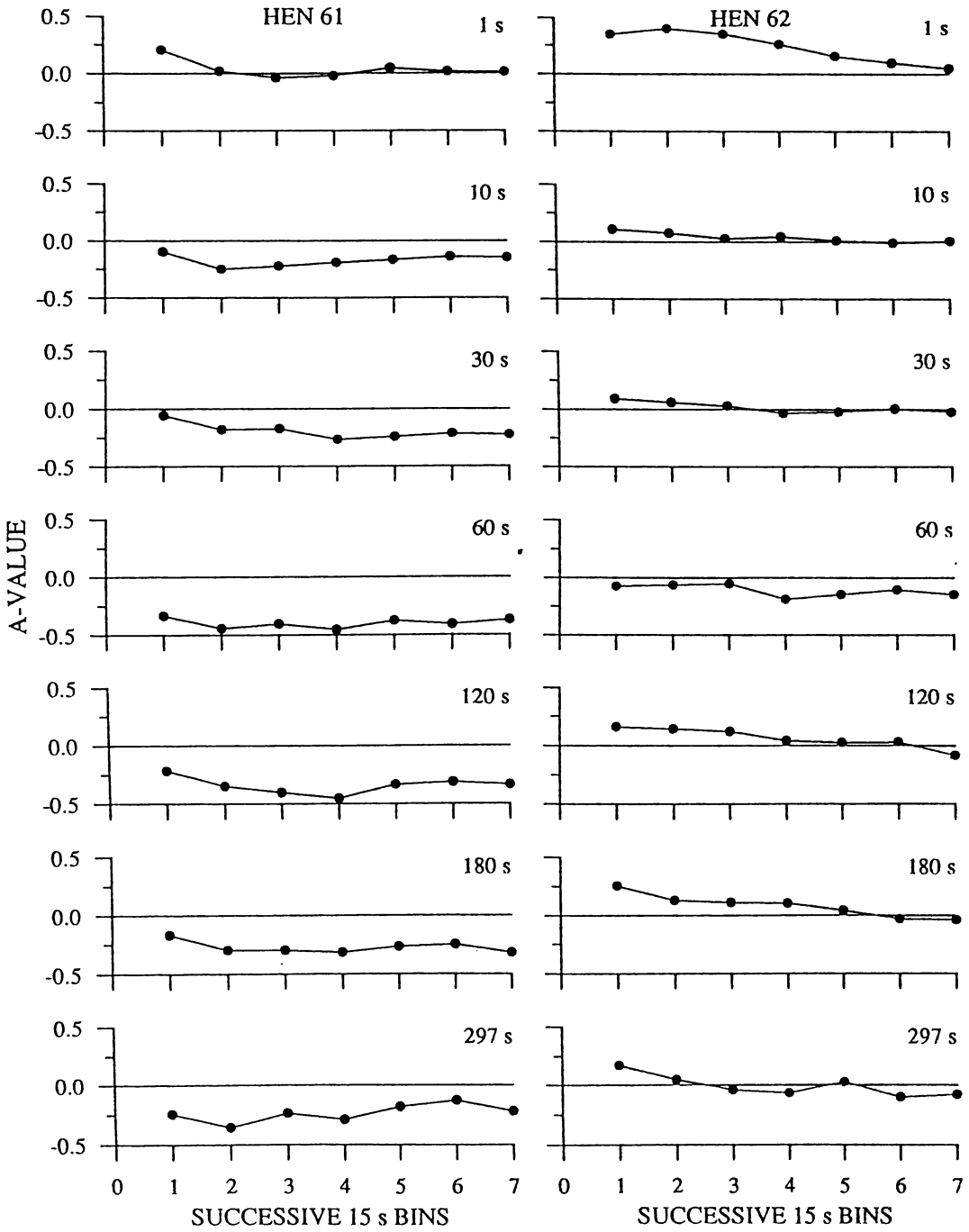
Figure 2.8 shows values of the parameter  $a$  of Equation 4 for responding in each successive 15-s subinterval (bin) of the components. Each graph shows  $a$  values obtained for the data from the five conditions at one blackout duration. For all hens values of  $a$  decreased as a function of time since component alternation when blackout duration was 1 s. The extent to which  $a$  values changed over successive 15-s subintervals diminished as the inter-component blackout increased, so that, for all hens' data, at least one blackout duration, values of  $a$  did not change systematically as a function of time since component alternation. The blackout duration at which no consistent decreases in  $a$  within components were first noted varied across hens. For three of the six birds' data (Hens 62, 64 and 65), the decreases in  $a$  values as a function of time since component alternation observed with shorter blackout durations, were again observed when blackout duration was further increased.

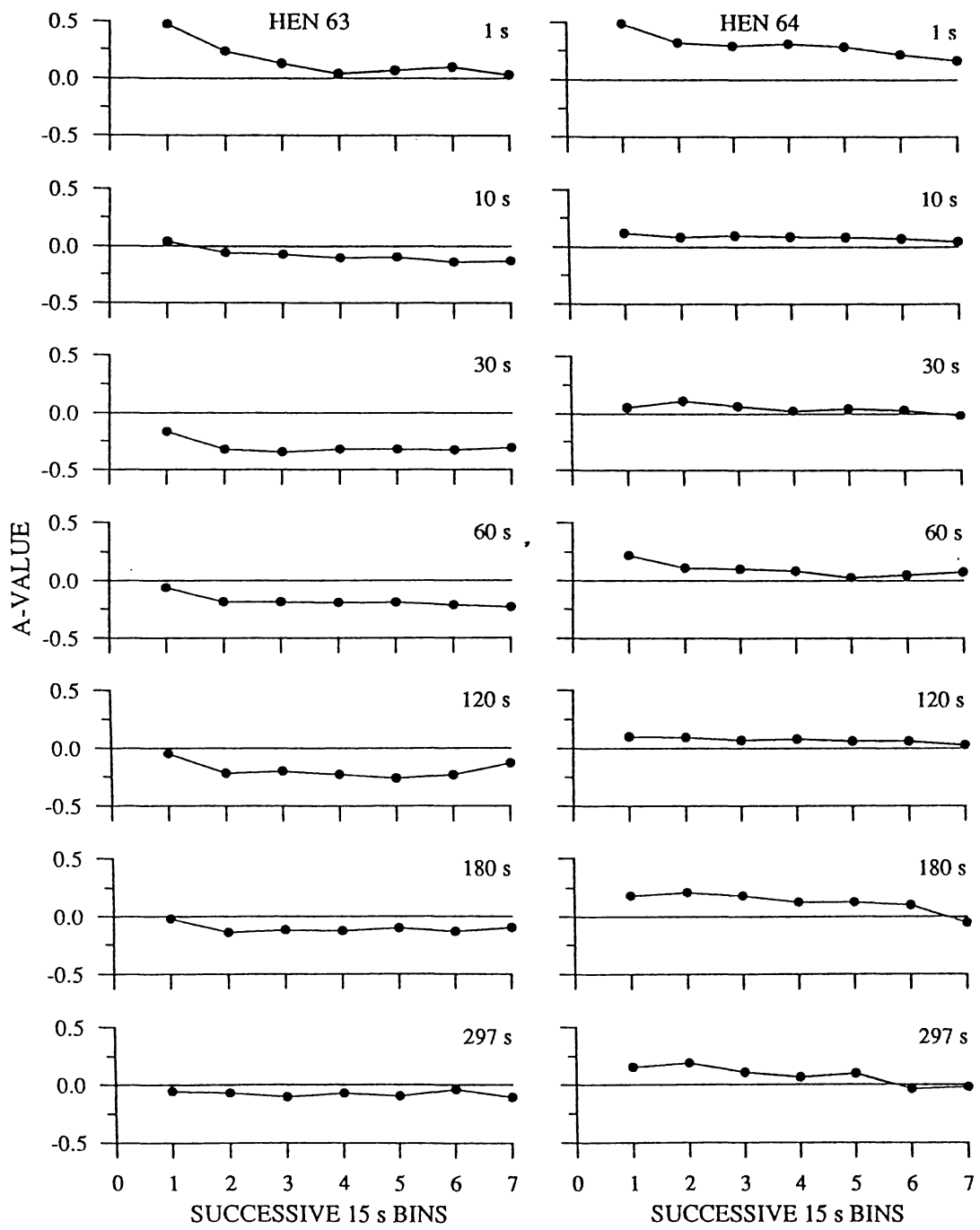
#### Conditions 36 to 41

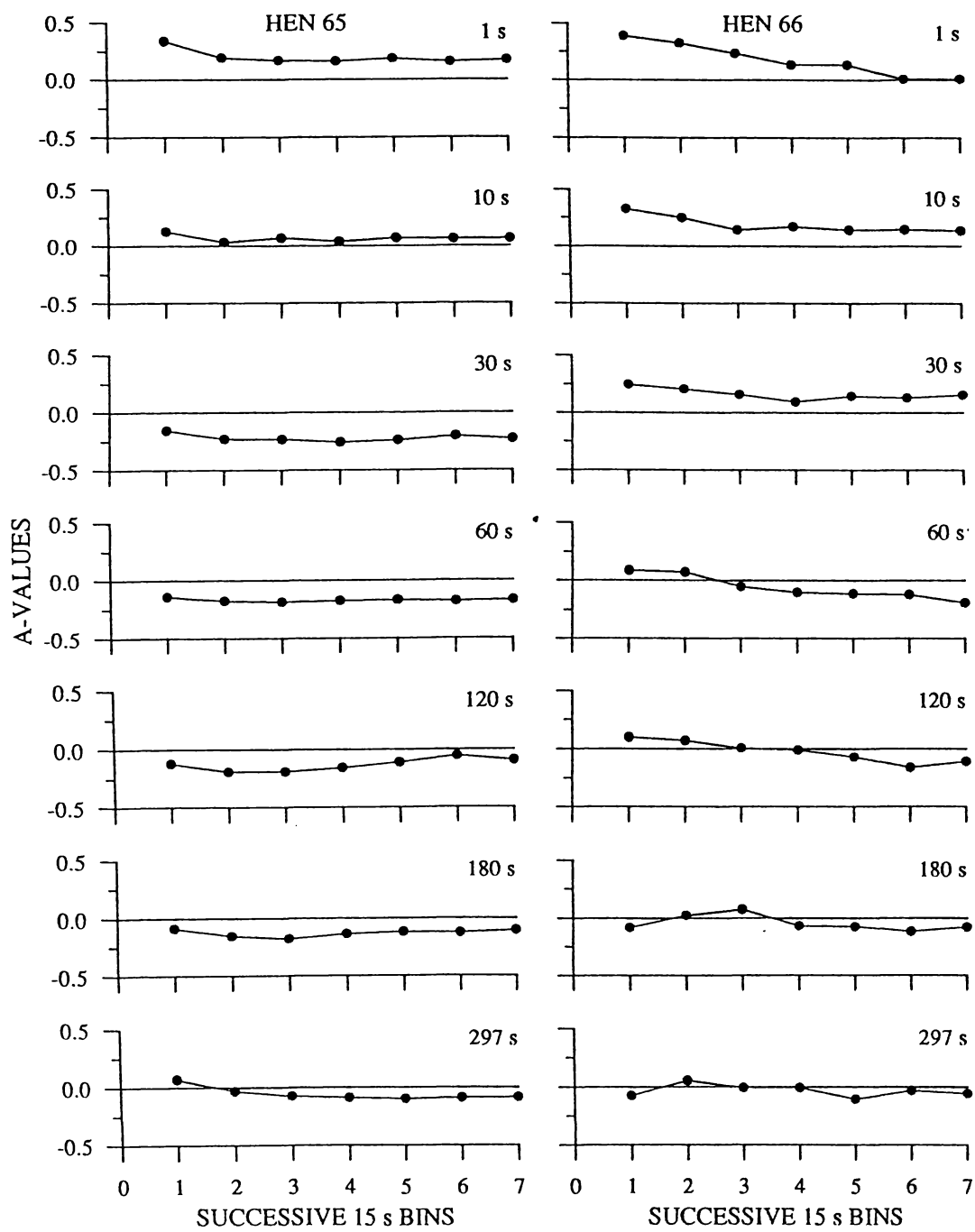
Analysis of within-component responding on Conditions 36 to 40 (30 s blackout with three component alternations) and 41 to 42 (seven component alternations) revealed no consistent differences in the data obtained from the two sets of conditions. Changes in response rates and in values of  $a$  obtained over successive subintervals were generally similar for Hens 61 to 65. For Hen 66  $a$  values obtained from Conditions 41 and 42 increased as a function of time since component alternation while  $a$  values obtained for Conditions 36 to 40 decreased as a function of time since component alternation. For consistency with the previous analyses Conditions 36 to 40 were used in the following analyses.

FIGURE 2.8

Values of the parameter  $a$  of Equation 4 for responding in each successive 15-s subinterval of the components for conditions in the ascending series. Each graph shows  $a$  values for one blackout duration.







### Descending Series

#### Response rates

Figure 2.9 shows values of D for responding on each component schedule plotted as a function of blackout duration on the descending series (decreasing blackout duration) together with response rates obtained with the same blackout durations in the ascending series (increasing blackout duration). Values of D obtained when blackout duration was 297 s are also shown. Values of D for responding on the richer schedule of a schedule pair are shown as squares (ascending series) or plusses (descending series) connected with a solid line and on the leaner schedule as circles (ascending series) and crosses (descending series) connected with a dashed line. For the equal schedule pair D values for responding on the schedule associated with S1 are shown as squares (ascending series) or plusses (descending series) connected by solid lines and on the schedule associated with S2 as circles (ascending series) and crosses (descending series) connected with dashed lines. Each graph shows values of D obtained for responding on one of the five schedule pairs used. Examination of Figure 2.9 reveals that, in general, values of D obtained for data from conditions with a 30-s blackout duration in the descending series, did not replicate values of D obtained in the ascending series. For all hens' data values of D were generally higher on the descending series than on the ascending series and were, for both rich and lean schedules, greater than zero. Thus negative local contrast and positive local induction were evidenced.

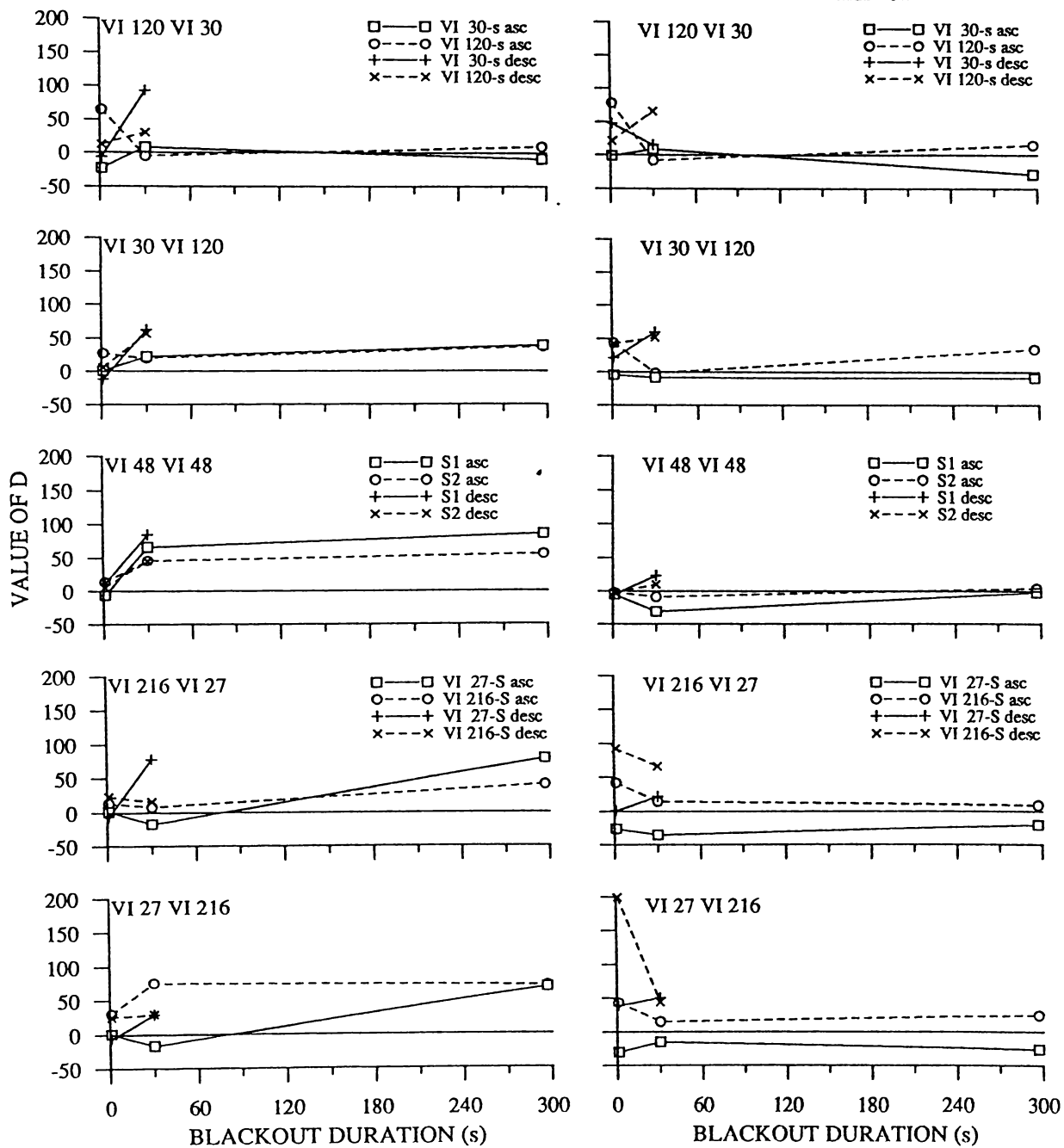
For four hens' data (Hens 61, 63, 65 and 66) values of D for responding on the richer schedule of a pair (+) decreased when blackout duration was reduced from 30 s to 1 s, and were generally similar in both magnitude and sign (positive or negative) to those obtained on the ascending series. For the remaining two hens (Hens 62 and 64) values of D for rich schedule responding also decreased when blackout duration was reduced. However, in general, they were higher than those obtained on the ascending series and positive indicating positive local induction. Values of D for responding on the lean schedules did not consistently increase or decrease when blackout duration was reduced from 30 s to 1 s. In general the

FIGURE 2.9

Values of D for responding on each component schedule plotted as a function of blackout duration on the descending series (decreasing blackout duration) together with response rates obtained with the same blackout durations in the ascending series (increasing blackout duration). Values of D obtained when blackout duration was 297 s are also shown. Values of D for responding on the richer schedule of a schedule pair are shown as squares (ascending series) or plusses (descending series) connected with a solid line and on the leaner schedule as circles (ascending series) and crosses (descending series) connected with a dashed line. For the equal schedule pair D values for responding on the schedule associated with S1 are shown as squares (ascending series) or plusses (descending series) connected by solid lines and on the schedule associated with S2 as circles (ascending series) and crosses (descending series) connected with dashed lines. Each graph shows values of D obtained for responding on one of the five schedule pairs used.

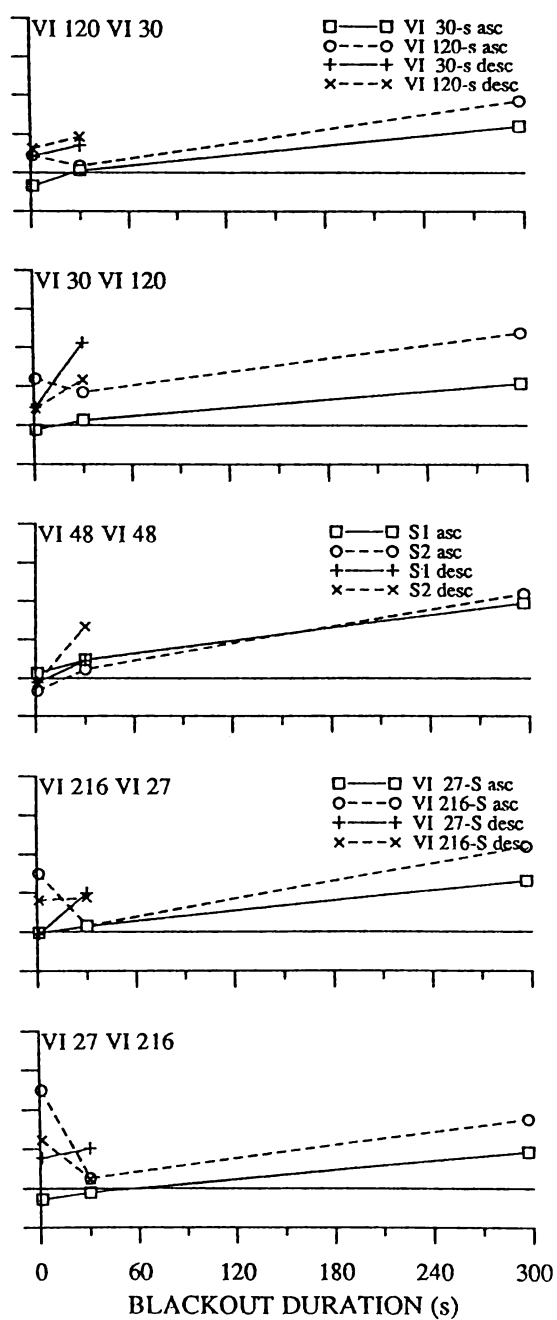
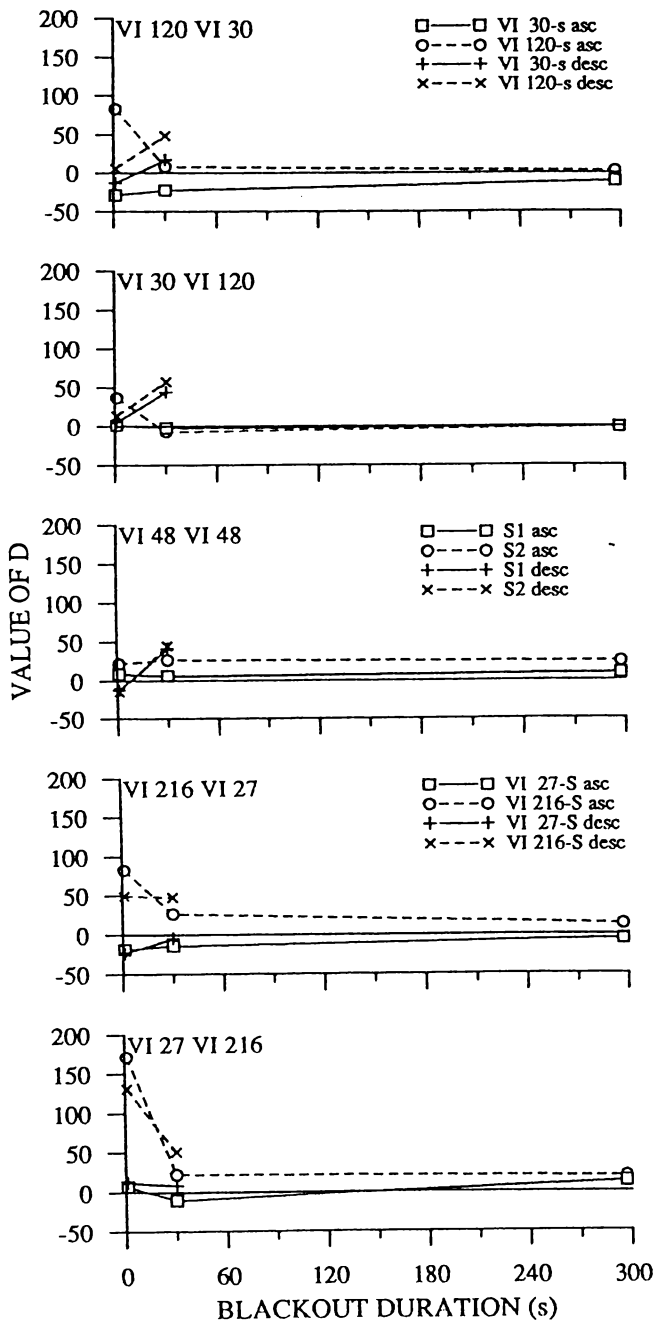
### HEN 61

### HEN 62



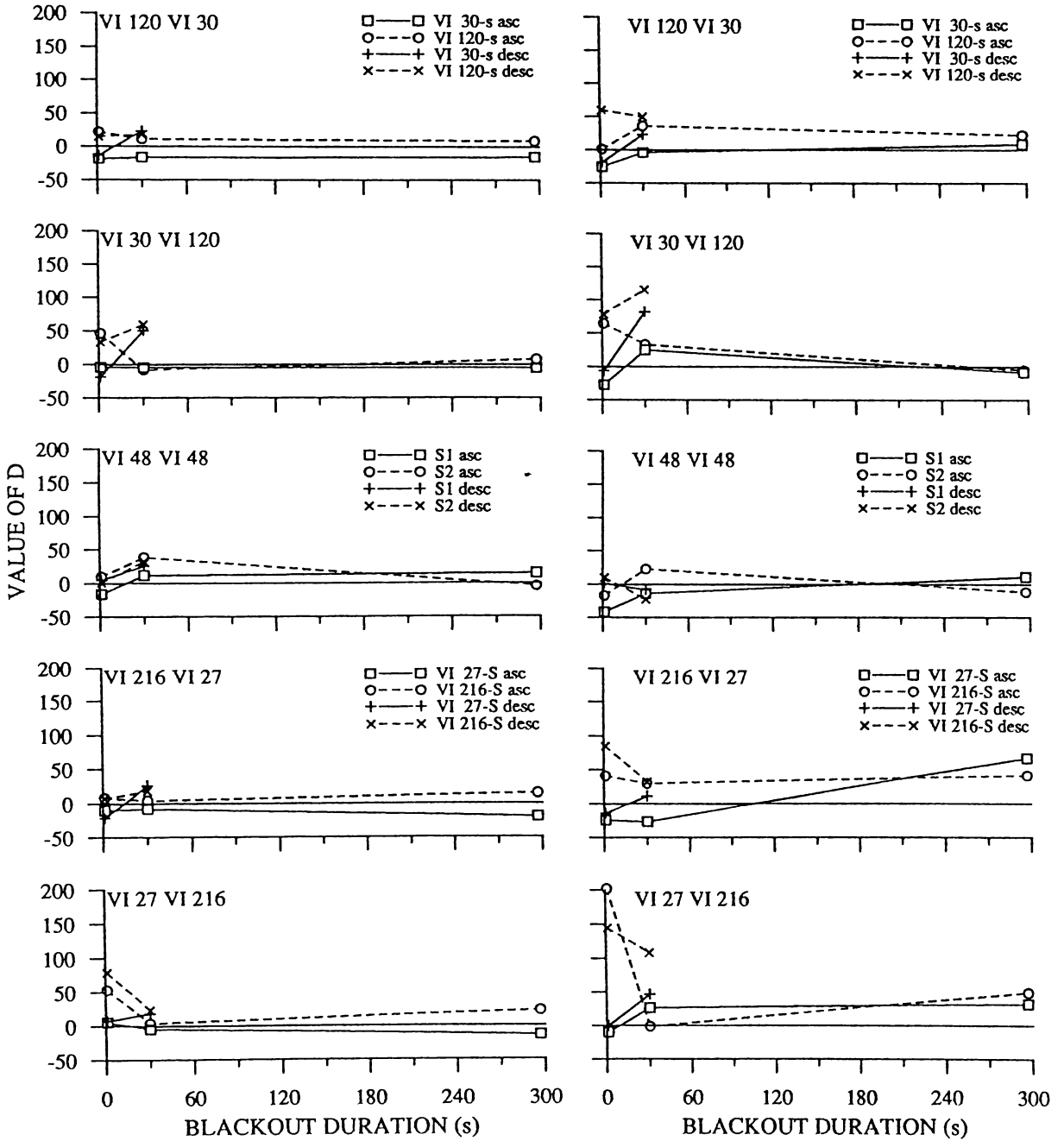
HEN 63

HEN 64



### HEN 65

### HEN 66



values of  $D$  obtained were positive as were those in the ascending series, although, in several instances, the magnitude of  $D$  varied considerably between the two sets of conditions.

### Generalised Matching Law analysis

The intercepts ( $\log c$ ), slopes ( $a$ ), standard errors and percentages of variance accounted for by regression lines fitted by the method of least squares to the data for each 15-s subinterval for conditions in the ascending series are given in Appendix 2.3. The percentage of variance accounted for by the fitted lines ranged from 0.0 to 84.0 % and did not vary consistently across hens either as a function of blackout duration or over successive subintervals. Standard errors of the lines ranged from 0.059 to 0.209 and also did not vary consistently as a function of time since component alternation or blackout duration. Values of  $\log c$  did not vary consistently over successive 15-s subintervals as observed on the ascending series.

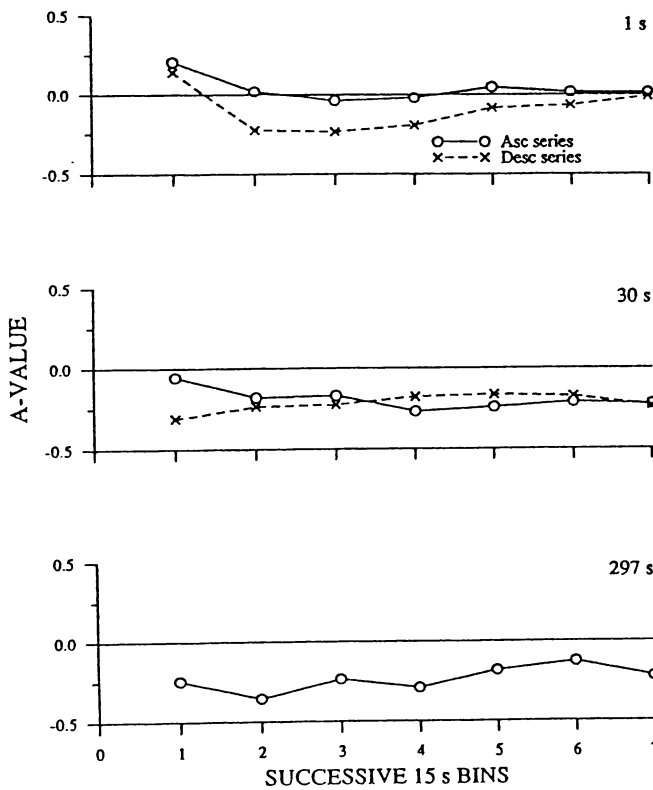
Figure 2.10 shows values of  $a$  obtained for each successive 15-s subinterval for both blackout durations in the descending series together with  $a$  values obtained for equivalent conditions on the ascending series. Values of  $a$  for the descending series are represented as crosses and for the ascending series as circles. Each graph shows  $a$  values obtained at one blackout duration. Values of  $a$  obtained for each successive subinterval for conditions where the blackout duration was 297 s are also shown.

For conditions where the blackout duration was 1 s,  $a$  values obtained decreased as a function of time since component alternation as was observed for equivalent conditions on the ascending series. A slight decrease in  $a$  values over successive subintervals was observed in the data from Hens 62, 63 and 66 when blackout duration was 30 s. For the remaining three hens' data  $a$  values either increased slightly over successive bins or remained at the same level. For four hens' data (62, 63, 64 and 65) the pattern of  $a$  values observed on the descending series was similar to that observed on the ascending series. For Hen 61's data  $a$  values on the ascending series decreased over successive subintervals, but on the descending series  $a$  values increased slightly over successive

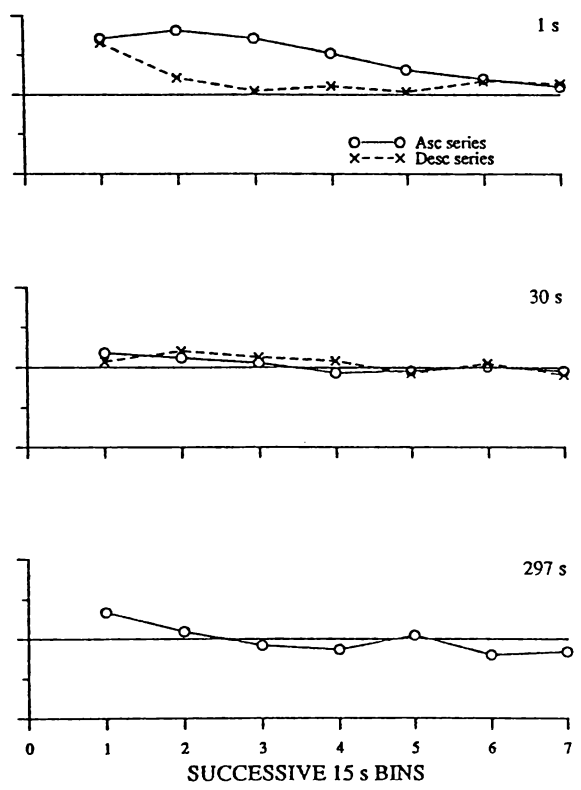
FIGURE 2.10

Values of  $a$  obtained for each successive 15-s sub-interval for both blackout durations in the ascending series together with  $a$  values obtained for equivalent conditions on the descending series. Values of  $a$  for the ascending series are represented as circles and for the descending series as crosses. Each graph shows  $a$  values obtained at one blackout duration.

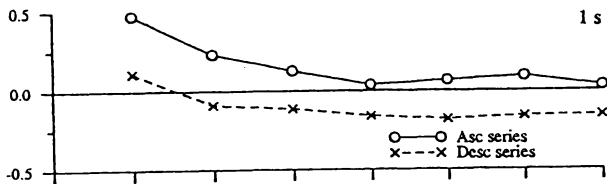
HEN 61



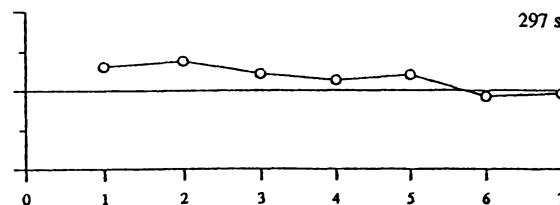
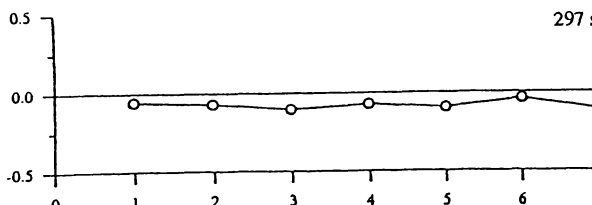
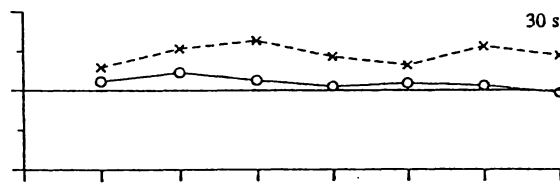
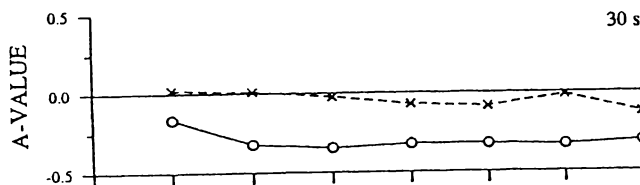
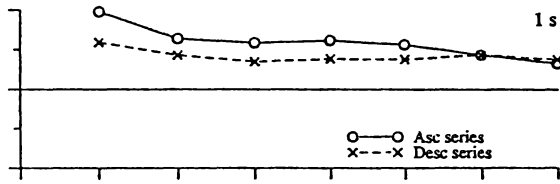
HEN 62



HEN 63



HEN 64





subintervals. Values of  $a$  obtained for Hen 66's data on both the ascending and descending series decreased across successive subintervals but the magnitude of this decrease was greater on the descending series. In general the changes in  $a$  values observed on the descending series were more similar to those observed for equivalent conditions of the ascending series than to the pattern observed when component duration was 297 s.

## DISCUSSION

The aim of this experiment was to examine further the proposition that sensitivity of behaviour on multiple schedules to relative reinforcement rate is a function of time since exposure to the alternative reinforcement rate. If multiple schedule behaviour could be described in terms of an underlying monotonic function relating sensitivity to relative reinforcement rates to time since exposure to the alternatives, as illustrated in Figure 2.0, then  $a$  values obtained would decrease as the duration of an inter-component blackout increased and then increase again as time between components was again reduced. This decrease in sensitivity as measured by  $a$  values would be predicted to occur as the result of the blackout eliminating the more reinforcement-sensitive behaviour typically observed after component alternation. The results of this experiment were examined in the light of these propositions.

### Behaviour Across Components

#### 1-s Blackout

The  $a$  values obtained for the first five conditions when the duration of the inter-component blackout was 1 s were similar to those from Experiment 1 for conditions with the longer component durations. However, for one bird's data the value of  $a$  for these conditions was considerably lower than those from Experiment 1, and overall hens, the range of  $a$  values obtained was slightly larger. The values of  $a$  ranged between 0.05 to 0.30 for conditions in this experiment with a 1-s blackout separating components and between 0.16 and 0.26 in Experiment 1 when the component duration was 120 s.

Given that the subjects were different and the component duration in the current experiment was not identical to any used in Experiment 1, such small differences between the data from experiments might be expected. When both experiments are considered, it appears that hens' performance may be less sensitive to relative reinforcement rates than that of other species. An alternative explanation offered in Experiment 1 for the low  $a$  values observed in that experiment, was that the stimulus discriminability may have been low. The stimuli used in the current experiment have been shown to

be easily discriminated by hens in a matching to sample task (Breen, 1987; Jones, 1988; Carroll, 1989; MacKenzie, 1990) hence it is unlikely that low discriminability gave rise to the low  $a$  values from this experiment. It is possible, however, that the 1-s blackout duration was sufficient to decrease the values of  $a$  in the current experiment. Thus the lower values from this experiment and Experiment 1, compared to those from other studies, may be attributed to procedural variables. However, given the similarity of  $a$  values obtained in this experiment and Experiment 1, species-related factors may be regarded as a more likely explanation.

This finding may be seen to be of particular interest as previous research has shown that when concurrent-schedule performance is examined the behaviour of hens is similar to that observed with pigeons (DeMello, 1984; Scown, 1983). Finding that hens performance on multiple schedules differs from that of pigeons may therefore be interpreted as evidence that performance on the two types of schedule is controlled by the different factors. Thus the use of the same equation to describe performance in both contexts may be misleading. Further examination of species-related factors on multiple-schedule performance may therefore be warranted. However as other procedural factors, albeit different factors in each experiment, may have led to the lower  $a$ -values, the possible influence of species differences must be regarded as speculative beyond the scope of this study.

#### Effects of Increasing Blackout Duration

In the ascending series values of  $a$  decreased for all birds' data as the inter-component blackout was initially increased. This finding supports those of Charman and Davison (1982) and Mackintosh, Little and Lord (1972). It may also be seen as consistent with the hypothesis that separating components in time is equivalent to eliminating the typically more sensitive period of responding following component alternation. That is, as the duration of blackout increased, a longer portion of the typically more reinforcement-sensitive period of responding may have been eliminated and thus measures of overall sensitivity to relative reinforcement rate would decrease. Other aspects of the data, however, suggest that the changes in  $a$  values may not be described

in terms of an underlying monotonic function relating time *per se* to sensitivity to relative reinforcement rate.

Firstly, although  $a$  values decreased as blackout duration was initially increased for four hens' data, they then increased as blackout duration was further increased. That is, for these birds' data,  $a$  values obviously did not decrease as a monotonic function of blackout duration. This finding does not preclude the possibility that increasing the duration of the blackout was equivalent to sampling progressively later portions of an underlying function relating the sensitivity of behaviour to relative reinforcement rates to time since exposure to the alternative rate. Rather the data from these birds suggest that if such a proposition were valid then the underlying function may not be monotonic. The results of a study by McSweeney (1982), which examined the effects of component duration on the magnitude of contrast, may be seen as consistent with this idea. In this study McSweeney found that the magnitude of contrast typically decreased as component duration was increased to 480 s. This result was consistent with other studies previously mentioned. However when component duration was further increased to 960 s the magnitude of contrast observed increased.

Another aspect of the data also threatens the proposal that sensitivity to relative reinforcement rate decreases as a monotonic function of time since exposure to the alternative rate. For five of the birds' data,  $a$  values not only decreased but became negative as blackout duration was increased.

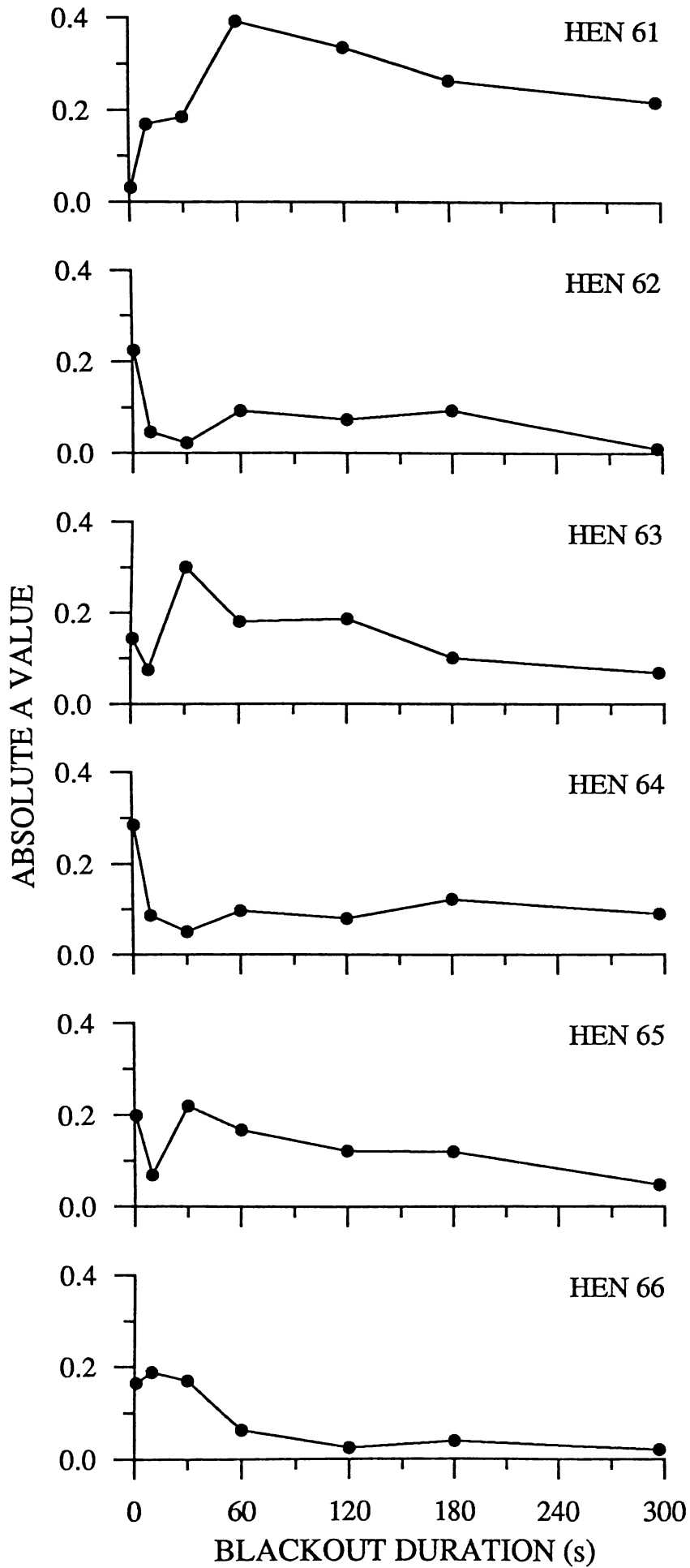
Although, in general, lower  $a$  values may be considered as representing decreased sensitivity of relative response rates to relative reinforcement rates, this interpretation can only apply where the values of  $a$  remain positive or close to zero. That is, when  $a$  values are close to 1.0 relative response rates may be described as highly sensitive to reinforcement rates in that they change in the same direction as, and to a similar degree to, changes in relative reinforcement rates. When lower but positive  $a$  values are obtained relative response rates may be described as being less sensitive to relative reinforcement rates. Behaviour does change with changes in reinforcement rates, indicating some sensitivity to relative reinforcement rates, but the change is less extreme than

would be predicted by the change in reinforcement conditions. If  $a$  values close to zero are obtained then an animals' behaviour may be described as being insensitive to relative reinforcement rates as relative response rates do not change with changes in relative reinforcement rates. However, if  $a$  values become negative behaviour cannot be described as becoming even less influenced by relative reinforcement rates. Rather, negative  $a$  values may arguably reflect similar sensitivity to relative reinforcement rates as positive  $a$  values of the same magnitude. That is, for a given change in relative reinforcement rate the changes in relative response rates observed would be of similar magnitude to changes observed given a positive  $a$  value of the same magnitude. Thus decreases in negative  $a$  values may be seen to reflect increased sensitivity of relative response rates to relative reinforcement rates.

If the changes in values of  $a$  in this study are interpreted in this manner, a different function relating the sensitivity, of relative response rates to relative reinforcement rates, to blackout duration is apparent. This function is shown in Figure 2.11 where the absolute values of  $a$  (i.e., the magnitude of the  $a$  values shown in Figure 2.3 irrespective of their direction) for all hens' data are plotted as a function of blackout duration. For Hen 61's data, the absolute values of  $a$  initially increased with increases in the duration of blackout and then decreased as blackout duration was further increased. For 63's and 65's data, absolute values of  $a$  decreased when blackout duration was increased but then increased markedly before again decreasing as blackout duration was further increased. A similar pattern, although the subsequent increase and decrease in the absolute values of  $a$  are less pronounced, is evident in Hen 62's and 64's data. For Hen 66's data, absolute values of  $a$  increased slightly then decreased as blackout duration was initially increased and then remained at a similar level as blackout was further increased. Thus sensitivity to relative reinforcement rates, defined as the extent to which response rates change given changes in reinforcement conditions, and measured in terms of the absolute values of  $a$ , does not appear to be a monotonic function of blackout duration. Moreover the relation between sensitivity to relative reinforcement rates to increases in blackout duration may be seen as less consistent across birds than the relation apparent

FIGURE 2.11

Absolute values of  $a$  for conditions in the ascending series plotted against blackout duration.



when the both the magnitude and direction of changes in  $a$  values are considered. However interpretation of the data in this manner may be misleading.

The magnitude of change in relative response rates with changes in relative reinforcement rates for negative and positive  $a$  values of the same magnitude may be the same. However the relations between relative response rates and relative reinforcement rates described by positive versus negative  $a$  values is different. Provided values of  $\log c$  are close to zero, if positive  $a$  values of reasonable magnitude are obtained, response rates on the leaner schedule of a schedule pair would be lower than those on the rich schedule. If the relative rate of reinforcement on the lean schedule was changed from for example, .2 to .4, then relative response rates would move closer to 0.5 (indifference) but response rate on the lean schedule would remain lower. If negative  $a$  values of similar magnitude are obtained response rate would be greater on the leaner schedule. If the difference between reinforcement rates on rich and lean schedules was then decreased, the relative response rates would also also move toward indifference and the change would be of the same magnitude as that observed if the  $a$  value was positive. Response rate on the leaner schedule would remain higher than response rate on the richer schedule. Thus a change from positive to negative  $a$  values represents a major qualitative change in behaviour and interpreting such  $a$  values as being different positions on a single continuum may seem questionable.

Interpreting increases in the absolute values of negative  $a$  values as indicating increased sensitivity, in the same way as increases in the magnitude of positive  $a$  values are seen as indicating increased sensitivity, is not consistent with the theory of matching underlying the GML and the interpretation of  $a$  values normally applied. Although some debate exists as to the actual process involved, as the name implies, underlying the Generalised Matching Law is the notion that animals behave so as to match approximately the amount of behaviour engaged in to the relative rate of reinforcement available for that behaviour. Such a prediction can be related to the Law of Effect proposed by Thorndike which states that behaviour which is followed by positive consequences is likely to be repeated and that behaviour followed by negative consequences

is unlikely to be repeated. The matching law may be seen as extending this law to state that behaviour followed by positive consequences more often, is likely to be repeated more than behaviour followed by positive consequences less often.

Finding positive  $a$  values of less than 1.0 is not inconsistent with this but rather may be seen as indicating that an animals' ability to match accurately, their relative response rates to relative reinforcement rates, may be limited. Undermatching may, as already discussed, relate to such things as limits on the animals ability to discriminate accurately between stimuli. However behaviour described by negative  $a$  values is clearly inconsistent with this process. That is, behaviour followed less often by reinforcement is repeated more often than behaviour associated with more frequent reinforcement. Thus behaviour described by values of  $a$  which deviate from 1.0 but remain positive may be described in terms of the same underlying process. Behaviour described by negative  $a$  values would appear to be related to relative reinforcement rates in some other way. This analysis also holds if matching is seen as the result of maximisation or melioration.

For four of the birds' data the negative  $a$  values obtained as a function of increasing the blackout duration were of a similar or greater magnitude to the positive  $a$  values obtained with smaller blackout durations. In the light of the above discussion it may be concluded that, for these hens, increasing blackout duration led to the process by which relative response rates were apparently related to relative reinforcement rates changing. Alternatively behaviour at all blackout durations may have been related to relative reinforcement rates by some process, different from that underlying the GML, which is consistent with obtaining both positive and negative  $a$  values. Some aspects of the data suggest a relation between the magnitude of the positive and the negative  $a$  values obtained consistent with such a proposition.

Although the blackout duration at which negative  $a$  values were obtained and the magnitude of the negative  $a$ s varied across birds, some orderly relations were evident. In general the lower the  $a$  values obtained when the blackout duration was 1 s, the more negative the  $a$  values became, and the greater the drop in  $a$  values

as a function of blackout duration. For example, the data from Hens 61 and 63 were described by the two lowest  $a$  values when component duration was 1 s. The  $a$  values for these two birds' data decreased to a greater extent and the magnitude of the negative  $a$  values obtained for these hens' data was greater than for the other hens' data. Similarly the  $a$  value obtained for Hen 64's data when component duration was 1 s, was higher than those for other hens. The  $a$  values for this hen's data did not decrease as much as  $a$  values for the other hens' data (with the exception of Hen 66), and did not become negative. This relation between the values of  $a$  with a 1 s blackout, the extent to which these decreased and the lowest values of  $a$  obtained was evident in the data for Hens 61 to 65.

For Hen 66 the degree of decrease in  $a$  values and the value of the lowest  $a$  value obtained showed a similar relation. However these were both smaller than would be expected, given the value of  $a$  obtained for this hens' data when blackout duration was 1 s. During the conditions with 60 s blackout this bird became ill and this may have influenced the relation between her behaviour on conditions preceding and subsequent to the illness.

Given the relation evident in the other hens' data it is reasonable to conclude that increasing blackout duration had more orderly effects than examination of the  $a$  values might suggest. That is, while the magnitude of  $a$ 's differed markedly across birds, the functions relating  $a$  values to blackout duration were remarkably similar. Thus it would seem possible that both the negative and the positive  $a$  values obtained could be described in terms of the same process and that, as such, all behaviour observed in this experiment may not be legitimately explained in terms of the GML. Even if behaviour in some conditions could be related to relative reinforcement rates in a way consistent with the matching relation implicit in the GML, behaviour in other conditions does not appear to be understandable with reference to such a process.

The continued use of Equation 4 in relation to behaviour observed in this experiment must therefore be seen as purely descriptive. The identification of an appropriate interpretation of the parameter  $a$  and the process underlying the changes in this parameter may be seen as having paramount importance. Possible interpretations of the

parameter  $a$  and the changes in  $a$  values across components will be discussed below. Examination of other aspects of the data may serve to clarify further the nature of the across component changes in  $a$ .

At this point it is worth noting that the percentages of variance accounted for (VAC) by the regression lines from which values of  $a$  were obtained were often quite low. However, the standard errors of the fits to Equation 4 were generally small indicating that this equation adequately described behaviour. The small percentages of variance accounted for may best be described as an artifact of the generally smaller changes in relative response rates, compared to the changes in relative reinforcement rates seen in this experiment. Where such a pattern of behaviour is observed, small deviations from fitted regression lines will have considerably more influence on the VAC than similar deviations when relative response rates change to a greater extent. The continued use of Equation 4 to describe behaviour may therefore be justified.

### Behaviour Within Components

#### 1-s Blackout

Instances of local positive and negative contrast as measured by  $D$  (Equation 6) were observed in all hens' data when the inter-component blackout was 1 s. This result may be seen as providing further evidence that these phenomena can occur in steady-state behaviour as found in Experiment 1 and in some previous experiments (e.g., Arnett, 1973; Catania & Gill, 1964; Hunt, 1985; McLean & White, 1981). Local positive and local negative contrast did not, always occur together, with more local negative contrast being observed than local positive contrast. This result is also consistent with those reported by others (Blough, 1983; Hunt, 1985; McLean & White, 1981; Nevin & Shettleworth, 1966 and others) but different from that found in Experiment 1. However, as found in Experiment 1, where both forms of local contrast were present, the magnitude of local negative contrast, as measured by  $D$ , was greater than that of local positive contrast.

For all birds' data, values of  $a$  decreased as a function of time since component alternation when the inter-component blackout

duration was 1 s, with the largest drop in  $a$  values occurring over the first few intervals. This result was consistent with the results obtained at long component durations in Experiment 1 and with the results of previous studies (e.g., Hunt, 1985; McLean & White (1981); White et al. (1984). Thus in general the within-component changes, in  $a$  values and response rates, on conditions with 1-s blackout were consistent with those reported in Experiment 1 and in previous studies.

#### Effects of Increasing Blackout Duration

Within-component changes in values of  $a$  obtained varied as a function of blackout duration. As blackout duration increased the within-component decrease in  $a$  values was attenuated. For three birds the changes in  $a$  values over the duration of a component, observed with 1-s blackout duration, were recovered as blackout duration was further increased.

The initial hypothesis that sensitivity of relative response rates to relative reinforcement rates would decrease as a monotonic function of time since exposure to the alternative reinforcement rate was clearly not supported by the changes in overall responding. However as previously suggested, it is possible that the behaviour observed may be described in terms of sampling different portions of an underlying non-monotonic function relating  $a$  values, whatever such values represent, to time since exposure to the alternative reinforcement rate. Examination of changes in behaviour within components allows some assessment of this possibility. For example, if this were so then the  $a$  values obtained for the first subinterval when the blackout duration was 30 s should be the same as, or very close to,  $a$  values obtained for the third subinterval when blackout duration was 1 s. (These two subintervals represent responding in a 15-s period commencing 30 s and 31 s respectively after the previous component was available).

An examination of Figure 2.8 shows that this relation does not hold. Values of  $a$  obtained for the first subinterval when blackout duration was 30 s were generally lower than  $a$  values obtained for the third subinterval when blackout duration was 1 s. The only exception to this occurred for Hen 66's data. A similar comparison

can be made between  $a$  values obtained in the first subinterval when blackout duration was 60 s, and the fifth subinterval when blackout duration was 1s. Again an examination of Figure 2.8 reveals, that for all birds data,  $a$  values obtained for the first subinterval when blackout duration was 60 s were lower than the  $a$  values obtained for the fifth subinterval when blackout duration was 1 s.

Another aspect of the data collected is also relevant. As stated on conditions with the longer blackout durations the typical pattern of changes in  $a$  values over a component was again observed in three hens data (Hens 62, 64 and 65). That is  $a$  values obtained for the first subintervals were higher than those obtained for later subintervals. This recovery of within-component changes was not necessarily related to the increases in  $a$ , for overall responding, evident in some birds' data on conditions with the longer blackout durations. For example, the within-component decrease in  $a$  values was recovered for Hen 64, and this hen showed no increase in  $a$  values for overall responding with longer blackouts. The changes in the pattern of  $a$  values over successive subintervals of components cannot therefore be explained in terms of the increases in blackout being equivalent to sampling later portions of an invariant underlying function.

Comparison of within-component changes in response rates and changes in overall response rates as a function of blackout duration confirm this conclusion. In general, response rates on the leaner schedule of a schedule pair tended to increase as a function of increasing blackout duration. Response rates on the richer schedule either stayed the same or decreased as blackout duration was initially increased, and then increased as blackout duration was further increased. These changes imply that, if increasing blackout duration was equivalent to sampling different portions of the same underlying function, response rates on a lean schedule would have to increase while response rates on the rich schedule would have to decrease or remain similar and then also increase as time since exposure to the alternate schedule increased.

The nature of within-component changes in response rates initially appear consistent with such a function. Values of  $D$  obtained indicate that response rates on a lean schedule generally increased

over the duration of a component. Response rates on the rich schedule tended to decrease over the duration of component with short blackout durations and then increase over the component with longer blackouts. On closer examination the within-component changes do not appear related to overall changes in response rates as would be predicted if such an underlying function existed.

If values of  $D$  indicate the change in response rates over different 105 s periods of the same function, then the shape of that function can be determined by examination of these values. Examination of overall response rates for each 105-s period should also allow the shape of the underlying function to be determined. If increasing the blackout duration was equivalent to sampling different portions of an underlying function, then the functions determined by changes in overall response rates and within component response rates should be the same. Examination of the data indicate that the functions suggested by the magnitude of within-component changes do not necessarily correspond with the functions indicated by the magnitude of changes in overall response rate. For example, as blackout duration increased values of  $D$  for Hen 64's data on the VI 30-s schedule of the MULT VI 120-s VI 30-s were initially negative, then close to zero before becoming positive for all blackout durations greater than 30 s. The shape of an underlying function suggested by these  $D$  values would be such that response rates on a rich schedule would first decrease then increase as a function of time since exposure to the lean schedule. Furthermore, for the values of  $D$  obtained for Hen 64's data, the actual increase in responses implied, would be such that the overall response rate for a 105 s period, 297 s after exposure to the lean component would have to be approximately 200 % that of the first 105 s. Although Hen 64's overall response rates initially decreased and then increased slightly but irregularly as blackout duration increased the percentage increase did not approach this level.

Response rates obtained on the equal schedules suggest a similar disparity between within-component changes and overall changes in response rates as a function of blackout duration. For four of the birds, overall response rates on the equal schedules increased as blackout duration was increased. Although within-component increases in response rates on both components of the equal schedule

pair were also noted, for some birds the magnitude of the within-component increases did not show any clear relation with the increases in response rates across blackout durations. For example, Hen 62's response rates on both components of the equal schedule pairs doubled as blackout duration was increased from 1 s to 120 s but very little within-component increases were noted. For Hen 65 the opposite was true.

In general the changes, in the change in behaviour observed over successive subintervals, suggest that increasing the duration of the blackout had some effect other than sampling different portions of an underlying function relating  $a$  values or response rates, to the time since exposure to alternative rate of reinforcement. Finding that any change in within-component effects are attributable to sampling different portions of an underlying function is necessary if changes in  $a$  values for overall behaviour may be so described. Thus finding that this was not the case may be interpreted as evidence that the changes in  $a$  values for overall responding discussed above, also cannot be described in terms of sampling different portions of an underlying function.

In this respect the results of this experiment support the findings of Experiment 1. That is within-component changes and, consequently, changes in responding across components, do not appear to be directly explicable in terms of an underlying function relating  $a$  values to the time since exposure to alternative reinforcement schedule. The results of the current experiment indicate that this is so even when component duration was relatively long and constant. It is also notable that, as found in Experiment 1, the within-component changes in response rates, which led to the changes in the within-component  $a$  values were variable across conditions and birds. For example, in some instances,  $a$  values did not change as a function of time in a component because response rates did not change on either the rich or the lean schedules. In others no change in  $a$  values occurred because both rich and lean schedule response rates changed in the same direction and to the same degree.

The results of Experiment 1 may be seen as similar to those obtained here with respect to one other aspect of the data. In discussing

the results of Experiment 1 it was suggested that, while behaviour observed could not be described in terms of an underlying function relating  $a$  values to time *per se*, there was some relation between overall behaviour and within-component effects. A similar conclusion may be possible here.

Quantitatively the changes in overall and within-component responding were not consistent with the blackout eliminating early portions of an invariant underlying function. However, the form of overall changes in behaviour were generally consistent with the within-component changes. For example, the overall increases in response rates on the rich schedule may arguably be consistent the hypothetical function implied by the changes in  $D$  values for rich schedule responding. However the increase in response rates was not as great as would be expected given the values of  $D$  obtained. Similarly behaviour in successive subintervals of components at longer blackout durations were, in form, consistent with changes within components with shorter blackout durations. For example, on the basis of changes in  $a$  values observed with a 1-s blackout separating components, it would be predicted that  $a$  values obtained for the first 15 s of components when the blackout duration was 30 s would be lower than those obtained in the first 15 s of components when the blackout duration was 1 s. In general this was so. However, while they were lower they were even lower than would be predicted from the within-component changes observed with shorter blackouts. The finding that the general direction, but not magnitude, of changes in overall responding and the changes typically observed within components may be related, suggests that while one phenomenon may be not be explicable in terms of the other, both may be influenced by the same variables.

However, as found in Experiment 1, even this weaker relation between overall responding and within-component changes in behaviour was not evident in all hens' data. For one bird, Hen 66, a different pattern of overall response rates was evident. For this bird response rates in both schedules increased and then decreased as blackout duration was increased. It is also worth note that for this bird's data the  $a$  values obtained for overall behaviour increased when the blackout duration was increased from 1 s to 10 s. However the within-component changes in behaviour observed in

Hen 66's data followed a similar pattern to those noted in the other birds' data. Given this it may be concluded that while within component responding and overall behaviour may be influenced by the same variables, or relate to a common process, such a relation between the phenomena will not necessarily occur. Alternatively it is possible that the apparent weak relation between overall and within-component behaviour observed in five of the hens' data was coincidental, and that the within-component effects result from a different process than changes in overall responding.

In summary for all hens' data increasing the duration of an inter-component blackout had two effects; Firstly, it decreased the values of  $a$  which described overall responding, and secondly it attenuated the change in  $a$  values across successive subintervals of components. When examined in terms of absolute response rates, the effects of blackout duration on behaviour were less consistent. As found in Experiment 1 within-component changes in  $a$  values were not related to any particular pattern of within-component changes in response rates. Although for five hens' data similar changes in overall response rates accompanied changes in  $a$  values, for the sixth bird a different pattern was observed. Similarly for five hens there was an apparent relation between the form of within-component changes in behaviour and the changes in overall responding but this relation was not evident in the other hen's data. Regardless of any relation between absolute response rates and  $a$  values, or between within-component effects and changes in behaviour across components, the effects observed were not consistent with the initial hypothesis. That is the data did not support the proposition that increasing the duration of blackout was equivalent to sampling later portions of an underlying function relating behaviour to time since exposure to alternative reinforcement rates. Alternative explanations of the results of this study must therefore be identified.

The evaluation of any explanations for the changes in  $a$  values observed in this experiment is hampered by the difficulty in interpreting the parameter  $a$ .

As discussed negative  $a$  values may be seen as indicative of a rather different relation between behaviour and the relative reinforcement

rate available for that behaviour than is indicated by positive  $a$  values. Given this, and the fact that negative  $a$  values were observed, it was suggested that the changes in values of  $a$  in this experiment may not be interpreted as indicating changes in the sensitivity of behaviour to relative reinforcement rates as it is usually understood. It was further suggested that either increasing blackout duration led to a change in the process by which animals' behaviour was apparently related to reinforcement rates, or that the process by which behaviour was related to relative reinforcement rates at all blackout durations was different from that implied by the GML. That is, behaviour on conditions with smaller blackout durations may have been influenced by the relative reinforcement rates in the component schedules as implied by the GML. At longer durations however behaviour may have been influenced by another variable. Alternatively behaviour at all blackout durations may have been influenced by some other variable.

The validity of either of these explanations relies firstly on the existence of some variable, other than the reinforcement rate associated with the other component schedule, influencing behaviour on a component of a multiple schedule. Moreover given that when behaviour is analysed in terms of the relation between relative response rates and relative reinforcement rates orderly relations were obtained, such a variable must itself vary with relative reinforcement rates. Secondly these explanations also imply that blackout duration influenced the effect of this other variable on behaviour. Thus the first step in validating any of these options must be to identify some other variable which may influence behaviour.

One such variable may be extraneous reinforcers available for behaviour other than the defined operant. It is generally accepted that even in the relatively controlled situation of an experimental chamber, extraneous reinforcers beyond the control of the experimenter may be available to an animal (Herrnstein, 1970; Staddon, 1982). Such reinforcers may be available for behaviours other than the defined operant, such as scratching, wing flapping etc. Furthermore it has been suggested that on single schedules an animal may allocate its responding between such other behaviours and the operant behaviour on the basis of the relative rate of

reinforcement for other behaviour (Herrnstein, 1970). If reinforcement rate for other behaviour was such that it remains relatively constant, regardless of the schedule in operation, then it would be predicted that as reinforcement rate for the operant behaviour increases, the operant response rate should increase. Thus responding influenced by this variable might be expected to show some relation to relative reinforcement rates.

To foreshadow future discussion, several theories of multiple schedule behaviour also propose that reinforcers for extraneous behaviours influence responding on multiple schedules. Several of these suggest that other behaviour and/or reinforcers available for that behaviour serve a major role in determining the relation between relative reinforcement and response rates. Thus the rate of extraneous reinforcement may be considered promising as a possible variable contributing to the  $a$  values observed in this study. In terms of the explanations offered above it appears that at least one variable, other than reinforcement rate for the defined operant responses, which may influence behaviour can be identified.

However, as already stated, to explain the results of this experiment, either the salience of extraneous reinforcers, the functional relation between extraneous reinforcement rate and response rate, or the rate of extraneous reinforcement must also change as a function of blackout duration. Thus, further examination of what function increasing the duration of blackout had, may be considered necessary.

It might be predicted that, given a long period of time between exposures to alternative reinforcement rates, such as when the blackout duration was increased, each component schedule may become similar to a single VI schedule. The proposition that increasing blackout duration led to the component schedules becoming effectively single schedules can be seen as consistent with the first of the explanations offered to explain the nature of the changes in values of  $a$ . That is, this notion implies that the variable influencing  $a$  values changed when blackout duration was increased. When blackout duration was short behaviour on each component may be described as being influenced by reinforcement rate in that component relative to reinforcement rate in the other. As

blackout duration increased, such that each component was effectively a single schedule, reinforcement rate in the other component would be seen to have no effect on behaviour. In these conditions behaviour on each component might instead be described in terms of the relative frequency of reinforcement available for the defined operant response in that component and the reinforcement rate for other behaviour (Herrnstein, 1970).

Some aspects of the data may be seen as consistent with the proposition that with long blackout durations the component schedules became equivalent to single schedules. The differences between response rates typically observed on single schedules over the range of VI schedules used in this study tend to be relatively small (e.g., Catania & Reynolds, 1968). Thus the relation between relative response rates on two single VI schedules, within this range, to their relative reinforcement rates would be described by low, although positive,  $a$  values. The decreases in  $a$  values obtained in as far as they remained positive, or close to zero, might therefore be seen as consistent with the components of the multiple schedules becoming similar to single schedules.

It is not however clear how such an effect might led to negative  $a$  values. Negative  $a$  values could be predicted if response rates on single VI schedules were such that response rates were higher on leaner schedules than on richer schedules. Although typically response rates on a single VI schedule decrease as the inter-reinforcement time increases, some variability in this function has been noted. Several studies have reported that response rate on very rich schedules may occasionally be lower than response rate on slightly leaner schedules (Bradshaw, Ruddle & Szabadi, 1981; Dougan & McSweeney, 1985 and others). Although the richness of the schedules at which these effects have been observed has been found to vary across birds, such effects tend to be associated with schedule parameters more extreme than those used in this study. However, in one study by Pear and Rector (1979), response rates for one of the three birds used increased when the reinforcement rate in single VI schedules was changed from VI 60 to VI 300. Thus it is possible that the negative  $a$  values could occur if each component became similar to a single VI schedule and the

hens' behaved like one of the Pear and Rector's subjects and unlike most others.

Other aspects of the data are not easily explained in terms of this proposition. For example the possibility that behaviour is influenced by one variable at some blackout durations and another at others may seem unlikely given the relation between the positive and the negative  $a$  values obtained and that the change from positive to negative  $a$  values observed for some birds was gradual. It could be argued that a gradual change could occur if at intermediate blackout durations behaviour for part of a component was influenced by reinforcement rates in an alternate component, while for later portions behaviour was influenced only by the reinforcers available in that component. However this explanation requires  $a$  values to change within components. While at shorter blackout durations such changes occurred these changes were not observed across all blackout durations where values of  $a$  for overall responding did change.

An alternative function of the increase in blackout duration is apparent if the other interpretation of the changes in  $a$  values, offered above, is considered. Behaviour at all blackout durations may be related to some variable other than relative reinforcement rate in the two components. That is, behaviour on each component of the multiple schedules, at all blackout durations, may be influenced only by the rate of extraneous reinforcement and the reinforcement rate for the defined operant response, in that component. Such a proposal underlies one theory of multiple schedule performance previously proposed (McLean & White, 1983). Rather than considering the effect of blackout on the relation between the two schedules, the effect of blackout on each schedule might then be examined.

Reynolds (1961a), Sadowsky (1973) and Taus and Hearst (1970) demonstrated that, within the behavioural contrast paradigm, if a VI schedule was alternated with a period of blackout and/or TO, response rates on the VI schedule increased. Taus and Hearst further showed that the magnitude of the increase in response rates was a direct function of the duration of the blackout. Increasing the blackout duration tended to lead to similar increases in response rates in this experiment. In this respect therefore the results of this experiment may be seen as consistent with the idea

that changes in behaviour as a result of increasing blackout duration may be explained in terms of the effects of blackout on each component. Such effects may also be explained in terms of the effects of blackout on reinforcement for other behaviour.

Although the mechanism by which such changes occur differ between the theories three existing theories of multiple schedule performance (Davison & McCarthy, 1988; McLean & White, 1983; Staddon, 1982) have suggested that behaviour on multiple schedules may be related to the distribution of other behaviour. In the context of the current analysis, changes in behaviour as a function of blackout duration may be related to the re-distribution of other behaviour from a component into the blackout. Such an analysis is consistent with the increase in response rates generally observed. This analysis does not explain how the changes in behaviour with changes in blackout may lead to negative  $a$  values being obtained.

The notion of response strength outlined by Nevin (1974, 1988) and Nevin, Mandell and Atak (1983) suggests an alternative way in which  $a$  values observed may be attributed to the effects of blackout duration on responding in each component.

According to Nevin and his associates' proposal, behaviour may be seen as having two properties, mass and velocity. Resistance to changes may be seen as analogous to mass and response rate as analogous to velocity. Of particular interest is the property of mass. In his model mass is seen to be influenced by reinforcement rate such that behaviour maintained by higher rates of reinforcement will be more resistant to change. Thus, in the presence of some disrupter, behaviour maintained by higher rates of reinforcement will change less than behaviour maintained by lower rates of reinforcement. Although not explicitly suggested by Nevin in this analysis the relative richness of a schedule may be defined in terms of the reinforcement rate for the operant response relative to reinforcement rate for other behaviour. If reinforcement rate for other behaviour remains constant, then relative reinforcement rate for the operant response in the component associated with the less frequent reinforcement may still be defined as leaner than the schedule with the higher frequency of reinforcement. In a number of experiments Nevin (1974) and Nevin et al. (1983) demonstrated that

behaviour maintained by higher rates of reinforcement decreased less or at a slower rate or with larger values of a given disrupter than behaviour maintained by leaner schedules.

Unfortunately, while Nevin and his associates examined a number of different disrupters, all those examined decreased response rates. Nevertheless it may seem reasonable to assume that such effects may be generalisable to disrupters that increase response rates. That is, if a variable which increased response rates was applied equally to behaviour maintained by rich and lean schedules, then response rate on the lean schedule might be expected to increase to a greater extent, or with smaller values of the disrupter, than response rates maintained by the rich schedule. The results of one study examining behavioural contrast may be seen as supporting this proposition. Spealman and Gollub (1974) carried out a study where in one set of conditions a MULT VI 30-s VI 30-s schedule was changed to a MULT VI 60-s Ext and in another a MULT VI 180-s VI 180-s was changed to a MULT VI 180-s EXT. In this study response rates during the constant VI schedule increased when the other component was changed to extinction, but the increase in response rates was greatest on the relatively lean VI 180-s schedule.

The results of this study are not easily interpreted in terms of relative reinforcement rates across components. However if changing one component of a multiple schedule to extinction is seen as applying a disrupter to behaviour, then the results may be seen as evidence that applying a disrupter, which increases behaviour to a rich and lean schedule, will result in greater change in the lean schedule.

Similarly, in the current experiment, increasing the duration of blackout generally increased response rates on both components, but the increase was greater on the lean schedule. The increase in  $a$  values at the longer blackouts may also be seen as consistent with this notion. That is the increased  $a$  values obtained at longer component durations appear to be a result of the rich schedule response rate increasing but this increase not occurring until the blackout duration was longer than that which produced consistent response rate increases in the lean schedule.

The changes in  $a$  values observed may thus be seen as a by-product of the effects of blackout duration on responding in each schedule. The apparent relation between relative response rate and relative reinforcement rates in the components may be seen to be a result of the relation between reinforcement rates and mass.

One reservation must however be applied to this analysis. The disrupters discussed by Nevin were generally such that they were applied for short periods after a stable baseline of behaviour presumably controlled by relative reinforcement rates was established. A sudden increase in blackout might be seen as a disrupter. However, the data presented here represent stable performance obtained after continued exposure to a particular blackout. At each blackout, reinforcement rates which are hypothesised to affect mass were changed, while blackout remained constant. That is, in most conditions the postulated disrupter (the increase in blackout duration) was presented before variables proposed to influence mass were changed. Thus some doubt may be placed on whether the increases in blackout with this procedure could be considered as disrupters.

Alternatively, the blackout in this study may be interpreted as a third multiple-schedule component. With such an interpretation the increases in response rates with increases in the duration of blackout may be seen to be consistent with studies which have found that the magnitude of contrast increased with increases in the duration of a lean component (e.g., Coelho de Rose, 1986; Taus & Hearst, 1970 and Wilton & Clements, 1971). One aspect of the data may be seen as inconsistent with this interpretation. If the blackout was similar to a third but lean component it would be predicted that within-component changes in the VI components would be similar in form. That is both VI schedules would effectively be rich in comparison to the blackout component which preceded and followed them.

Although for several birds within-component response rate changes in each component were in the same direction, they were in the opposite direction from that which would be predicted. If both schedules were relatively rich, then response rates would be expected decrease over the duration of a component (values of  $D$  should be negative).

As indicated by the positive values of  $D$ , response rates tended to increase over the duration of the component. However, given that some other studies (e.g., Buck, Rothstein & Williams, 1975) have found that response rates on rich schedules increase as a function of time since component alternation, it may still be possible to interpret the blackout as a third and leaner component. However given this interpretation of the blackout an alternative explanation of the negative  $a$  values must be found. While it is conceivably possible to explain negative  $a$  values in terms of changes in reinforcers for extraneous behaviour within such a framework, to do so maybe seen as requiring a number of assumptions which are not verifiable given the data obtained from this experiment. It is however worth noting that the increase in the magnitude of contrast with increases in the duration of a lean component may be related to the effects observed here.

The preceding discussion suggests some ways in which the data from this experiment may be reconciled with those of other studies and the somewhat unexpected results (i.e., negative  $a$  values ) may be explained. Other explanations consistent with various theories of multiple schedule behaviour are also possible. However one major reservation must be placed on the data examined and should be addressed before conclusions regarding the possible mechanisms underlying the effects may be made.

The  $a$  values obtained for overall responding when the duration of the inter-component blackout was 1 s and 30 s in the ascending series were not replicated in the descending series. For some birds  $a$  values from the first determination at a particular blackout duration were higher than those from the second set of conditions at that duration. For other birds they were lower. In general the  $a$  values obtained during the descending series were closer to those obtained when blackout duration was 297 s than they were to those obtained for the same duration on the ascending series.

One explanation of these findings is that the results of this experiment were confounded by hysteresis. The use of frequent schedule reversals allow some assessment of short-term hysteresis effects as measured by the response differentials and none were consistently observed. It is worth note that on the ascending

series the response differentials for some birds data did differ notably between the first and second conditions involving the same schedules. However as the difference between the response differentials were not consistently related to whether the condition was the first or second involving a schedule pair, such differences may be interpreted as bias. Examination of the values of  $\log c$  obtained confirms that bias did increase as blackout duration was reduced.

While the results did not evidence short-term hysteresis the failure to replicate the results of the descending series could be explained in terms of the long-term hysteresis discussed in Experiment 1. That is, as the number of prior conditions increased, responding could be described as becoming closer to the average rate of responding observed in previous conditions associated with a particular stimulus rather than to the particular reinforcement schedule in effect. Other studies involving VI schedules either singly, or successively in a compound schedule have also reported poor replications of early conditions (e.g., Ortega & Marcucella, 1987; Pear & Rector, 1979; Pear & Wilkie, 1971; Williams, 1989).

If long term hysteresis were present it becomes difficult to interpret the results. For example, it is unlikely that the negative  $a$  values resulted from such hysteresis, but it is possible that the increase in values of  $a$  observed in later conditions may have been. In general any conclusion made relating to other findings in the data must be viewed with caution and the need to replicate the results observed must be considered a priority.

## EXPERIMENT 3

In Experiment 2, the values of  $a$  describing both overall and within-component responding changed as a function of increasing blackout duration. Analysis of these changes suggested that patterns of behaviour observed were inconsistent with the hypothesis that values of  $a$  could be described in terms of an invariant negative monotonic function relating  $a$  values to time since exposure to the alternative rate of reinforcement. These results may be seen as similar to those of Experiment 1. In that experiment the changes in behaviour observed when component duration was reduced also were inconsistent with the existence of an underlying function relating sensitivity to relative reinforcement rates with time *per se* independent of component duration.

The results of these two experiments thus clearly indicate that the initial hypothesis presented in this dissertation has limited validity. However identifying an alternative explanation of these results was hampered by difficulties in interpreting the parameter  $a$ . Although several possibilities were suggested, the failure in Experiment 2 to replicate the results obtained in the initial conditions, when blackout duration was increased (the ascending series), when blackout duration was subsequently reduced (the descending series) make the assessment of the relative merits of these or other explanations difficult.

One explanation suggested for this failure to replicate the data obtained in the ascending series was that the values of  $a$  obtained were influenced by the number of previous conditions. As previously discussed other studies of multiple-schedule and concurrent-schedule performance have reported that values of  $a$  decline as a function of the number of prior conditions (McSweeney, et al. 1986; Todorov et al., 1983; Williams, 1989). In previous experiments of this dissertation this effect has been termed long-term hysteresis to distinguish it from hysteresis effects observed where the immediately preceding condition influences performance. While long-term hysteresis may be a phenomenon worth further study its possible appearance in Experiment 2 limits any conclusion regarding the effects of blackout duration, a primary concern of this dissertation.

This next experiment, therefore, attempted to replicate the results obtained in that experiment but with a different procedure designed to limit the number of conditions examined.

Two obvious methods of reducing the number of conditions examined are to reduce either the number of blackouts examined or the number of schedule pairs at each blackout duration. While the use of two schedule pairs is sufficient to obtain estimates of the parameters of the GML, the use of more schedule pairs has the advantage of enabling a measure of the goodness of fit of the data to this equation, to be determined. The use of fewer blackout durations may be considered a better option. However given that the effects observed in Experiment 2 occurred at different blackout durations for each hen a reasonable range of blackout durations must be examined. An alternative method of reducing the number of conditions which has been used in other studies is to include more than one value of the manipulated variable in a single session. For example, as previously reported, several studies of the effects of stimulus similarity on multiple-schedule performance included several stimuli associated with component schedules within sessions (e.g., Farthing, 1974 and White, Pipe & McLean, 1984). That is each of the two component schedules were associated with several stimuli and, although with each successive presentation of a component only one of these stimuli was presented, in the course of a session all stimuli were presented at some point.

A slightly different procedure was used to examine the effects of various procedural variables on concurrent schedule performance in hens by Hatton (1990) and Phillips (1990). In these two studies a multiple-concurrent schedule was used where hens were exposed to two concurrent schedules presented successively in each session. Data from these studies indicated that animals behave differentially according to the particular procedure in each of the concurrent schedules and that the results were comparable with studies which used the more traditional methodology. A similar procedure was therefore used in this study.

Hens were exposed to multiple-multiple (MULT MULT) schedules where the reinforcement rates in the component schedules of each of the five multiple schedules were different. To facilitate

discrimination, each of the five multiple schedules was associated with a different key. Each of these keys also had a different symbol painted on it. The duration of a period of blackout inserted between component alternations in each of the multiple schedules was varied across conditions. This design was considered preferable to other options as it enabled estimates of the parameters of the GML to be made while also minimising the chance that behaviour on one multiple schedule would be influenced by conditions operating in another multiple schedule. Given however, that the effects of this procedure on multiple-schedule performance without a blackout separating components was unknown, the first set of conditions compared performance on the multiple-multiple procedure with performance of the same hens on a traditional procedure.

## METHOD

### Subjects

#### Phase I

Six hens numbered 21 to 26 served. Three of these hens, 21 to 23 were experimentally naive and the other three had been subjects in undergraduate laboratory class where they had exposure to several simple schedules. All hens were maintained at 80 (+/-10)% of their free-feeding bodyweight by supplementary feeding at the end of each experimental session. Water was continuously available in their home cages and grit was occasionally provided.

#### Phase II

Hens 21, 22 and 25 served.

### Apparatus

#### Phase I

The apparatus used was similar to that used in Experiments 1 and 2 except that the experimental chamber had five response keys. These keys were sited 300mm from the grid floor 52mm apart. Each key had a different symbol painted on it. These were; a horizontal line, a vertical line, a cross, an open circle and an S. All keys could be illuminated by a red (S1) or green (S2) light.

#### Phase II

During the first condition of this phase the same apparatus used in Phase I was employed. In the subsequent conditions two experimental chambers, identical to that used in Phase I were used and experimental events were programmed and data recorded using MED-PC software running on a Commodore PC10-III computer. Experimental data were stored on the hard disc of this computer. In both chambers pecks to lighted keys caused a tone to sound for 35 ms but the keylight remained on.

## Procedure

The naive subjects were trained to feed from the raised hopper and then to peck a lighted centre key. After this training the first experimental phase was commenced.

### Phase I

This phase consisted of six conditions. Three hens (Hens 21, 22 and 23) were exposed to Condition 1 and then to Conditions 2 to 6. The remaining hens were exposed to Conditions 2 to 6 and then to Condition 1. In all conditions each key was associated with a multiple schedule consisting of two components which alternated successively every 60 s. One component was associated with S1 and the other with S2. The reinforcement schedules associated with each key differed and were in order from the leftmost to rightmost key: MULT VI 120-s VI 30-s; MULT VI 30-s VI 120-s; MULT VI 48-s VI 48-s; MULT VI 27-s VI 216-s and MULT VI 216-s VI 27-s.

Condition 1: Multiple-Multiple. Each experimental session consisted of one successive 10 minute exposure to each of the five multiple schedules. Multiple schedules were always presented in the same order and this order was based on key location with the multiple associated with the leftmost key being presented first and that associated with the rightmost key last. A 120-s period of blackout separated the completion of one multiple schedule and the start of the next. This condition remained in effect until the stability criterion outlined in Experiment 1 was met for all birds on all multiple schedules.

Conditions 2 to 6: Traditional procedure. In each of these five conditions one key and its associated multiple schedule was available and other keys were dark and inoperative for the entire 30 minute session. The multiple schedules in effect on each condition were in order of occurrence: VI 120-s VI 30-s; VI 30-s VI 120-s; VI 48-s VI 48-s; VI 27-s VI 216-s and VI 216-s VI 27-s. Conditions were changed when the stability criterion outlined in Experiment 1 was met by all birds.

## Phase II

In the first experimental condition of this phase each component of each of the multiple schedules was preceded and followed by a 1 s period of blackout. In subsequent conditions the duration of the blackout was varied. The duration of blackouts were in order of presentation 1 s, 30 s, 60 s, 0 s and 120 s. On the first of these conditions each hen had an experimental session every alternate day. For the remaining conditions experimental sessions were conducted daily with the exception that hens did not have an experimental session if their weight exceeded 90% of their free-feeding bodyweight.

Table 3.1 gives for both phases the blackout duration, reinforcement schedules and minimum number of training days on each condition.

In all conditions of both phases the number of responses made, the number of reinforcements obtained in each component schedule and the time each component was available were recorded. In addition the number of responses made in each successive 15-s subinterval of each component were recorded.

Table 3.1 The blackout duration, reinforcement schedules and the minimum number of training days on each condition of both phases.

Condition	VI Schedules (in seconds)	Blackout Duration	Days
PHASE I			
1	VI 120 VI 30; VI 30 VI 120; VI 48 VI 48; VI 27 VI 216; VI 216 VI 27	0	32
2	VI 120 VI 30	0	44
3	VI 30 VI 120	0	24
4	VI 48 VI 48	0	17
5	VI 27 VI 216	0	39
6	VI 216 VI 27	0	21
PHASE II			
7	VI 120 VI 30	1	26
8	VI 30 VI 120	30	56
9	VI 48 VI 48	60	27
10	VI 27 VI 216	0	46
11	VI 216 VI 27	120	39

## RESULTS

The total number of responses made and reinforcers obtained in each component, the total time each component was available and the number of responses made in successive 15-s subintervals of each component for all hens in the last five days of each condition are given in Appendix 3.1. All following analyses were based on these data. Analyses were similar to those used in Experiments 1 and 2 with the exception that parameters of the GML were determined using the means of the last five days data. This was necessary as on a number of occasions at least one of the hens obtained no reinforcements in one component of one of the multiple schedules.

### Phase I

#### Behaviour Across Components

##### Response Rates

Figure 3.1 shows the response rates on both components of each schedule pair (presented in the order of exposure). Plusses (+) indicate response rates obtained for Conditions 2 to 6 (traditional procedure) on the richer schedule of each schedule pair and open squares indicate the response rates obtained for the corresponding schedules on Condition 1 (MULT MULT procedure). Crosses (x) represent response rates on the leaner schedule of each schedule pair obtained using the traditional procedure, and open circles the response rates obtained for the corresponding schedules for Condition 1. For the equal schedule pairs, response rates on the component associated with S1 are indicated by plusses (traditional procedure) and open squares (MULT MULT procedure). Response rates on the component associated with S2 are shown as crosses (traditional procedure) and open circles (MULT MULT procedure).

This figure shows that there were no consistent differences in response rates obtained on each component schedule between the traditional and MULT MULT procedures. Hen 22's response rates on both components of each schedule pair tended to be higher on the MULT MULT procedure (circles and squares) than response rates on corresponding schedules when the traditional procedure was employed.

FIGURE 3.1

Response rates on both components of each schedule pair (presented in the order of exposure).

Plusses (+) indicate response rates on the richer schedules on Conditions 2 to 6 (traditional procedure).

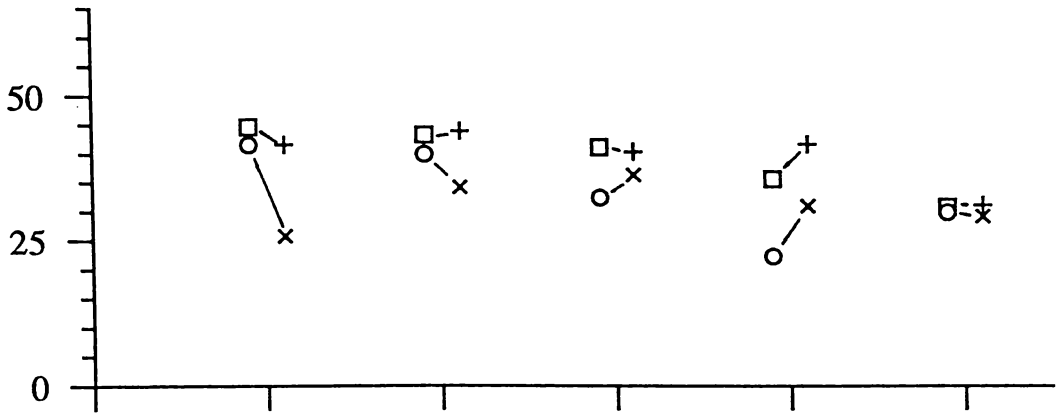
Open squares indicate the response rates on the richer schedules for Condition 1 (MULT MULT procedure).

Crosses (x) indicate response rates on the leaner schedules for Conditions 2 to 6 (traditional procedure).

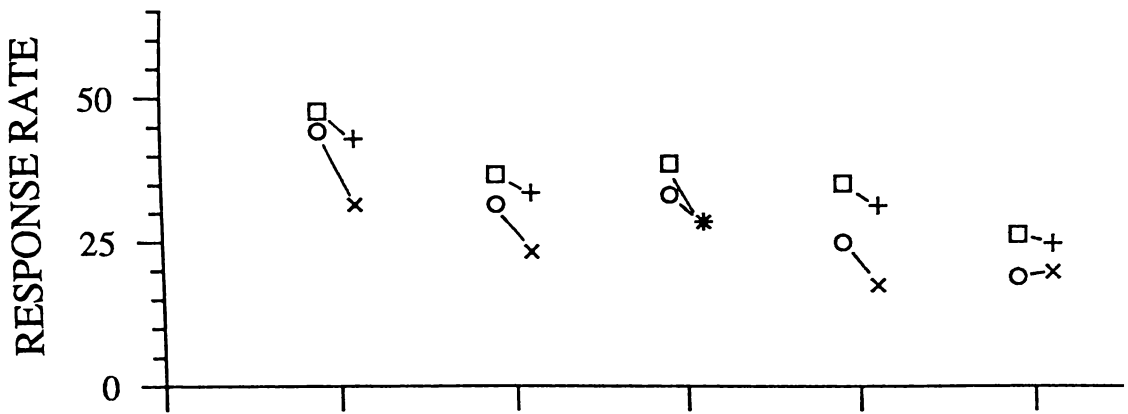
Open circles indicate response rates on the leaner schedules for Condition 1 (MULT MULT procedure)

For the equal schedule pairs response rates on the component associated with S1 are indicated by plusses (traditional procedure) and open squares (multiple-multiple procedure). Response rates on the component associated with S2 are shown as crosses (traditional procedure) and open circles (multiple-multiple procedure).

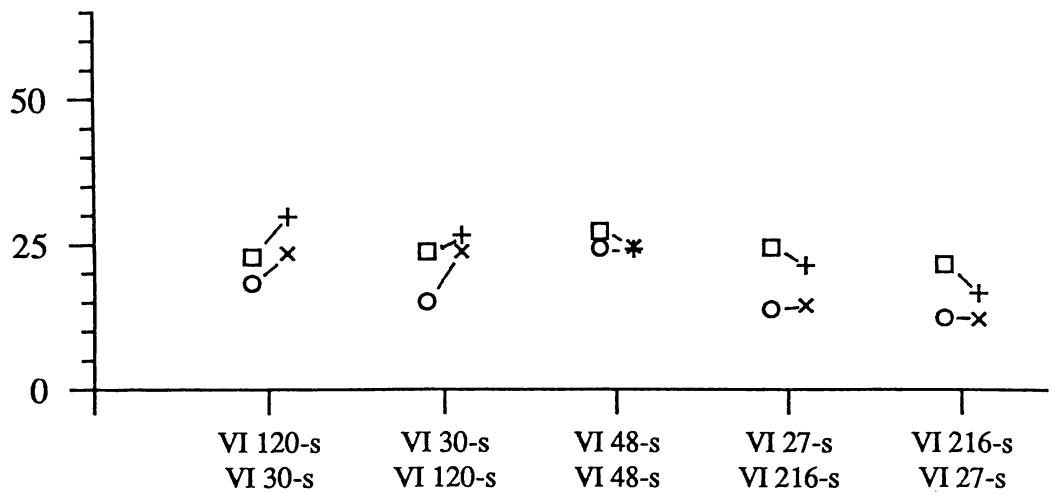
### HEN 21



### HEN 22

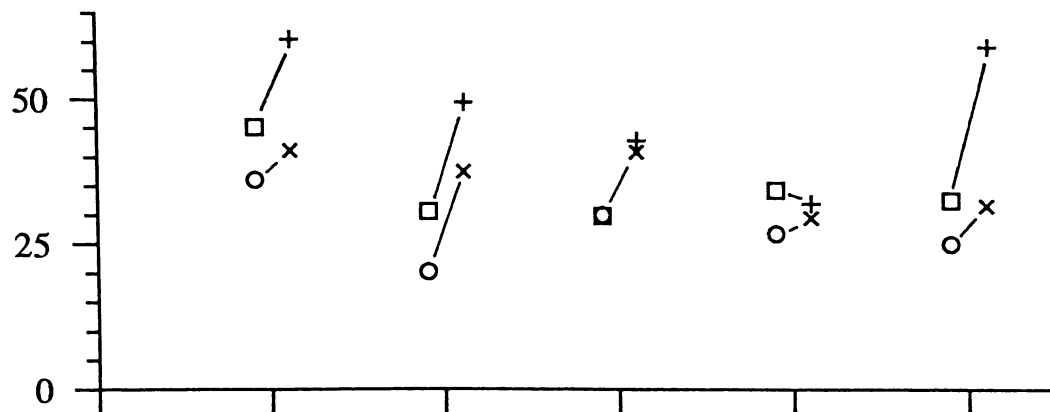


### HEN 23

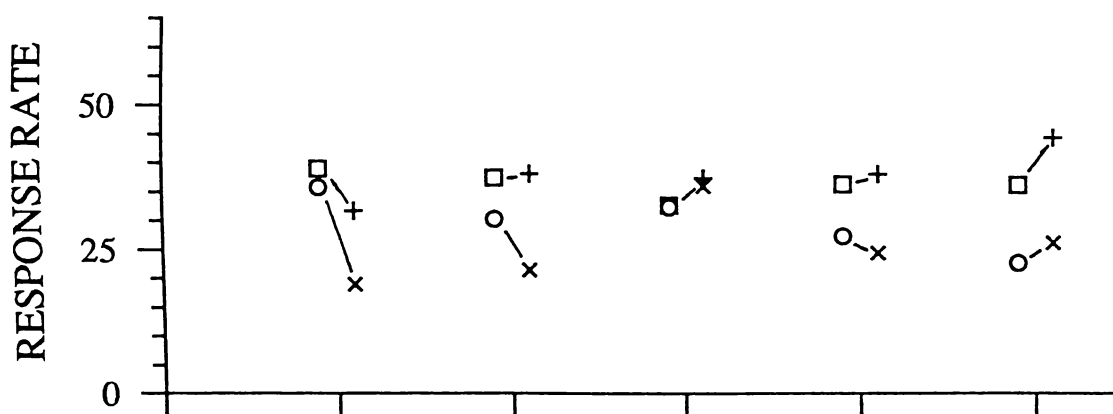


SCHEDULE PAIR

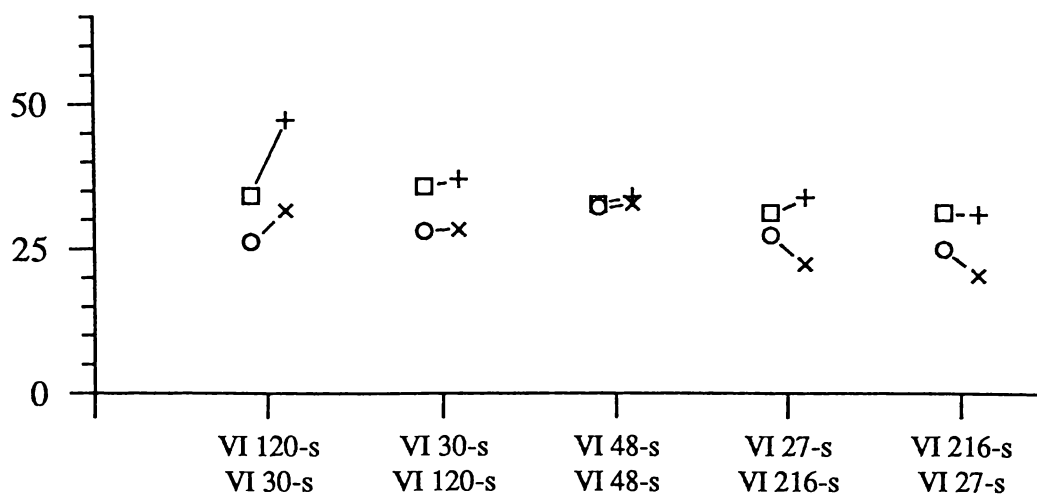
### HEN 24



### HEN 25



### HEN 26



SCHEDULE PAIR

Conversely, Hen 24's response rates on conditions using the traditional procedure (plusses and crosses) tended to be higher than on corresponding conditions with the MULT MULT procedure. For the remaining hens the differences between response rates obtained for the two procedures varied across schedule pairs. For both procedures response rates on the richer component of the schedule pairs (plusses and squares) were higher than response rates on the leaner (crosses and circles) for all hens. For Hens 23, 24, 25 and 26, response rates on both components of the equal schedule pair were similar. For Hens 21 and 22, response rates on the schedule associated with S1 (squares) were higher than those obtained on the schedule associated with S2 (circles) on the MULT MULT procedure. For Hens 21, 22 and 26 response rates on multiple schedules presented later tended to be lower than response rates on multiple schedules presented earlier.

In order to determine if the schedules in effect in the previous multiple schedule of the MULT MULT procedure influenced responding, the response differentials for each schedule pair, and its reversal, were calculated. No consistent differences in the response differentials as a function of whether the multiple represented the first or second schedule involving a particular schedule pair were found. However, the higher response rates found on the schedule associated with S1 of the equal schedule pair for Hens 21 and 22 outlined above, suggest that the preceding condition may have had some effect. That is, S1 was associated with the richer schedule on the preceding condition. Although only small differences in equal schedule responding were noted in the other birds' data, where differences occurred, they were in the same direction as those observed for Hens 21 and 22.

A similar analysis was carried out for the data obtained with the traditional procedure. For Hens 21, 22 and 23, Conditions 2 to 6 (the traditional procedure) followed Condition 1 (the MULT MULT procedure). The response differentials for these hens on the second condition involving the same schedule pair were lower than on the first condition with that pair. That is, the response differential was greater on Condition 2 than Condition 3 and on Condition 5 compared to Condition 6. For the remaining hens no consistent differences in the response differentials as a function of whether

the condition represented the first or second condition involving a particular schedule pair were found. Any difference in the response rates on the equal schedule pair were also such that response rates were higher on the schedule associated with the higher reinforcement rate in the previous condition (S1).

### Generalised Matching Law Analysis.

Table 3.2 gives, for all hens, the intercepts (values of  $\log c$ ), slopes (values of  $a$ ), standard errors and percentage of variance accounted for by regression lines fitted by the method of least squares to the data obtained from the five schedule pairs, for both procedures. The variance accounted for by the regression lines ranged from 66.7% to 97.1% for the traditional procedure and from 65.6% to 91.6% for the MULT MULT procedure. For five of the six hens the variance accounted for by the regression lines was greater for data obtained with the traditional procedure. The standard errors of the estimates ranged from 0.024 to 0.090 for the traditional procedure and from 0.037 to 0.087 for the MULT MULT procedure. The standard errors obtained with the two procedures were not consistently different across hens.

Values of  $a$  for data from the traditional procedure ranged from 0.15 for Hen 23 to 0.29 for Hen 25 and for data using the MULT MULT procedure from 0.10 for Hen 21 to 0.19 for Hen 23. For five hens' data (Hens 21, 22, 24, 25 and 26)  $a$  values for the MULT MULT procedure were lower than those for the traditional procedure. Values for  $\log c$  obtained were generally small and did not vary consistently across the two procedures.

## Behaviour Within Components

### Response Rates

Figure 3.2 shows for the two procedures, response rates for each successive 15-s subinterval of both components of each schedule pair. Points connected by solid lines represent response rates obtained on the multiple multiple and those connected with a dashed lines response rates obtained on conditions with the traditional procedure. Squares and plusses represent response rates on the

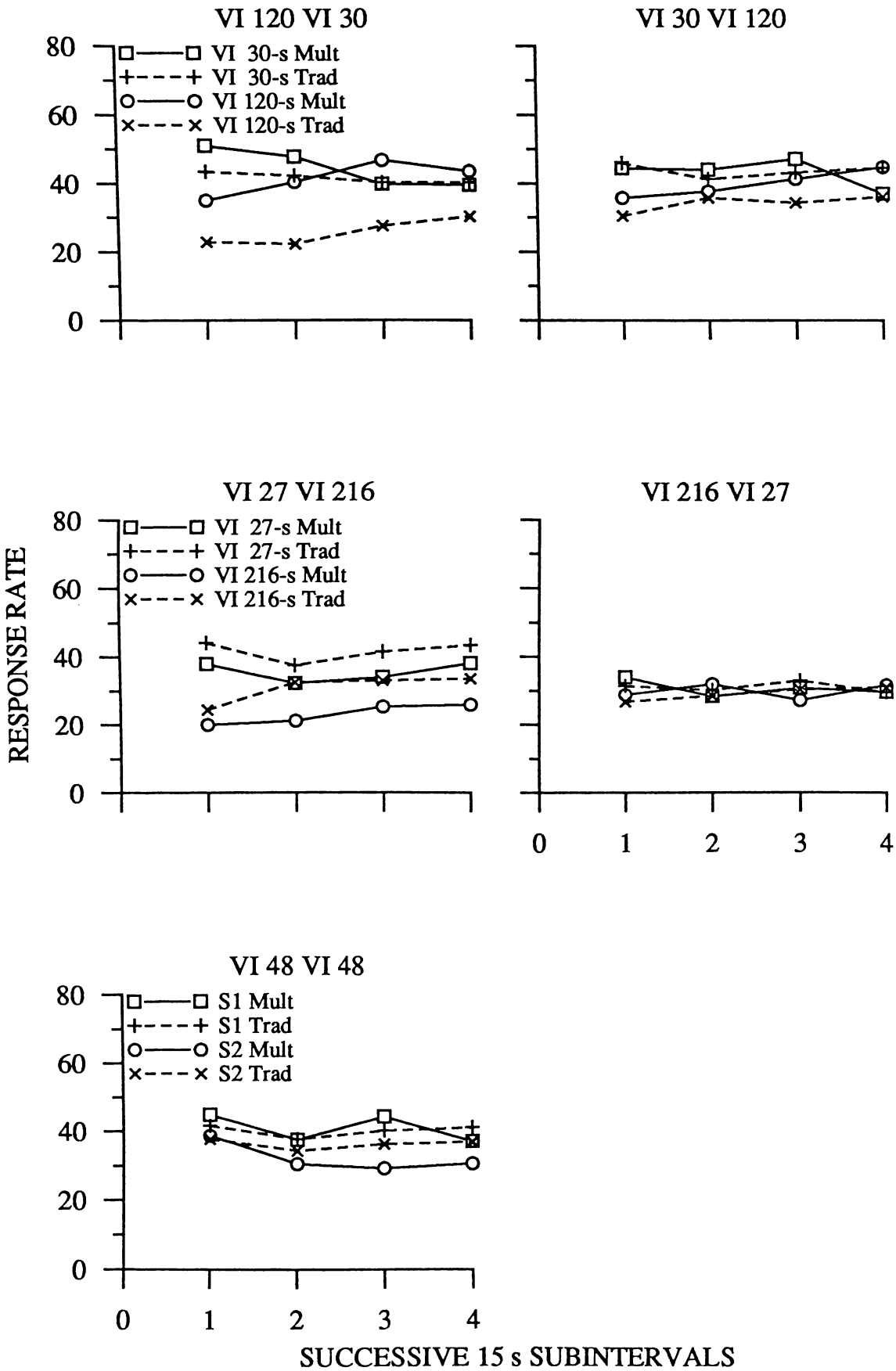
TABLE 3.2. The intercepts (values of  $\log c$ ), slopes (values of  $a$ ), percentage of variance accounted for (VAC) and standard errors (S.E) of the fits of regression lines fitted by the method of least squares to the data obtained from the five schedule pairs for both procedures.

Hen	Procedure	$\log c$	$a$	S.E	VAC
21	Traditional	0.01	0.17	0.090	66.7
	MULT MULT	0.07	0.10	0.059	71.2
22	Traditional	0.03	0.20	0.054	92.1
	MULT MULT	0.02	0.11	0.037	91.6
23	Traditional	-0.01	0.15	0.024	97.1
	MULT MULT	0.04	0.19	0.076	89.0
24	Traditional	-0.05	0.21	0.081	81.1
	MULT MULT	0.01	0.14	0.086	66.8
25	Traditional	-0.01	0.29	0.069	92.9
	MULT MULT	0.04	0.13	0.087	65.6
26	Traditional	-0.01	0.21	0.037	96.3
	MULT MULT	0.02	0.11	0.040	86.9

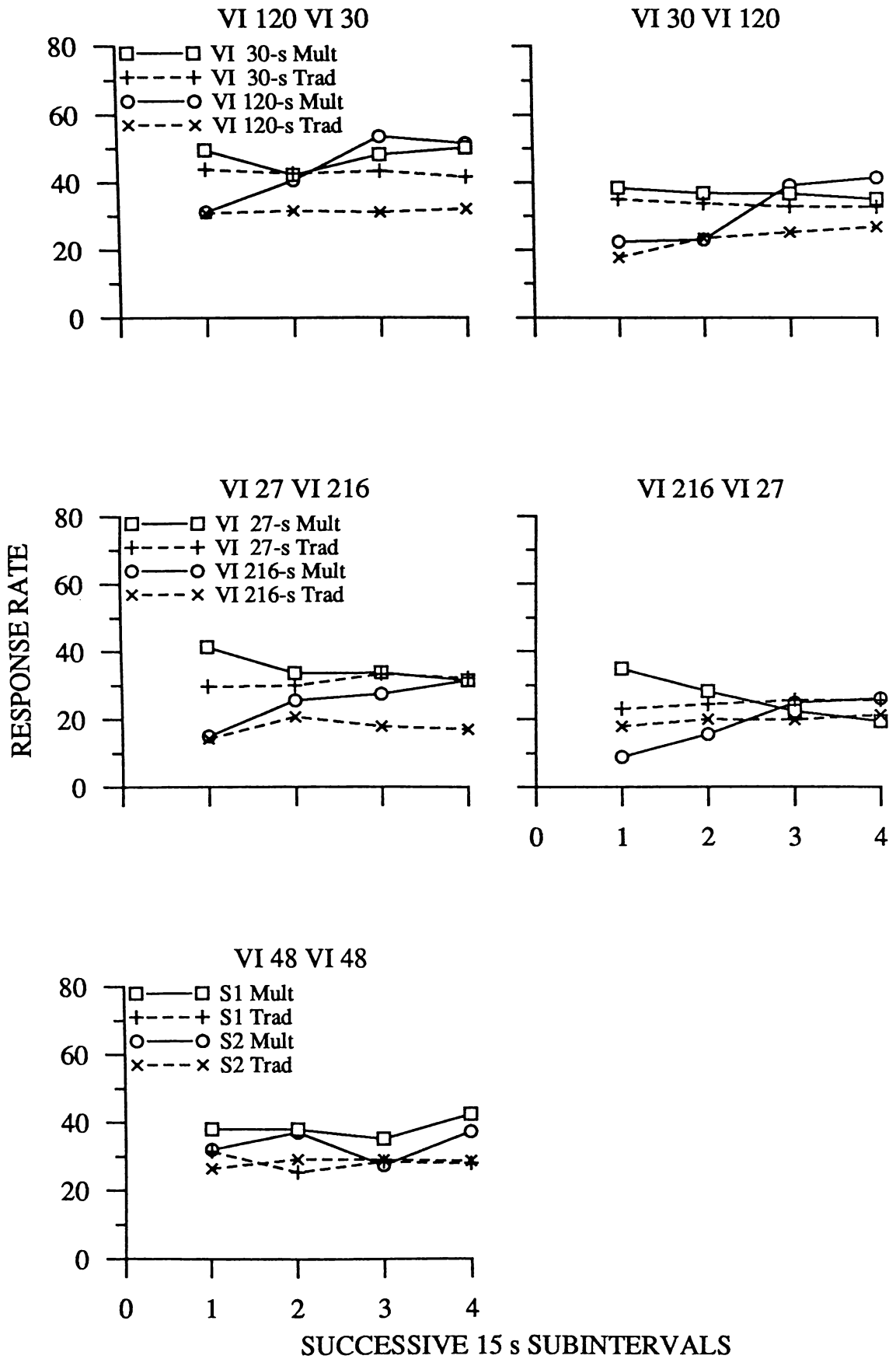
FIGURE 3.2

Response rates on each successive 15-s subinterval of both components of each schedule pair. Points connected by solid lines represent response rates on the multiple-multiple and those connected with a dashed lines response rates obtained on conditions using the traditional procedure. Squares and plusses represent response rates on the richer schedule of the schedule pairs for the multiple-multiple and traditional procedures respectively. Response rates on the leaner component of a schedule pair are shown as circles (MULT MULT procedure) and crosses (Traditional procedure). Response rates on the schedule associated with S1 when the schedule in effect was a MULT VI 48-s VI 48-s are represented as squares (MULT MULT procedure) and plusses (Traditional procedure). Response rates on the schedule associated with S2 in these conditions are represented as circles (MULT MULT procedure) and crosses (Traditional procedure).

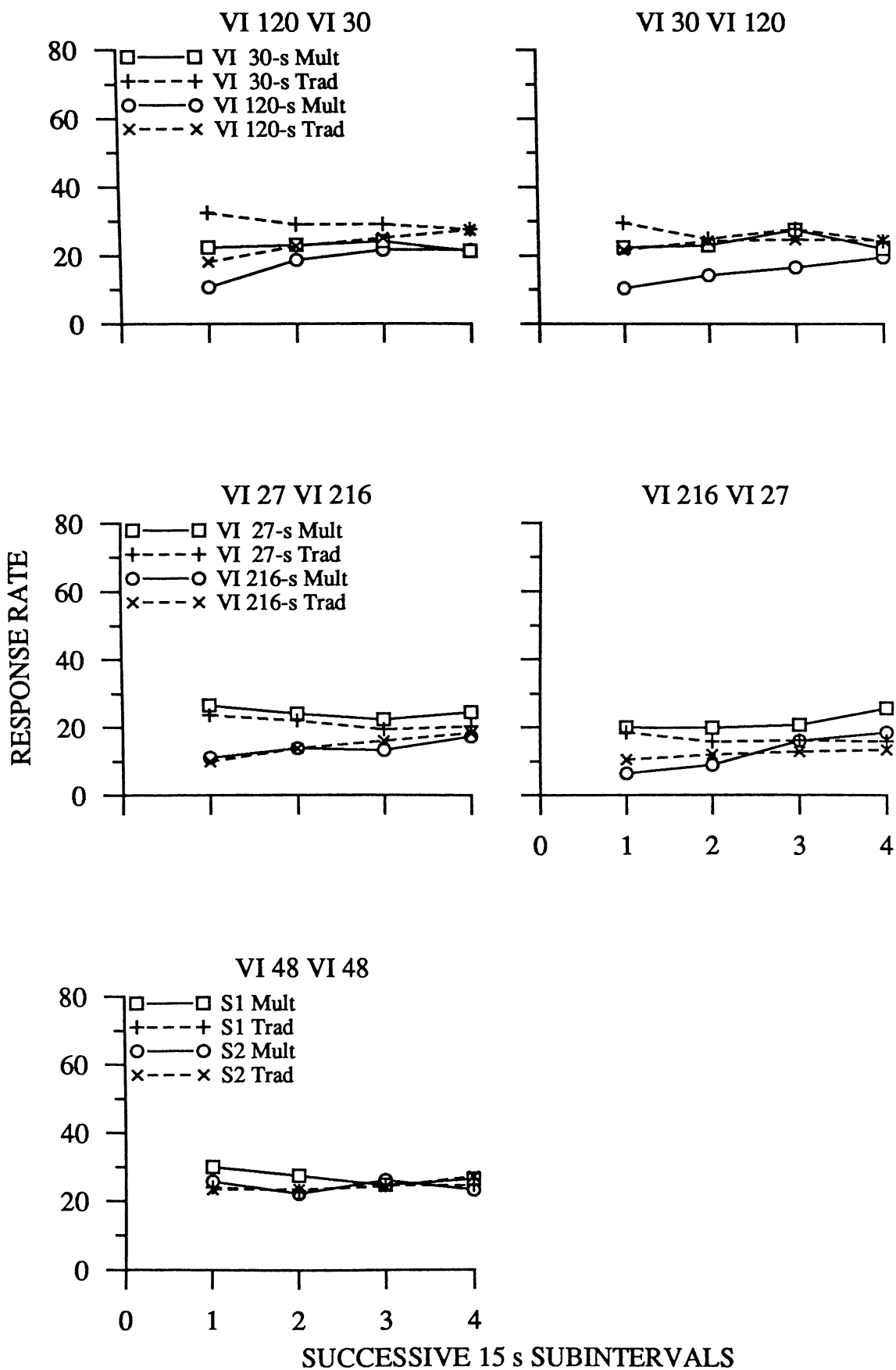
# HEN 21



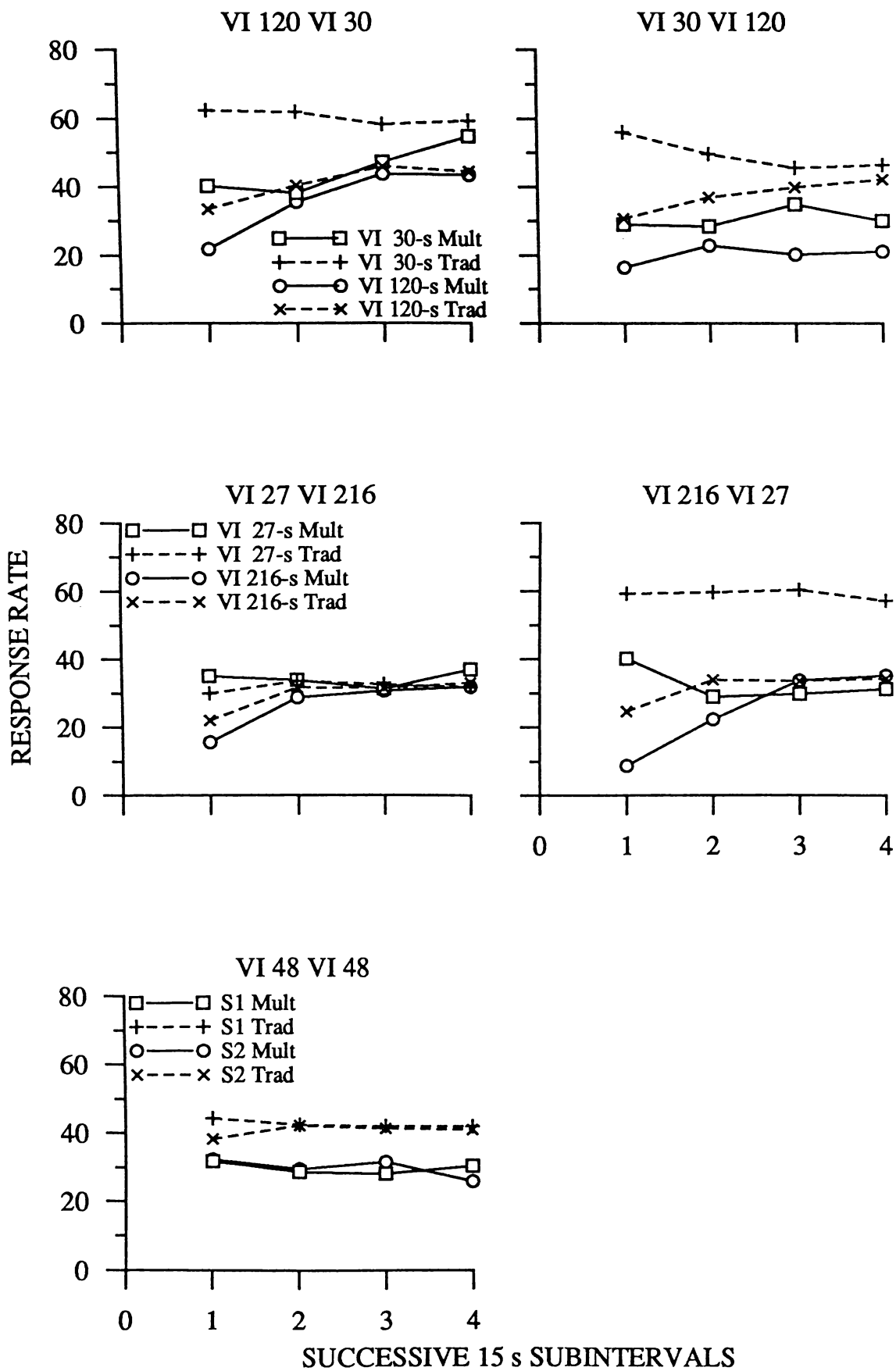
# HEN 22



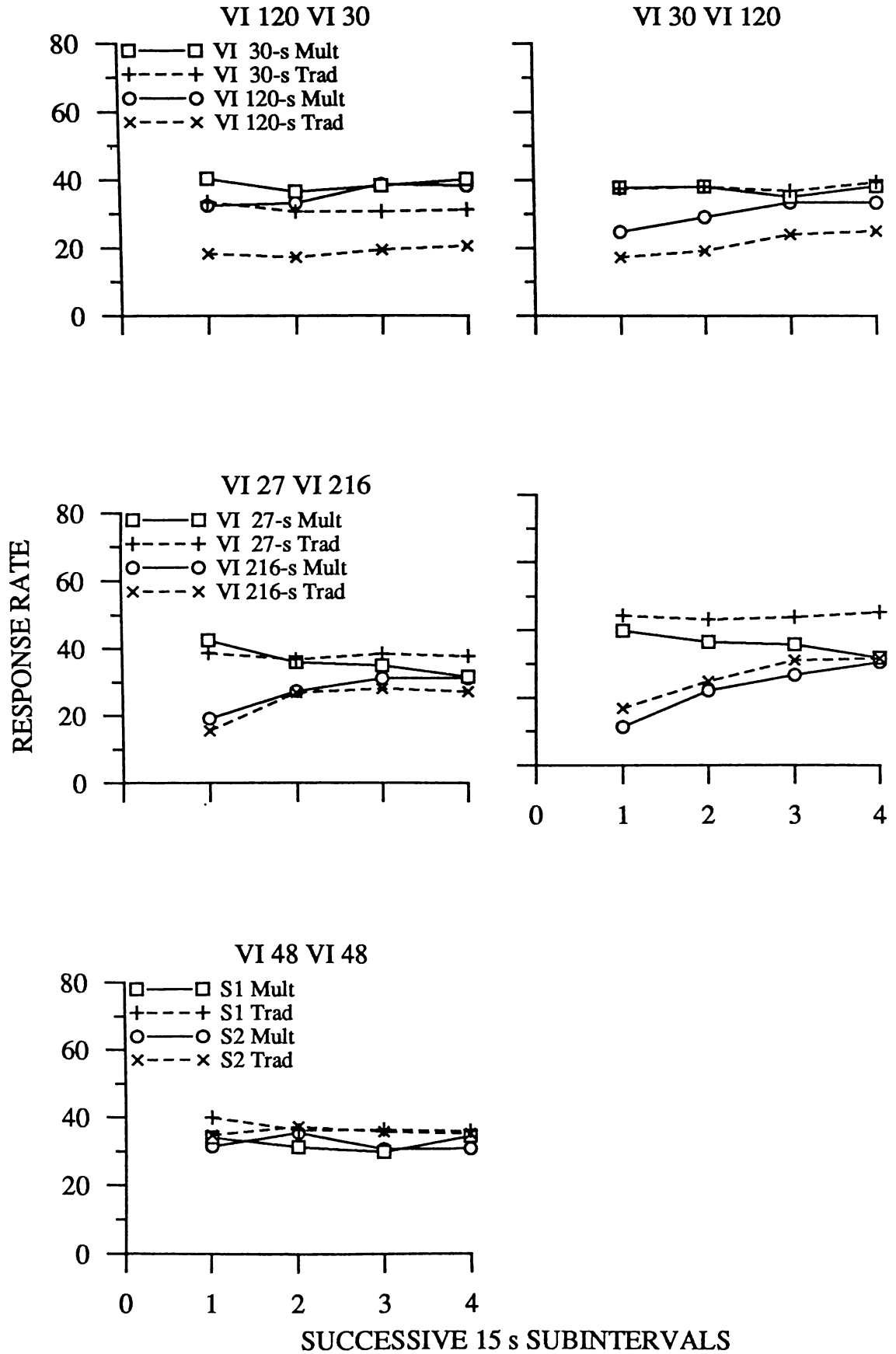
# HEN 23



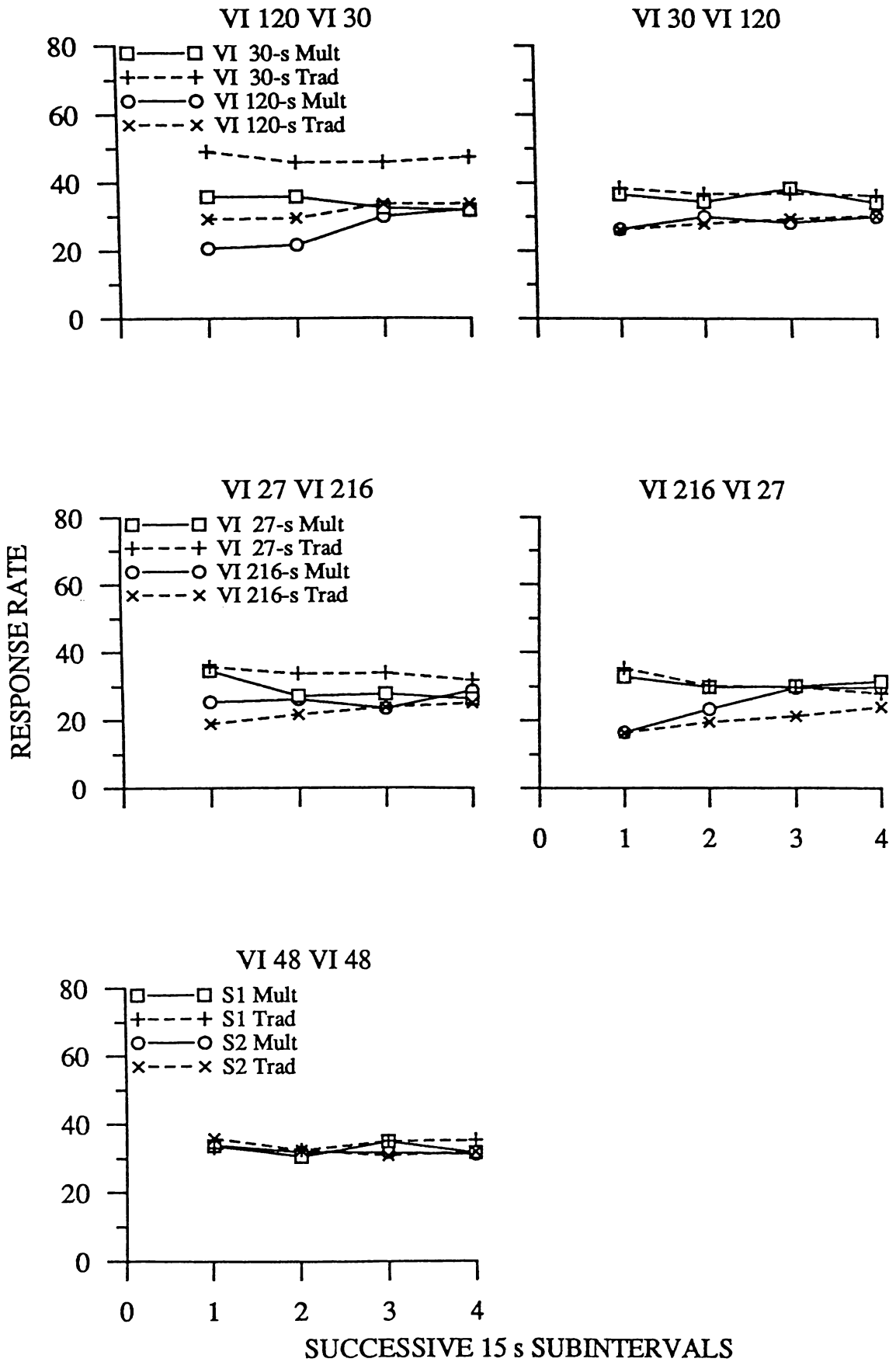
# HEN 24



# HEN 25



# HEN 26



richer schedule of the schedule pairs for the MULT MULT and traditional procedures respectively. Response rates on the leaner component of a schedule pair are shown as circles (MULT MULT procedure) and crosses (Traditional procedure). Response rates on the schedule associated with S1, when the schedule in effect was a MULT VI 48-s VI 48-s, are represented as squares (MULT MULT procedure) and plusses (Traditional procedure). Response rates on the schedule associated with S2 in these conditions are represented as circles (MULT MULT procedure) and crosses (Traditional procedure).

In general, for five hens, observed changes in response rates over successive 15-s subintervals were similar across the two procedures. For Hen 22 response rates changed notably more on the MULT MULT procedure. Similarly where differences occurred in the other hens data across the two procedures, local contrast was more likely to be observed in the MULT MULT procedure. Local negative contrast was evident in 33 of 48 possible instances while local positive contrast was observed in 22 of 48 possible instances. In general the local negative contrast observed was of greater magnitude than the local positive contrast observed. Local positive induction was occasionally evident in one schedule pair. On the equal schedule pairs there were no consistent changes in response rates over successive 15-s subintervals.

#### Generalised Matching Law Analysis

The intercepts ( $\log c$ ), slopes (the parameter  $a$ ), standard errors of and variance accounted for by regression lines fitted by the method of least squares to data from each successive 15-s subinterval of components for both procedures are given in Table 3.3. There was a tendency for the variance accounted for by the regression lines describing data from the MULT MULT procedure to be lower, for the later subintervals, than that accounted for by the regression lines fitted to data from the traditional procedure for the same subintervals. There were no consistent differences in the standard errors of the fitted lines, between the two procedures. Values of  $\log c$  did not change consistently across birds over the successive 15-s subintervals and no consistent differences between the two procedures were evident.

TABLE 3.3. The intercepts ( $\log c$ ), slopes (values of  $a$ ), standard errors (S.E.) and percentage of variance accounted for (VAC) by regression lines fitted by the method of least squares to data from each successive 15-s subinterval of components for both procedures.

Subinterval	Log c		$a$		S.E		VAC	
	TRAD	MULT	TRAD	MULT	TRAD	MULT	TRAD	MULT
HEN 21								
1	0.02	0.06	0.29	0.19	0.074	0.109	80.2	85.4
2	-0.03	0.07	0.15	0.08	0.072	0.124	44.7	54.4
3	0.01	0.08	0.14	0.07	0.078	0.070	70.5	41.2
4	0.03	0.05	0.11	0.03	0.102	0.069	58.9	7.4
HEN 22								
1	0.08	-0.03	0.27	0.41	0.085	0.063	93.8	68.6
2	0.01	0.01	0.16	0.16	0.087	0.064	84.3	65.3
3	0.02	0.05	0.20	0.00	0.060	0.063	89.6	59.5
4	0.03	0.03	0.18	-0.06	0.056	0.075	82.7	0.7
HEN 23								
1	0.00	0.01	0.34	0.37	0.155	0.064	95.7	88.0
2	-0.01	0.03	0.15	0.22	0.128	0.053	87.0	79.5
3	-0.01	0.06	0.10	0.14	0.010	0.085	99.0	78.8
4	-0.02	0.03	0.04	0.10	0.055	0.031	61.4	79.6
HEN 24								
1	-0.04	-0.01	0.38	0.39	0.072	0.116	86.6	95.5
2	-0.05	0.01	0.21	0.07	0.041	0.074	82.9	70.2
3	-0.06	0.02	0.16	0.07	0.152	0.076	72.9	12.0
4	-0.06	0.02	0.13	0.11	0.093	0.069	70.1	48.6
HEN 25								
1	0.02	0.09	0.48	0.35	0.220	0.040	99.1	68.6
2	-0.02	0.03	0.29	0.14	0.095	0.110	84.0	65.3
3	-0.01	0.01	0.21	0.06	0.049	0.066	88.4	59.5
4	0.00	0.02	0.22	0.00	0.043	0.062	89.9	0.7
HEN 26								
1	-0.03	0.02	0.34	0.25	0.034	0.014	99.8	98.0
2	-0.01	-0.02	0.23	0.11	0.073	0.041	95.9	67.3
3	0.01	0.06	0.17	0.07	0.040	0.040	93.5	71.4
4	0.00	0.00	0.12	0.01	0.041	0.062	74.7	7.4

Figure 3.3 shows values of  $a$  obtained for all birds' data on each successive 15-s subinterval of components. Open circles represent  $a$  values for hens' data obtained on the MULT MULT procedure and crosses  $a$  values obtained using the tradition procedure. For all birds' data the values of  $a$  obtained for both procedures decreased across successive 15-s intervals. No consistent differences across birds, in the decrement in  $a$  values over successive 15-s subintervals, between the two procedures were evident.

## Phase II

### Behaviour Across Components

#### Response Rates

Figure 3.4 shows response rates on each component schedule, for all conditions in Phase II, plotted against blackout duration. For comparison, response rates obtained for Condition 1 are also included. Each panel represents response rates on one of the five multiple schedules used. In all cases where reinforcement rates on the two components differed, squares indicate response rates on the richer schedule of the pair and circles response rates on the leaner schedule. Response rates on the schedule associated with S1 when the schedules in effect were both VI 48-s are indicated by squares and response rates on the schedule associated with S2 are represented as circles. Unconnected points indicated by M on the abscissa represent response rates for the same schedules obtained for Condition 1 (Phase I: MULT MULT procedure - 0 s blackout).

Examination of Figure 3.4 reveals that changes in response rates as a function of incorporating a blackout between components tended to be idiosyncratic. For Hen 21 response rates on all component schedules were higher when the blackout duration was 1 s compared to response rates when there was no blackout. Conversely, for Hen 25, response rates on each component schedule, with one exception, were lower when blackout duration was 1 s compared to response rates when no blackout separated components. For Hen 22's data, a similar pattern was observed on two of the schedule pairs, MULT VI 120-s

FIGURE 3.3

Values of  $a$  obtained for each successive 15-s subinterval of components. Open circles represent  $a$  values for hens' data obtained with the multiple-multiple procedure and crosses  $a$  values for hens' data from the tradition procedure.

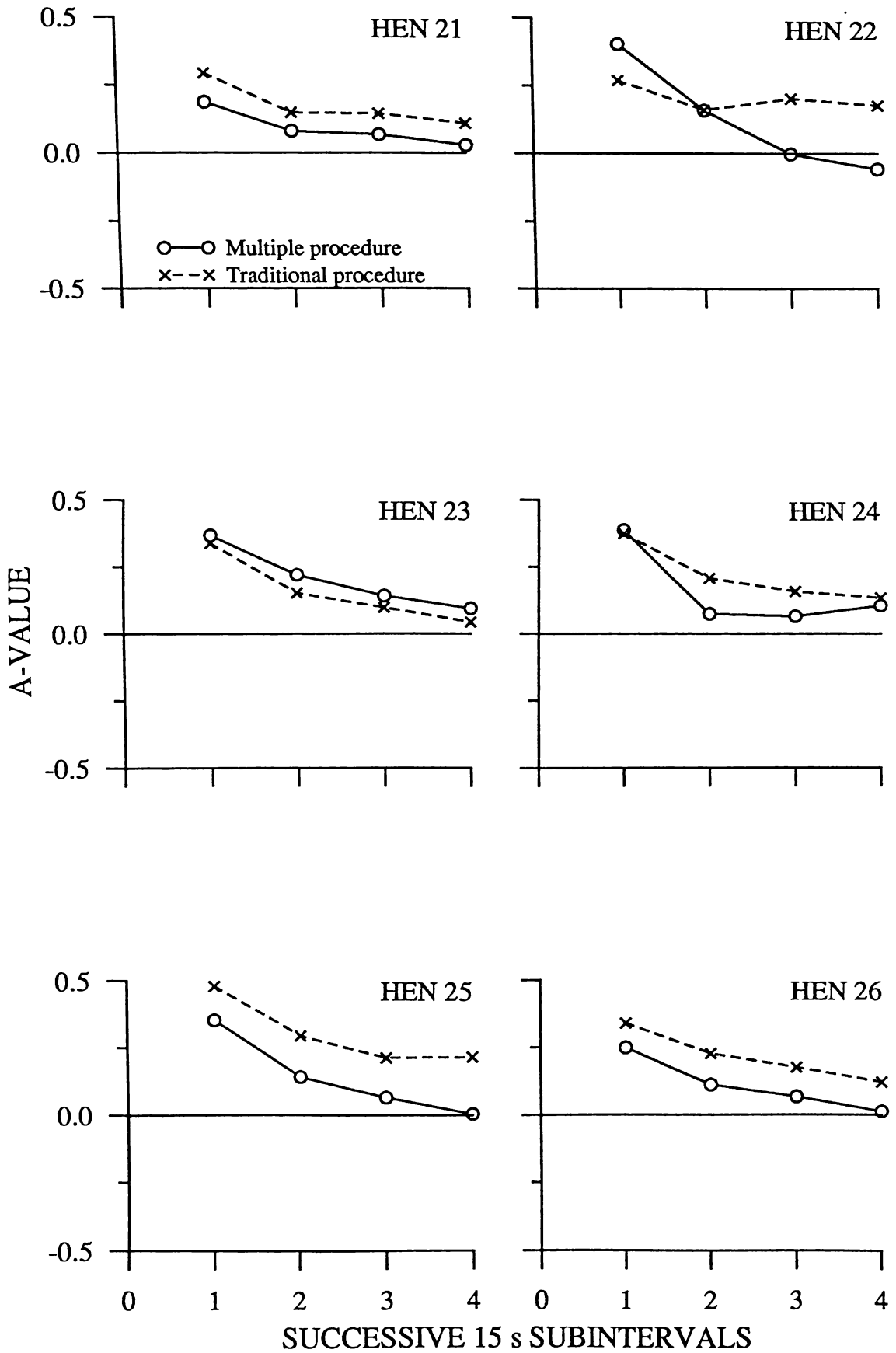
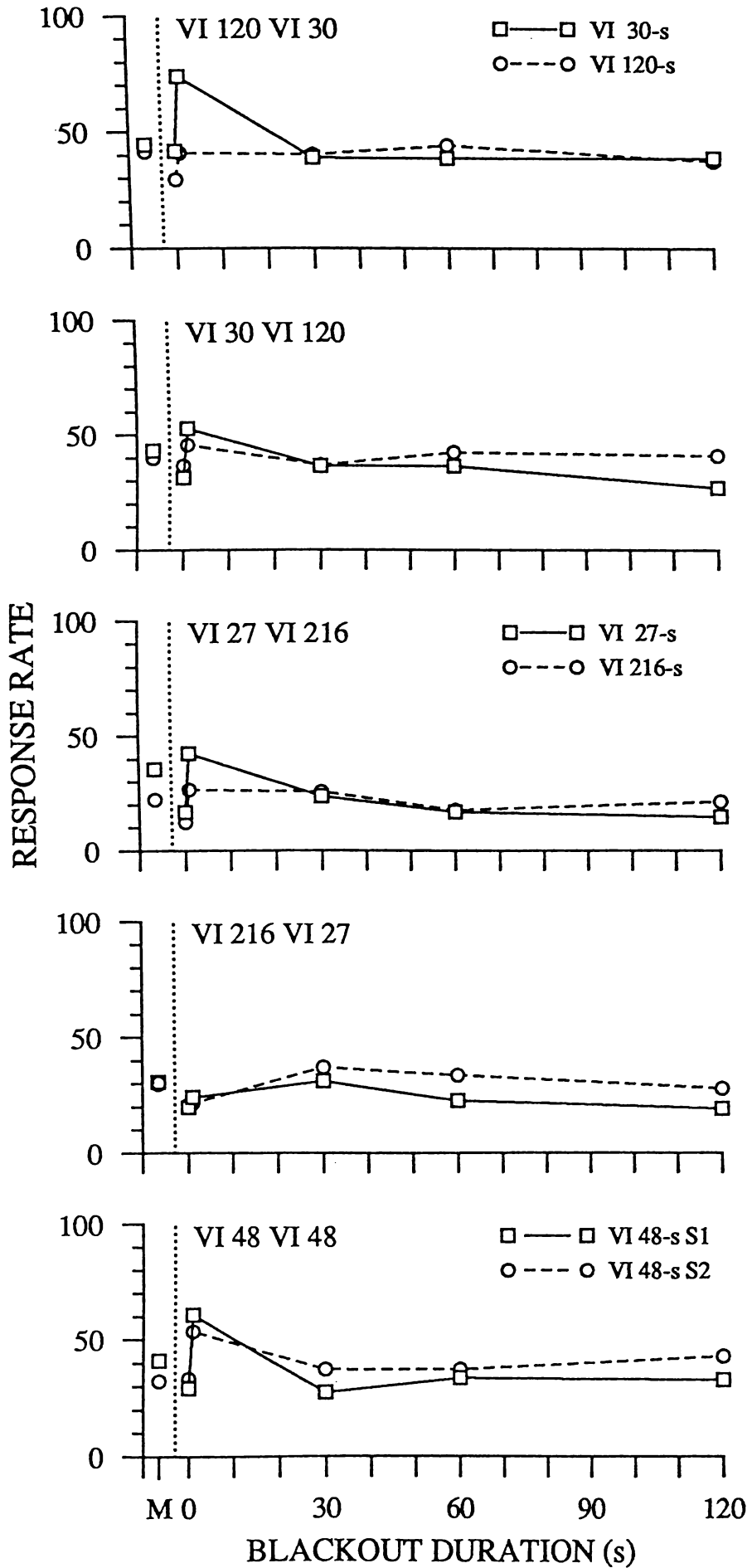


FIGURE 3.4

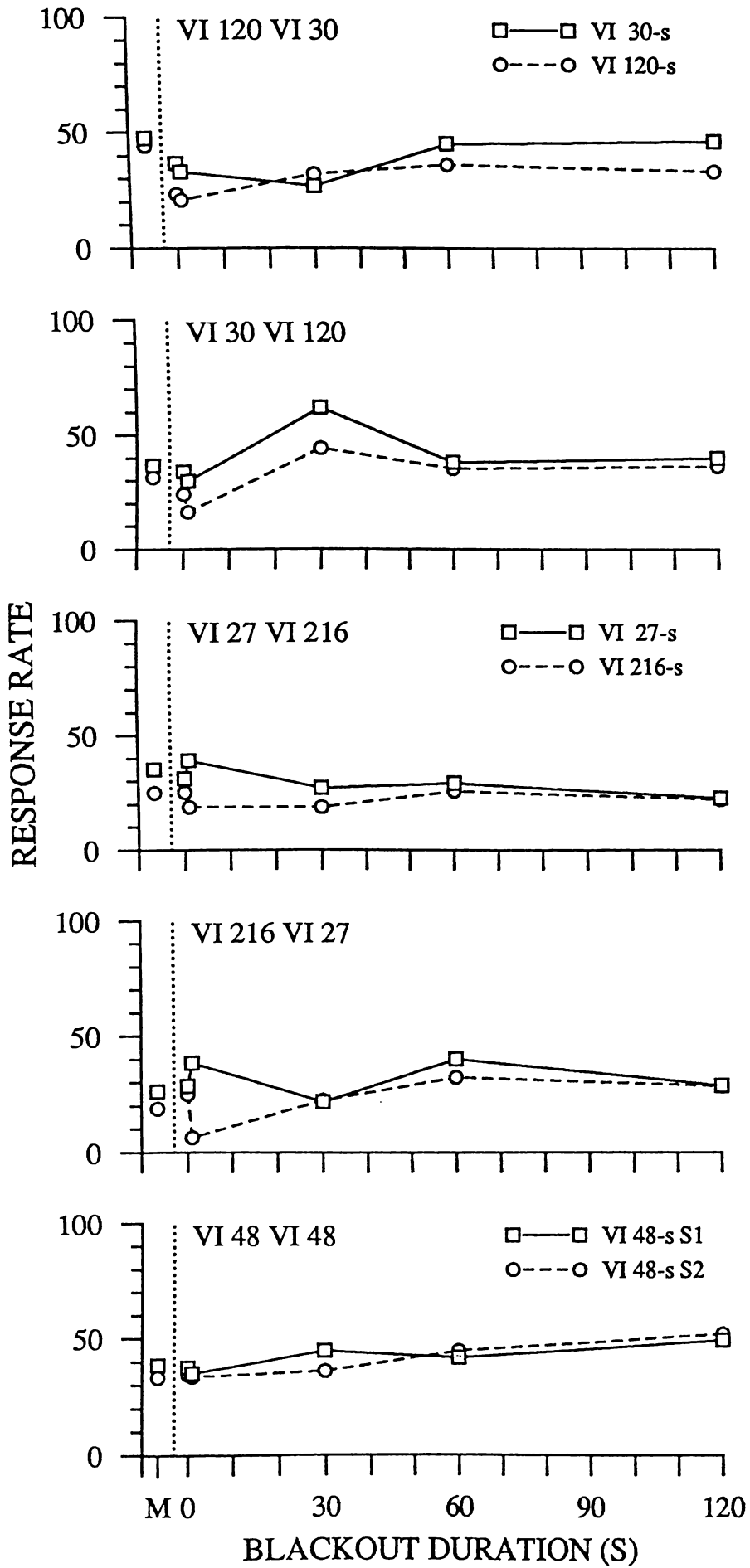
Response rates on each component for Phase II (Conditions 7 to 11) plotted against blackout duration. For comparison response rates obtained for Condition 1 are also included. Each graph represents response rates on one of the five multiple schedules used. Squares indicate response rates on the richer schedule of the schedule pair and circles response rates on the leaner schedule. For the equal schedule pair response rates on the schedule associated with S1 are shown as squares and on the schedule associated with S2 as circles. Unconnected points, indicated by M on the abscissa, represent response rates on the same schedules for Condition 1 (Phase I: multiple-multiple procedure - 0 s blackout).

Data were obtained from all hens in all conditions. Occasionally response rates on the schedules were very similar and on these occasions squares obscure the circles.

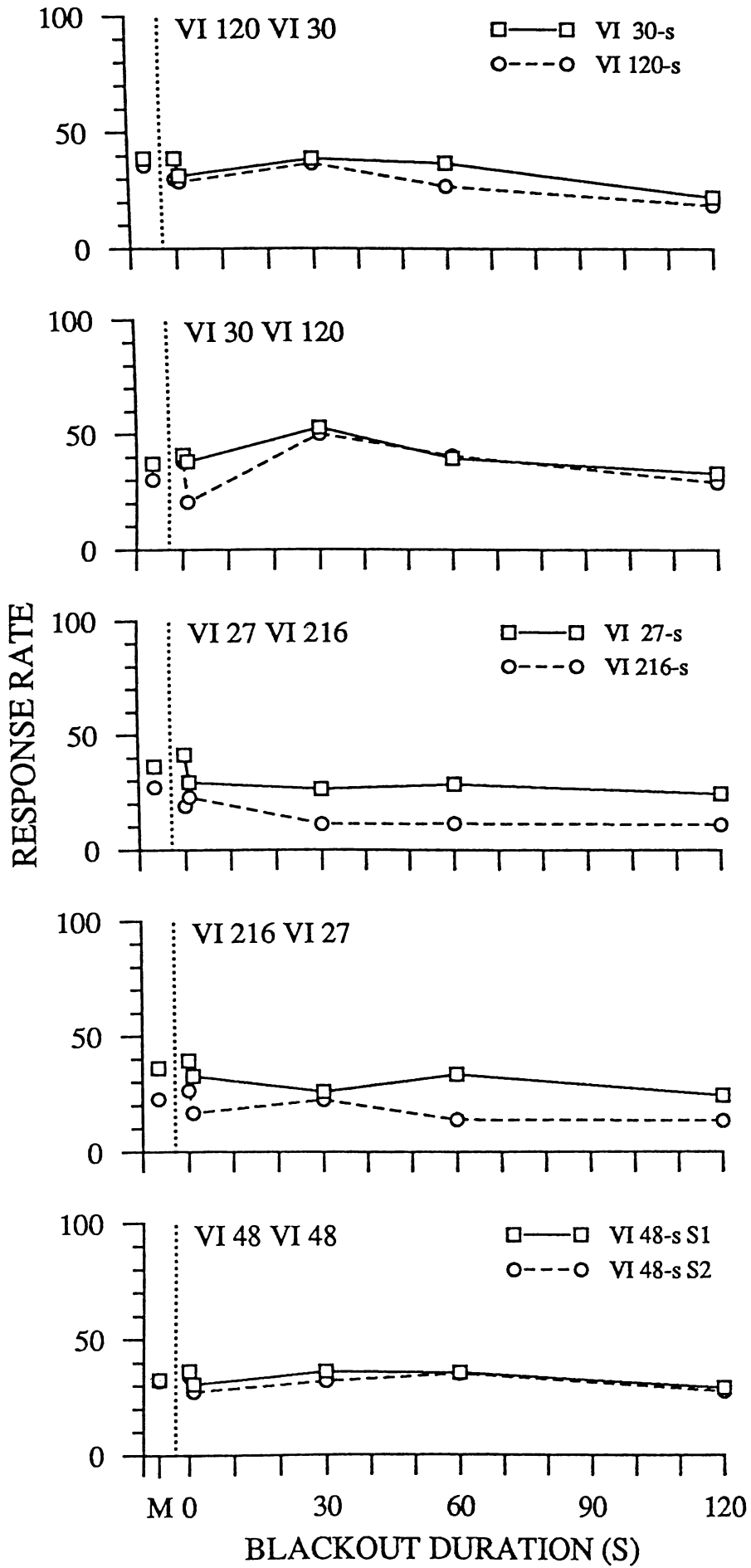
# HEN 21



# HEN 22



# HEN 25



VI 30-s and its reversal, but this bird's data differed with respect to the other schedule pairs. On the MULT VI 27-s VI 216-s schedule and its reversal response rates on the richer schedules were higher when component duration was 1 s than those obtained with no blackout. Response rates on the lean schedules were lower when 1 s of blackout separated components than they were when no blackout separated components.

No consistent differences across birds or schedule pairs between the two conditions with no blackout (Phase I, Condition 1 and Phase II, Condition 10) were noted.

Changes in response rates as a function of changes in blackout duration from 1 s to 120 s, also varied across birds and conditions. For example, Hen 21's response rates on the richer schedules of the schedule pairs generally decreased when the blackout duration was increased to 30 s and then remained at a similar level as blackout duration was further increased. This pattern of responding was also apparent on both schedules of the equal schedule pair. Response rates on the lean schedule for the same bird tended to remain at a similar level across blackout durations. Conversely, Hen 22's response rates on the lean schedules and on both schedules of the equal schedule pairs tended to increase as a function of blackout duration, while response rate changes on the rich schedules varied across schedule pairs.

In order to determine if the schedule in effect in the previous multiple schedule influenced responding, the response differentials obtained for each schedule pair and its reversal were examined. Some instances where response rates did not reverse across multiple schedules where reinforcement rates were reversed were noted. However no consistent differences in the differentials, as a function of whether a multiple schedule was the first or second presented with a particular pair of component schedules, were found. For example, as seen in Figure 3.4 with 1 s blackout duration, response rates obtained for each component schedule for Hen 21 on the MULT VI 120-s VI 30-s and the MULT VI 27-s VI 216-s were more disparate than response rates on the reversals of these conditions. However such effects were not observed in the other birds' data and nor was this effect evident in Hen 21's data at the longer blackout durations.

### Generalised Matching Law Analysis

Table 3.4 gives for all birds, the intercepts, the slopes, standard errors and the percentage of variance accounted for by regression lines, fitted by the method of least squares to the data obtained from the five schedule pairs, for all conditions in Phase II. The variance accounted for by the regression lines ranged from 19.6% for Hen 21's data with 30 s blackout, to 99.5% for Hen 22's data with 60 s blackout. Standard errors of the estimates ranged from 0.149 for Hen 25 with 60 s blackout, to 0.006 for Hen 22 also with 60 s blackout. Neither the variance accounted for, nor the standard errors of the estimates, varied consistently across birds as a function of blackout duration.

Values of  $\log c$  were generally small ranging from -0.03 to 0.10 and did not vary consistently as a function of blackout duration.

Figure 3.5 shows values of the parameter  $a$  plotted as a function of blackout duration. For comparison the values of  $a$  obtained in Condition 1 of Phase I are shown as unconnected points on the left hand side of the figure. For all birds values of  $a$  obtained for the data from the two conditions with no blackout separating components were similar. For two birds' data (Hens 21 and 22) the  $a$  values obtained on Condition 1 (0 s; Phase I) were higher than those obtained on Condition 10 (0 s; Phase II), while for Hen 25's data, the  $a$  value for Condition 10 was higher than that for Condition 1.

For all hens' data  $a$  values obtained increased as a function of incorporating a 1 s period of blackout between components. For two hens' data (Hens 21 and 22) values of  $a$  obtained decreased as blackout duration was increased to 30 s. For one of these hen's data, Hen 21, the  $a$  value obtained was negative and the values of  $a$  obtained continued to decrease as a function of increasing blackout duration. Values of  $a$  for Hen 25's data showed a slight decrease when blackout duration was increased to 30 s and then a marked increase as blackout duration was further increased to 60 s but again decreased at the longest blackout duration.

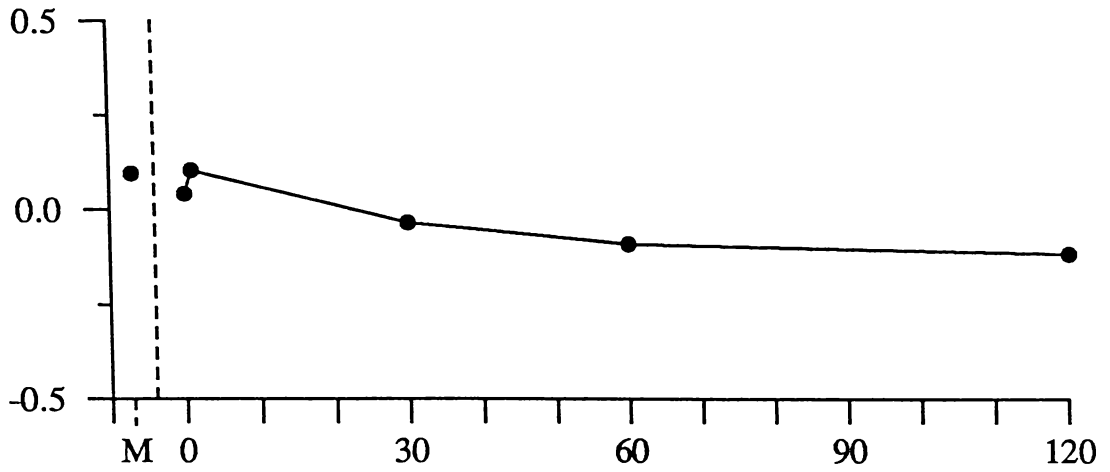
Table 3.4 The intercepts ( $\log c$ ), slopes (values of  $a$ ), percentage of variance accounted for (VAC) and standard errors (S.E) of the fits of regression lines fitted by the method of least squares to the data obtained from the five schedule pairs for Conditions 7 to 11.

Blackout Duration (s)	$\log c$	$a$	S.E	VAC
		HEN 21		
0	-0.03	0.04	0.108	20.3
1	0.02	0.11	0.147	44.2
30	-0.01	-0.03	0.079	19.6
60	0.01	-0.09	0.043	85.2
120	-0.08	-0.12	0.070	81.1
		HEN 22		
0	0.01	0.09	0.115	46.2
1	0.01	0.31	0.02	99.4
30	0.10	0.06	0.020	91.2
60	-0.03	0.09	0.006	99.5
120	-0.05	0.12	0.016	97.4
		HEN 25		
0	0.03	0.18	0.094	83.1
1	0.03	0.19	0.107	79.7
30	0.07	0.15	0.129	58.0
60	-0.02	0.32	0.149	79.1
120	0.02	0.21	0.106	82.4

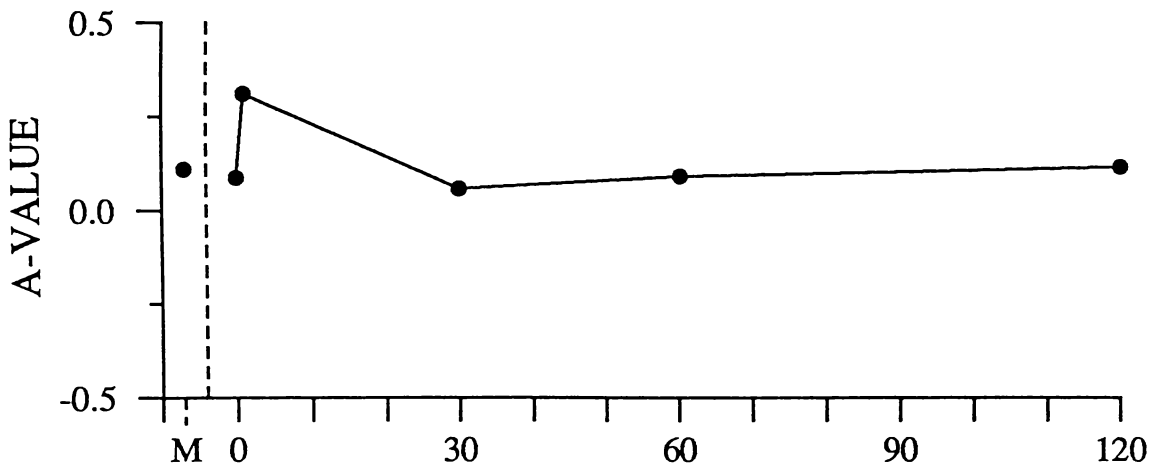
FIGURE 3.5

Values of the parameter  $a$  for all conditions in Phase II. The values of  $a$  obtained for Condition 1 of phase I are shown as unconnected points on the left hand side of the figure.

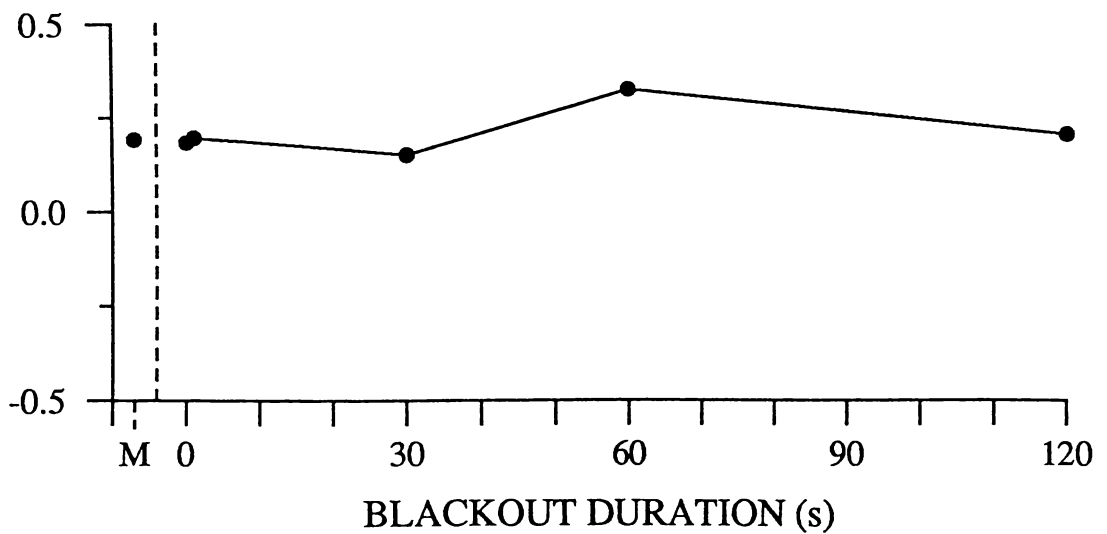
HEN 21



HEN 22



HEN 25



## Behaviour within components

### Response Rates

Changes in response rates within components were assessed as in Experiment 2 using Equation 6. This equation yields a measure  $D$ , where  $D$  indicates the change in response rates from the first to last 15-s subinterval as a percentage of the response rates in the first 15-s subinterval. If response rates decrease between the first and last subintervals,  $D$  will be negative. If response rates increase,  $D$  will be positive. Values of  $D$  were calculated for both components for all conditions. Each graph of Figure 3.6 shows values of  $D$  obtained for both components of one schedule pair plotted as a function of blackout duration. In all cases values of  $D$  for the leaner schedule of a pair are shown as open circles and for the richer schedule as squares. For conditions with equal reinforcement schedules,  $D$  values for S1 responding are shown as squares and S2 responding as circles. The unconnected points indicated by M, on the left of the graph represent values of  $D$  obtained for Condition 1.

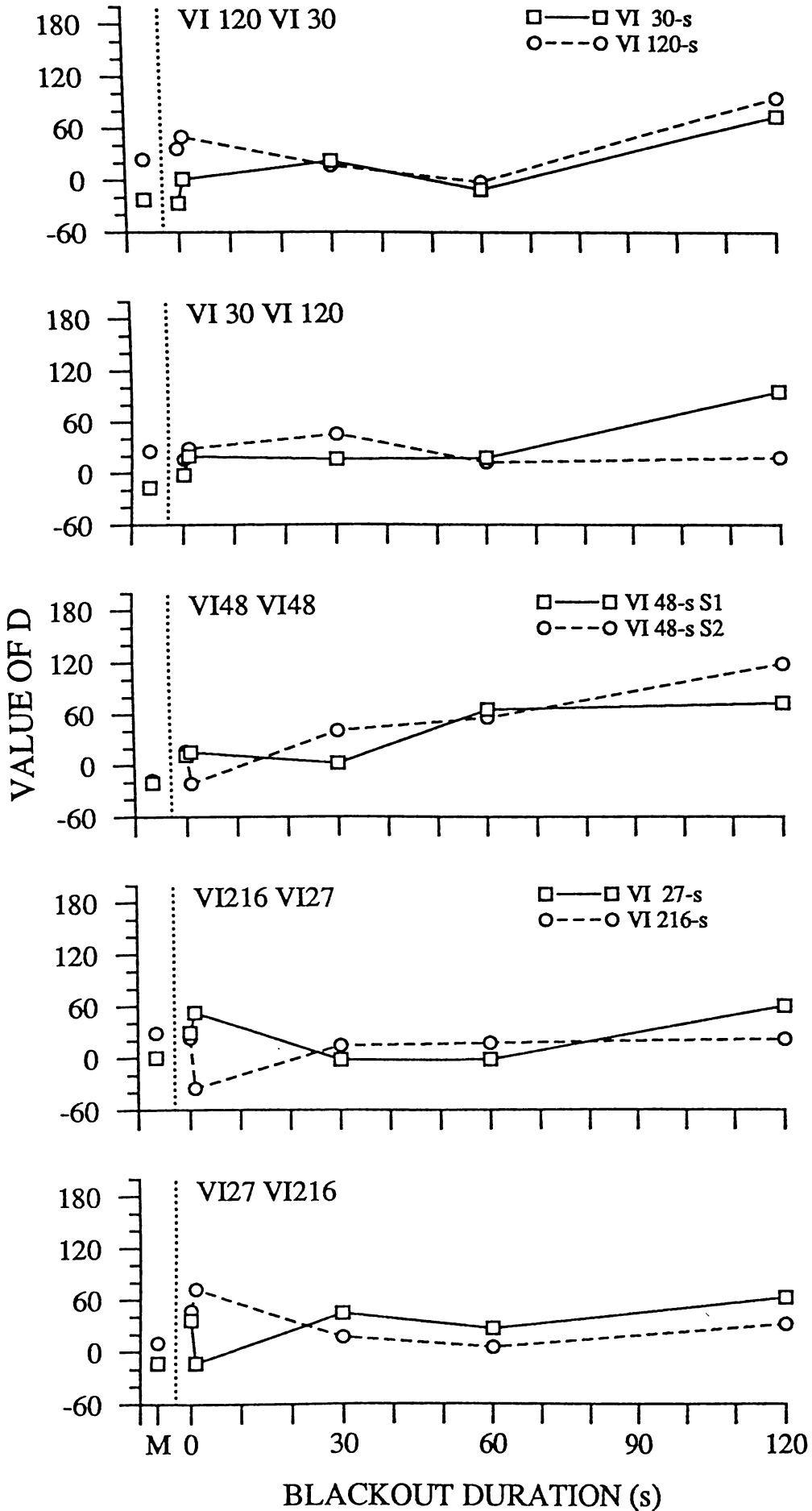
For Condition 10, where no blackout separated components, values of  $D$  for lean schedule responding tended to be positive. That is, local negative contrast was evident in all birds' data in most lean schedules. In total, 10 out of a possible 12 instances of local negative contrast were observed. For Condition 1 (Phase I), which also involved no blackout between schedules, negative local contrast (as measured by  $D$ ) was observed on all possible occasions. Values of  $D$  obtained were generally greater for Condition 1 (Phase I) than Condition 10 (Phase II; 0 s blackout), but several exceptions to this were evident. Changes in the values of  $D$  obtained for lean schedule responding, when a 1 s period of blackout was inserted between components, were variable across hens. For Hen 21's data values of  $D$  generally increased, for Hen 22's data they decreased and for Hen 25's data they decreased for two schedule pairs and increased for the other two. Changes in the values of  $D$  obtained as a function of the duration of the blackout between components were variable across hens and schedule pairs and in several cases, the relation between blackout duration and values of  $D$  appeared to be nonmonotonic.

FIGURE 3.6

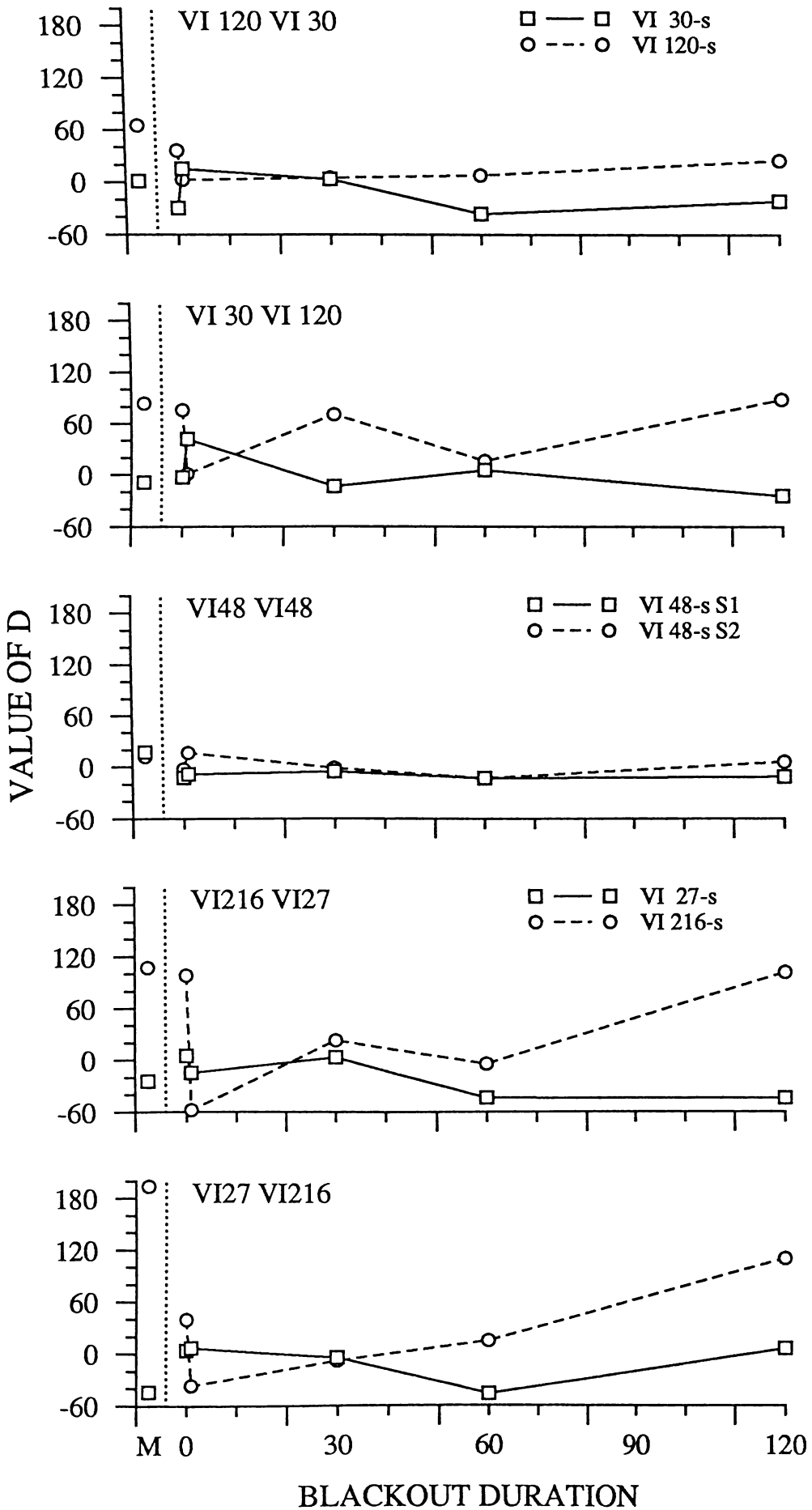
Values of D obtained for responses on both components of each schedule pair. Each graph shows values of D obtained for both components of one schedule pair. Values of D for the leaner schedule of a pair are shown as open circles and for the richer schedule as squares. For conditions with equal reinforcement schedules D values for S1 responding as shown as squares and S2 responding as circles. The unconnected points on the left of the graph represent values of D obtained for Condition 1.

Data were obtained from all hens in all conditions. Occasionally response rates on the schedules were very similar and on these occasions squares obscure the circles.

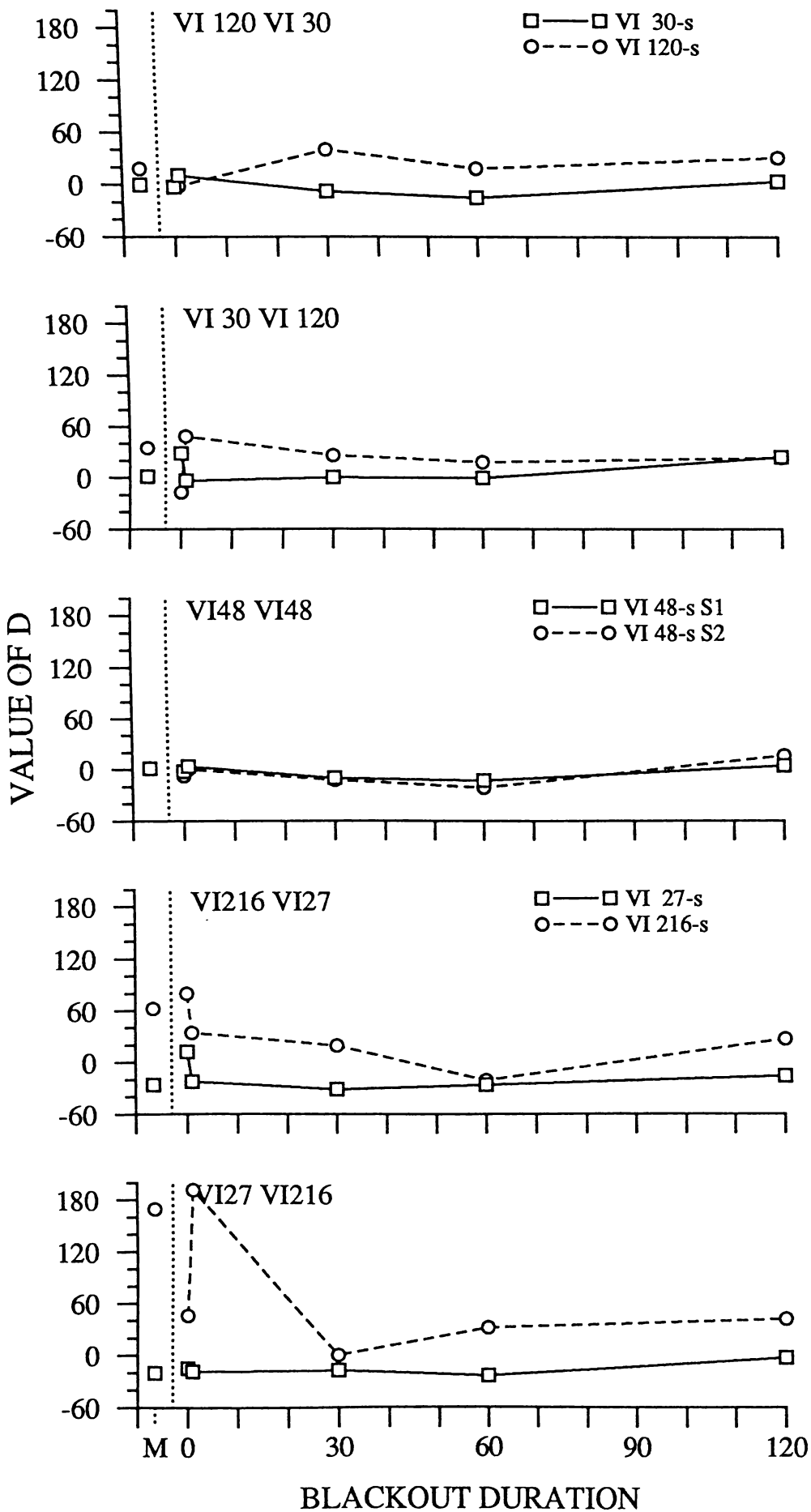
# HEN 21



# HEN 22



# HEN 25



Values of  $D$  obtained for rich schedule responding for Condition 10 (0-s blackout) were generally small. In total three instances of local positive contrast, as evidenced by negative values of  $D$ , and five instances of local induction, as evidenced by positive values of  $D$ , were observed. For Condition 1 values of  $D$  obtained for rich schedule responding were generally negative. In total, local positive contrast as measured by  $D$  was observed in 8 of the 12 possible instances. Changes in the values of  $D$  for responding on the rich schedule, as a function of incorporating a 1 s period of blackout, varied across birds and schedule pairs. For Hen 25's data values of  $D$  tended to decrease and for Hen 21's and 22's data to increase. Changes in  $D$  for rich schedule responding as a function of changes in the duration of the inter-component blackout were variable across birds and schedule pairs, as were changes in  $D$  for lean schedule responding.

For data from Hens 22 and 25 values of  $D$  for responding on both components of the equal schedule pairs for all conditions were close to zero. Changes in values of  $D$  for the equal schedule pair for Hen 21's data tended to increase as a function of increasing blackout duration.

#### Generalised Matching Law Analysis

Table 3.5 gives the intercepts (values of  $\log c$ ), the slopes (values of  $a$ ), standard errors of and variance accounted for by regression lines fitted by the method of least squares to data for each 15-s subinterval of all conditions. The percentage of variance accounted for by the fitted lines ranged from 0.5% to 99.8%, and standard errors from 0.018 to 0.199. Neither of these measures varied consistently across birds as a function of blackout duration or across successive 15-s subintervals.

Values of  $\log c$  were generally close to zero and did not vary consistently, across birds or conditions, over the successive 15-s subintervals.

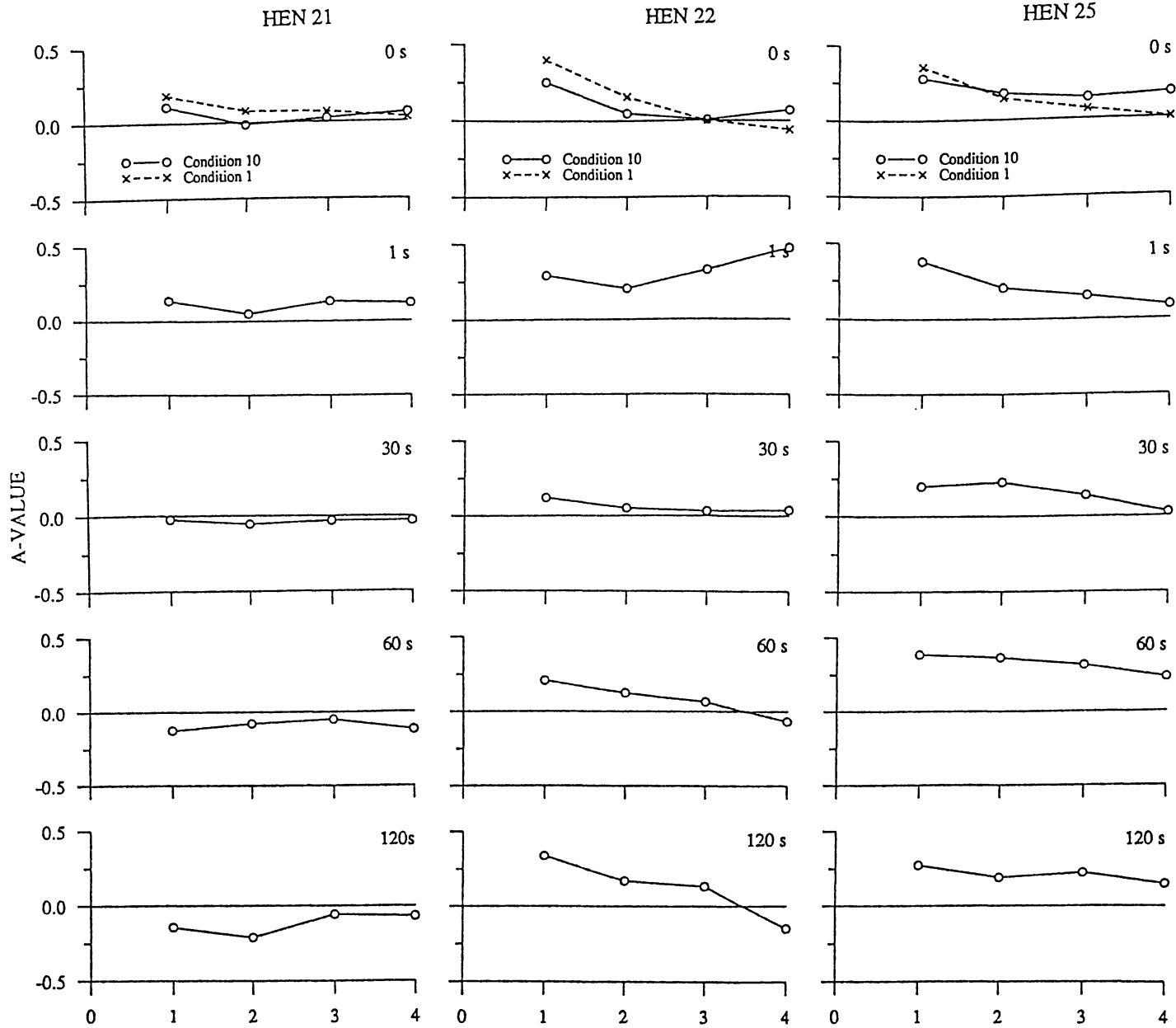
Figure 3.7 shows values of  $a$  for responding in each successive 15-s subinterval of components. Each panel shows  $a$  values obtained for conditions at one blackout duration. The top panel shows  $a$  values

TABLE 3.5. The intercepts (values of  $\log c$ ), slopes (values of  $a$ ), standard errors (S.E) and percentage of variance accounted for by regression lines fitted by the method of least squares to data for each 15-s subinterval of Conditions 7 to 11.

BIN	Blackout duration (in seconds)									
	0	1	30	60	120	0	1	30	60	120
HEN 21										
	Intercept ( $\log c$ )					Slope ( $a$ )				
1	-0.05	-0.10	0.03	-0.02	-0.11	0.11	0.14	-0.02	-0.12	-0.14
2	-0.03	0.00	-0.00	0.05	-0.10	-0.01	0.05	-0.05	-0.08	-0.21
3	-0.02	0.08	-0.02	0.03	-0.08	0.03	0.13	-0.03	-0.05	-0.06
4	0.00	0.09	-0.05	-0.04	-0.06	0.06	0.12	-0.03	-0.12	-0.07
	S.E.					VAC				
1	0.166	0.121	0.078	0.053	0.070	42.3	66.6	11.1	87.8	81.1
2	0.079	0.171	0.087	0.093	0.149	3.8	11.6	33.6	48.3	76.4
3	0.105	0.151	0.068	0.069	0.071	8.8	54.6	22.5	42.4	51.8
4	0.135	0.199	0.108	0.052	0.062	25.5	35.3	9.4	87.1	64.9
HEN 22										
	Intercept ( $\log c$ )					Slope ( $a$ )				
1	0.05	-0.01	0.14	-0.04	-0.00	0.26	0.29	0.12	0.21	0.34
2	-0.02	0.00	0.10	-0.03	-0.04	0.05	0.20	0.53	0.13	0.17
3	-0.01	0.01	0.07	-0.04	-0.06	0.01	0.33	0.34	0.07	0.14
4	0.03	0.07	0.07	0.01	-0.09	0.07	0.47	0.43	-0.07	-0.15
	S.E.					VAC				
1	0.180	0.071	0.085	0.056	0.075	75.5	93.7	71.7	91.7	93.5
2	0.182	0.056	0.057	0.038	0.026	9.9	92.1	51.5	89.4	96.7
3	0.125	0.061	0.028	0.044	0.023	0.5	96.2	63.7	65.6	96.2
4	0.040	0.018	0.046	0.049	0.112	82.3	99.8	51.1	60.0	54.8
HEN 25										
	Intercept ( $\log c$ )					Slope ( $a$ )				
1	0.02	0.02	0.08	-0.04	0.03	0.28	0.38	0.20	0.39	0.27
2	0.02	0.03	0.07	-0.05	0.00	0.17	0.21	0.23	0.37	0.19
3	0.02	0.01	0.05	-0.01	-0.01	0.14	0.15	0.14	0.32	0.22
4	0.06	0.03	0.07	0.02	0.04	0.17	0.09	0.03	0.23	0.15
	S.E.					VAC				
1	0.188	0.199	0.157	0.161	0.153	73.3	81.2	62.5	82.1	79.6
2	0.098	0.106	0.141	0.145	0.116	79.9	81.7	72.8	83.5	76.4
3	0.069	0.105	0.126	0.123	0.086	83.6	71.1	56.1	83.8	89.1
4	0.066	0.097	0.108	0.176	0.107	89.3	49.9	6.2	58.2	69.6

FIGURE 3.7

Values of  $a$  for responding in each successive 15-s subinterval of components. Each graph shows  $a$  values for one blackout duration. The top graph shows  $a$  values obtained for Conditions 10 (open circles) and 1 (crosses).



SUCCESSIVE 15 s SUBINTERVALS

obtained for Conditions 10 (open circles) and 1 (crosses). For all hens' data, values of  $a$  decreased as a function of time since component alternation in both conditions where no blackout separated components. The decrease in  $a$  values was, however, greater in Condition 1 than Condition 10 for all hens. For Hen 21's data no decrease in  $a$  values over successive subintervals was evident when a period of blackout was incorporated between components, regardless of the duration of the blackout. For Hen 22's data  $a$  values tended to increase as a function of time since component alternation when a 1 s period of blackout separated components but decreased as a function of time since component alternation with longer blackout durations. For this hen's data the greatest decrease in  $a$  values over successive subintervals was observed for conditions with a 120-s blackout duration. For Hen 25's data  $a$  values decreased as a function of time since component alternation at all blackout durations. For this hen's data the decrease in  $a$  values was attenuated over conditions.

## DISCUSSION

Phase I

The aim of this phase was to assess whether behaviour on multiple schedules, when a multiple-multiple procedure was employed, would be comparable with behaviour observed on the same multiple schedules when one multiple schedule was presented in each condition.

Examination of the data from the two procedures indicate that in some respects behaviour observed on a multiple-multiple procedure may be similar to that observed when the component multiple schedules are presented singly. In other respects behaviour on the multiple-multiple differed from that observed when a traditional procedure is used.

If absolute response rates on each component of the multiple schedules were compared over the two procedures no consistent differences across hens were noted. However, the differences between response rates on the rich and lean schedule of each of the multiple schedules were generally greater on the traditional procedure. This difference was reflected in the  $a$  values obtained for overall responding. Generally these were lower when the multiple-multiple procedure was used. This difference may result from behaviour on each multiple schedule of the multiple-multiple procedure also being influenced by the previously presented multiple. However, in general, response rates did reverse across multiple schedules where reinforcement schedules were reversed and the  $a$  values obtained for both procedures were within the range of those obtained in Experiment 1 with a 60-s component duration and with those obtained for conditions with 1 s blackout in Experiment 2.

While the  $a$  values for responding on each successive subinterval of components when the multiple-multiple procedure was used were generally lower than  $a$  values obtained for equivalent subintervals when the traditional procedure was used, the form of the within-components changes in  $a$  values over successive subintervals was similar. Changes in within-component response rates were also similar across the two procedures.

In general the results of the first phase of this experiment indicate that the behaviour observed using a multiple-multiple procedure may differ quantitatively from that which might be observed if the traditional procedure had been employed. However, given that the form of the within-component changes were similar, behaviour observed using a multiple-multiple procedure may be expected to be qualitatively the same as that which would be observed if one multiple schedule was presented in each condition. The use of this procedure may therefore be considered a valid alternative to the procedure used in Experiment 2 provided functional relations between behaviour and an independent variable are considered rather than the actual response rates or values of  $a$ .

The results obtained in this phase may also be viewed as providing confirmation of the robustness of two findings of earlier experiments namely the persistence of within-component changes in response rates, and in values of  $a$ . As found in Experiments 1 and 2 values of  $a$  decreased as function of time since component alternation and local contrast of both forms were evident in all birds' data in at least one multiple schedule. Local negative contrast was observed more consistently than local positive contrast as found in Experiment 2 and in studies by Hunt (1985), Nevin and Shettleworth (1966), McLean and White (1981) and others. The results also may be taken as further confirmation of the finding that  $a$  values which described hens' behaviour on multiple schedules were generally lower than those which describe pigeons' performance on multiple schedules. As the stimuli used in this study have been shown to be easily discriminable by hens, the component duration (60 s) was not unusually large and there was no blackout separating components, the alternative explanations offered in the previous studies for the low  $a$  values evident can not apply to the results obtained here. Thus the low  $a$  values, at least where the traditional procedure was used, may be seen as conclusive evidence that multiple-schedule performance can be influenced by the species used. As previously discussed, the results of some studies using rats as subjects failed to find behavioural contrast under conditions similar to those where contrast has been found with pigeons. In a study by Spealman (1978), which used squirrel monkeys as subjects, positive induction was found under conditions previously found to favour the development of contrast in pigeons.

Thus some previous research also indicates that at least in some circumstances species-related factors may influence multiple-schedule performance. This finding may be viewed as important particularly as other studies have found that concurrent-schedule performance at least with hens as subjects, is similar to that of pigeons. Ideally any explanation of behaviour on multiple-schedules should accommodate such differences.

### Phase II

The aim of this phase was to determine whether the decrease in  $a$  values as a function of increasing blackout duration found in Experiment 2 was a replicable phenomenon. Of particular interest was whether negative  $a$  values could be obtained with longer blackout durations, and if so, whether positive  $a$  values would be obtained if blackout duration was again reduced. The extent to which the results of this experiment replicated those of Experiment 2 can be examined with regard to the four measures of behaviour used. These were, behaviour across components, in terms of response rates and values of the parameters of Equation 4, and behaviour within components, in terms of response rates and values of the parameters of Equation 4.

#### Behaviour across components

When analysed in terms of the Equation 4 two of the birds' data (Hens 21 and 22) may be considered similar to that obtained in Experiment 2. For both these birds,  $a$  values decreased as a function of increasing the duration of the inter-component blackout. For one of these hens  $a$  values became negative. Thus Hen 21's behaviour may be seen as similar to that of Hens 61, 62, 63, 65 and 66 and Hen 22's similar to that of Hen 64. It was noted in Experiment 2, that the decrease in  $a$  values as a function of blackout duration appeared to be functionally related to the  $a$  values obtained for hens' data when the blackout duration was 1 s. The data from Hens 21 and 22 also appear consistent with this relation.

The  $a$  value obtained for Hen 21's data with a 1-s blackout duration was 0.11. This  $a$  value was within the range of the  $a$  values

obtained, with the same blackout duration, for those hens in Experiment 2 whose data from conditions with longer blackout durations were described by negative  $a$  values. For Hen 22's data the  $a$  values obtained with a 1 s blackout duration was 0.31 which was higher than any obtained in Experiment 2. The highest  $a$  value obtained in that experiment was for Hen 64's data and this was the only hen in that experiment whose data at all blackout durations was described by positive values of  $a$ . Although  $a$  values obtained for Hen 21 were negative they were closer to 0.0 than would be predicted on the basis of the relation between positive and negative  $a$  values found in Experiment 2. That is, for hens in Experiment 2, whose data could be described by  $a$  values of similar magnitude to those obtained for Hen 21's data when the blackout duration was 1 s, the magnitude of negative  $a$  values obtained were greater than those found for Hen 21. However, given the results of Phase I of this experiment some quantitative differences between the results of this experiment and Experiment 2 may be expected. In general therefore, the overall  $a$  values for Hens 21 and 22's data replicate in form the findings of Experiment 2.

For Hen 25's data values of  $a$  were not similar to those obtained for either the other hens' data in this experiment or those obtained in Experiment 2. For this hen's data  $a$  values did not appear to decrease consistently as a function of blackout duration.

One other aspect of the data evident in this study and not assessed in Experiment 2 suggests one explanation for this hen's data. In the current experiment, two conditions examined performance with no blackout separating components. With no blackout,  $a$  values for all hens were lower than  $a$  values obtained with 1 s blackout. The blackout in such cases may serve a different function from blackouts of longer duration. For example a blackout of short duration may be regarded as similar to a change-over-delay (COD) in concurrent schedules. That is, the blackout may serve to eliminate any advantageous responding associated with schedule transitions. It may also be the case that the duration of a blackout associated with increases in  $a$  values differs across birds in much the same way as the duration of the COD's, found to be necessary for matching to occur in concurrent-schedule performance, may differ across subjects (Brownstein & Pliskoff, 1968). The difference between Hen 25's data

and that of other birds may be seen as consistent with such a proposal. That is, all birds' data may be described in terms of blackout serving to increase  $a$  values when the duration of blackout is small and then to decrease  $a$  values as the duration is increased beyond some minimal level. For Hen 25, the duration of blackout associated with increased sensitivity, may be longer than that for other hens.

Some aspects of the data are consistent with this explanation. For Hen 25's data the difference between  $a$  values obtained for conditions with no blackout and 1 s blackout was very small and, in general, very little change in  $a$  values was noted for this bird until blackout duration was increased to 60 s. At this duration the  $a$  value for this birds' data increased and the magnitude of this increase was similar to the magnitude of increase observed in  $a$  values for another hen's data between conditions with no blackout and 1 s blackout. The  $a$  value obtained for Hen 25's data for conditions with a 120-s blackout was lower than that obtained for conditions with a 60-s blackout. Although in Experiment 2 no large increases in  $a$  values were noted with initial increases in blackout duration, for Hen 66's data  $a$  values did increase slightly when blackout duration was increased from 1 to 10 s. In this respect the  $a$  values obtained for Hen 25's and Hen 66's data may be seen as similar.

These findings also confirm the suggestion that  $a$  values are not related by a monotonic function to blackout duration. Finding that  $a$  values are not a monotonic function of blackout duration suggests some similarity between the effects of increasing blackout duration and the effects of reducing component duration reported in Experiment 1 and in experiments by Shimp and Wheatley (1971) and Todorov (1972). In these experiments it was found that decreases in component duration increased  $a$  values until some minimal duration was reached. When component duration was then further reduced  $a$  values for some hens' data decreased.

Given that the decreases in  $a$  values reported in Experiment 2 were observed to some extent in the data in this experiment, it would appear that these decreases were attributable to the variation in the duration of blackout. This conclusion gains further support in

that, in this experiment,  $a$  values for one of the hens decreased and became negative when blackout duration was increased from 1 s to 60 s, but then increased and became positive when blackout duration was reduced to 0 s. For this hen's data  $a$  values again decreased and became negative when the blackout duration was again increased. Thus the  $a$  values obtained were clearly related to the blackout duration rather than the order of conditions. For the other two hens' data the contribution of blackout duration to the effects observed was less clear.

For Hen 25's data  $a$  values obtained increased as blackout duration was increased to 60 s, and then did decrease again when blackout duration was reduced to 0 s, such that values of  $a$  were similar to those obtained with a 1 s blackout. However when blackout duration was increased to 120 s  $a$  values did not increase. Thus  $a$  values for this birds' data, at 120 s blackout, were lower than  $a$  values for conditions with 60 s blackout duration. While this decrease in  $a$  values may be attributable to the increase in blackout, as suggested above, given that the previous increases in blackout lead to increased  $a$  values, it is possible that the decrease seen in both of the later conditions was the result of increased number of prior conditions. For Hen 22's data  $a$  values obtained for all blackout durations, which allow some assessment of the relative effects of the order of conditions versus blackout duration (that is conditions with 0 s, 60 s, or 120 s blackout) were similar.

In general, given the similarity of the results obtained here to those obtained in Experiment 2, and the clear relation between  $a$  values and blackout duration evident in Hen 21's data, it is reasonable to conclude that changes in  $a$  values observed were largely attributable to changes in blackout duration.

However, for all birds' data, values of  $a$  for later conditions, may also have been affected, to some extent, by previous conditions. The values of  $a$  obtained with 0 s blackout were generally slightly different from those obtained for data from Condition 1 of Phase I (this condition also used the multiple-multiple procedure with no blackout separating components of the multiple schedules). Moreover, the direction of the difference in  $a$  values was related to the trend in  $a$  values evident in the immediately preceding

conditions (Figure 3.5). That is, for 21's and 22's data  $a$  values decreased when blackout duration was increased and when blackout duration was subsequently reduced to 0 s the values of  $a$  obtained for these hens' data were lower than the  $a$  values obtained in Condition 1, Phase I. For Hen 25 the opposite pattern was observed. That is,  $a$  values increased when blackout duration was increased to 60 s and the  $a$  values for this hen's data when blackout duration was then decreased to 0 s were higher than that obtained in Phase I.

In general when examined in terms of  $a$  values, it may be argued that the behaviour across components observed in this experiment was similar to behaviour observed in Experiment 2. However, if absolute response rates for overall responding are examined differences between the results of the experiments are evident.

In Experiment 2 response rates on the lean schedule tended to increase as a function of increasing blackout duration and then level off while response rate on the rich schedule tended to either decrease or remain at a similar level with initial increases in blackout and then increase. Negative  $a$  values appeared to be a result of response rates on the lean schedule increasing more, or at smaller blackout durations, than response rates on the rich schedule.

In the current experiment, response rate changes were generally smaller and more variable across birds and multiple schedules. For Hen 21 response rates on both rich and lean schedules were higher when a 1-s blackout duration separated components, compared to response rates when no blackout separated components. At all other blackout durations response rates on the lean schedule were generally similar while response rates on the rich schedule decreased. Thus, although for this bird's data negative  $a$  values were obtained, the changes in response rates contributing to these  $a$  values were considerably different from those typically observed in Experiment 2.

For Hen 22 a different pattern of response rates were observed. For this hen response rate changes on the rich and lean schedules varied across multiple schedules. However, in general, the changes in  $a$  values appeared to be the result of lean schedule response rates

increasing and rich schedule response rates decreasing. Thus the decrease in  $a$  values found in this experiment appeared to be independent of a particular pattern of within-component changes. In Experiment 2 four hens' response rates increased on the equal schedule pair. This effect was also not evident in the current experiment.

### Behaviour Within Components

When changes in behaviour within components were analysed in terms of Equation 4 some of the results of this experiment can be seen as similar to the results obtained in Experiment 2. For the data from Hens 21 and 22  $a$  values decreased across successive subintervals of a component when no blackout separated components and as blackout duration was increased this decrease in  $a$  values was attenuated. For Hen 22's data the decrease in values of  $a$  over successive subintervals was re-established when blackout duration was increased to 60 s. Hen 21's data can thus be seen as similar to that of Hens 61, 63 and 66 in Experiment 2, and Hen 22's data similar to that of Hens 62, 64 and 65.

Two aspects of the data were different from those found in Experiment 2. Firstly, for Hen 25's data, the decrease in  $a$  values over successive subintervals was attenuated as blackout duration was increased from 1 s but remained evident at all blackout durations. This finding may be reconcilable with the results of Experiment 2 if the range of blackout durations over which the effects were seen are considered. In the current experiment, the longest blackout duration was 120 s, while in Experiment 2 the longest blackout was 297 s. The duration at which the decrease in  $a$  values across successive subintervals was eliminated in Experiment 2 varied across hens. For one hens' data, Hen 66, this effect was not observed until the blackout duration was 180 s. It is possible therefore, that the change in  $a$  values over successive subintervals was not eliminated in Hen 25's data as a result of the the duration of blackout not being increased sufficiently.

Secondly, in this experiment, while changes in  $a$  across successive subintervals were noted when no blackout duration separated components, the effect was eliminated in two birds' data (Hens 21

and 22) when the blackout was only 1 s in duration. In Experiment 2 decreases in  $a$  values across subintervals were noted for all hens' data when blackout duration was 1 s. As already discussed the values of  $a$  obtained when a multiple-multiple procedure is used may be expected to be different from  $a$  values obtained when one multiple schedule is presented per condition. It may also be reasonable to suggest that changes in  $a$ , as a function of an independent variable, will also occur at different values of that variable. Thus finding that the within-component decrease in  $a$  values was eliminated at different durations of blackout in the two experiments may not seriously question the generality of the finding.

However, in the current experiment, when the blackout duration was 1 s, the decrease in  $a$  values over successive subintervals was not only eliminated for Hen 22's data but for this hen's data at this blackout duration the opposite effect was evident. That is, the  $a$  values increased across successive subintervals of a component when blackout duration was 1 s. A similar effect was noted in Hen 21's data when the blackout duration was 120 s. In Experiment 2 a change in  $a$  values across successive subintervals of this form was not present in any of the subjects' data. The increase in  $a$  values over successive subintervals occurred for each of the two hens at only one blackout duration, and this duration was different across the two hens. Thus this finding may be considered less important than the other aspects of the data which were common across hens.

However such a pattern was also noted in one of the hen's data in Experiment 1, and serves to demonstrate that values of  $a$  for overall responding are not necessarily related to a particular pattern of within-component changes in  $a$  values. This is also confirmed by Hen 25's data. For that hen's data changes in  $a$  values over successive subintervals were similar at all blackout durations, while  $a$  values for overall responding both increased and decreased with changes in blackout duration.

This independence of within-component changes to overall changes in  $a$  values was also noted to some extent in Experiment 2. In that experiment, however, the attenuation of the within-component effects occurred over conditions where  $a$  values for overall responding decreased. In the current experiment the elimination of within-component effects in two of the hens' data, when a blackout of 1 s

was inserted between components, corresponded with an increase in  $a$  values for overall responding. Thus the independence of overall changes in  $a$  from a particular pattern, or change in pattern, of within-component effects was more clearly demonstrated.

Within-component changes in behaviour may also be considered in terms of changes in absolute response rates as measured by values of  $D$ . In the current experiment changes in  $D$  as a function of blackout duration were variable both across birds and within birds but across multiple schedules. For example, for Hen 21's data, values of  $D$  changed as a function of blackout duration such that, at the longest duration, values of  $D$  for all component schedules became positive. For Hen 22's data, changes in  $D$  were observed in both component schedules of all multiples but the direction and magnitude of these changes varied across multiples and did not appear to be related by a monotonic function to blackout duration. It is also notable that values of  $D$  obtained for data from Condition 10 of this phase where no blackout separated components, did not replicate those obtained in Condition 1 of the first phase of this experiment. In general these results confirm the finding, in Experiments 1 and 2, that within-component changes in  $a$  are independent of a particular pattern of response rate changes on the rich, lean and equal schedules. For example, for some birds, values of  $a$  decreased over successive subintervals of a component as a result of response rate on the lean schedule increasing while response rate on the rich decreased. For others, a similar change in  $a$  values resulted from response rate on the lean schedules increasing while response rate on the rich remained the same.

In general, although quantitative differences were noted, many of the changes in behaviour observed in this study, as a function of blackout duration were similar to those found in Experiment 2. In these respects the results of this study support the results of Experiment 2. They can also, in some respects, be seen to extend these findings.

Firstly, as discussed, many of the effects seen in Experiment 2 were observed in this experiment, although this experiment employed a different procedure and component duration. Secondly, because blackout duration was increased, decreased and then increased again,

the changes in behaviour observed in the current experiment were more clearly the result of the changes in blackout duration. Thus it appears that the decrease in  $a$  values for overall responding may be attributed to the change in blackout duration. That such a decrease can, although it does not necessarily, lead to  $a$  values becoming negative was also confirmed by the findings of this experiment. Thirdly, the attenuation of the decrease in  $a$  values within a component may similarly be attributed to blackout duration changes. Hen 22's data also suggest that the finding, that in some instances the decrease in  $a$  values within components may be re-established, may also be attributed to the change in blackout duration. Fourthly, the results of this study clearly demonstrate that changes in overall values of  $a$  were not necessarily related to within-component changes in  $a$ .

Some of the results obtained in Experiment 2 were not supported by the results of the current experiment. The increase in  $a$  values at longer blackout durations seen in Experiment 2 was not confirmed by the results of this experiment. However the very long blackout durations used in that study were not replicated in the current experiment. For two hens' data (Hens 21 and 25)  $a$  values decreased between the longest two blackouts examined. For Hen 22's data  $a$  values appeared to have fallen to an asymptotically low value, in that increases in blackout duration beyond 30 s lead to no further decreases in  $a$  values. It might therefore be expected that if further increases in blackout duration could lead to increases in  $a$  values then they would have been observed in this hen's data. However, the changes in  $a$  values for this hen's data were similar to those in Hen 64's data in Experiment 2. No increase in  $a$  values were observed in that hen's data at the longer blackout durations. Therefore, while decreases in  $a$  values may be seen as a function of blackout duration, no conclusive statement may be made regarding subsequent increases in  $a$  values seen in Experiment 2 for some birds' data.

Although for one bird a somewhat different pattern of behaviour was observed, in general, the results of Experiment 2 suggested the change in  $a$  values could be attributed to a particular pattern of changes in absolute response rates. The results of this experiment did not indicate a similar relation.

The results obtained for Hen 25 and for all birds for conditions with no blackout versus those obtained with 1 s blackout also suggest that the effects of blackout duration may require some qualification. In general, it appears that an inter-component blackout can increase  $a$  values when blackout duration is short, and decrease these as blackout duration is increased. The duration of the blackouts which lead to increases or decreases in  $a$  values may vary across birds.

### Conclusion

If behaviour is examined in terms of  $a$  values the results of this experiment generally confirm the findings of Experiment 2, and thus may be seen to support conclusions made in that experiment regarding the use of the GML to describe the multiple-schedule performance observed in these studies. In Experiment 2 it was suggested that interpretation of the results of that experiment may require recourse to some variable other than reinforcement rate in the alternative component, and that the process underlying the  $a$  values obtained may be different from that implicit in the GML. One possible explanation of the results offered, was that behaviour could be understood in terms of reinforcement for extraneous behaviour and various mechanism by which this variable might effect performance were suggested. The validity of these explanations however require further examination in as far as they were related to changes in absolute response rates not observed in this study.

## GENERAL DISCUSSION

Past research suggests that the extent to which relative response rates on multiple schedules change when relative reinforcement rates are changed, is influenced by the temporal proximity of the component schedules. In general, when component duration is reduced relative response rates more closely approximate relative reinforcement rates. If components are separated in time changes in relative response rates become less extreme than would be predicted by changes in reinforcement rates. It was originally hypothesised that such effects could be attributable to sensitivity to relative reinforcement rates declining as a function of time since component alternation, independently of the time a component was available. Shortening component duration was thus seen as being equivalent to sampling a portion of that function where sensitivity was higher. Increasing the duration of an inter-component blackout was seen as equivalent to sampling a portion of that function where sensitivity was lower.

The results of the three experiments in this study did not support this hypothesis. Moreover the results of Experiments 2 and 3 suggest that the use of the GML as an explanation of behaviour in these experiments may be questionable, and that the parameter  $a$  may not reflect sensitivity to relative reinforcement rates as it is usually interpreted. In the discussion of Experiment 2, it was suggested that behaviour on multiple schedules may be better understood in terms of the availability of reinforcers for other behaviour, and that the apparent relation between relative reinforcement and response rates may in part be an artifact of the relation between reinforcers for other behaviour and reinforcers in the component schedules. It was further suggested that changes in  $a$  values could be attributed either to the salience of reinforcers in an alternate component compared with the reinforcers available for other behaviour changing, or to changes in the reinforcement rate for other behaviours.

A number of theories proposed to explain behaviour on multiple-schedules are, to various degrees, compatible with one or other of these propositions. The results of the experiments of this dissertation were thus examined in terms of these theories. Each of

these theories rely to varying extents on the assumption that other behaviours and reinforcers are present when animals work in an experimental chamber. Thus the validity of this assumption is also discussed.

### Herrnstein's Context of Reinforcement

Herrnstein (1970) proposed a series of related equations to describe single, concurrent and multiple schedule performance. Response rates on single schedules were described by Equation 7, where

$$B_1 = \frac{k R_1}{R_1 + R_e} \quad (7)$$

$B_1$  and  $R_1$  represent response rate and reinforcement rate for the operant behaviour, and  $R_e$  reinforcement rate for other behaviours.  $k$  is a constant which represents asymptotic response rate (i.e the total number of responses possible in a given time period) and in the case of single schedules is equivalent to  $B_1 + B_e$  where  $B_e$  is a measure of other behaviour in units of  $B_1$ .

Herrnstein's equation for concurrent-schedule performance can be seen as a simple extension of this equation. Responding on each component schedule of a two component concurrent schedules is expressed as

$$B_1 = \frac{k R_1}{R_1 + R_2 + R_e} \quad (8)$$

where  $B_1$ , and  $R_1$  represent response rate and reinforcement rate respectively, associated with the component of interest and  $R_2$  and  $R_e$  reinforcement rate in the alternate component and for other behaviour.  $k$  again represents an asymptotic response rate which in units of the  $B_1$ .

Three assumptions are implicit in these equations. These assumptions are; one, that animals will strictly match relative response rate to relative reinforcement rates; two, that in addition to operant reinforcers, reinforcers for other behaviours (e.g., wing flapping, scratching etc.) exist and three, that the total output of behaviour in a given time period will be constant. Herrnstein suggests Equation 8 can be modified to describe multiple schedule

performance by the addition of an interaction parameter  $m$  as in Equation 9.

$$B_1 = \frac{k R_1}{R_1 + mR_2 + R_e} \quad (9)$$

As defined by Herrnstein, the parameter  $m$  should range between 0 and 1 and is a measure of the extent to which reinforcers for the operant response in one component influence behaviour on another. Where  $m$  is equal to 1.0, strict matching between relative response rates and relative reinforcement rates will occur. Where  $m$  is less than 1.0, undermatching will occur. When  $m$  equals 1.0, Equation 8 becomes equivalent to Equation 9. Herrnstein thus suggested that Equation 9 could be used to describe both multiple and concurrent-schedule performance and that the differences between performance on the two types of schedules could be primarily understood in terms of the parameter  $m$ . However, it is apparent that the changes in  $a$  values with changes in component or blackout duration could have occurred if either of the two free parameters,  $m$  and  $R_e$ , changed as function of component and blackout duration. Changes in  $m$  would imply that the salience of reinforcement rates in the alternate component changed, while changes in  $R_e$  would reflect changes in the reinforcement rates for other behaviour.

#### Changes in $m$

In discussing his equations Herrnstein proposed that changes in the temporal proximity of schedules should influence  $m$ , in that values of  $m$  should become closer to 1 as the temporal proximity of schedules is increased. Qualitatively the increases in  $a$  values observed in Experiment 1 when component duration was reduced are consistent with this prediction. In so far as increasing the duration of the inter-component blackout may be interpreted as decreasing the temporal proximity of alternative reinforcers, the decrease in positive  $a$  values as blackout duration was increased may also be considered consistent with this. However, as previously discussed, decreases in negative  $a$  values imply that changes in relative response rates become more closely related to changes in relative reinforcement rates. Thus the decrease in  $a$  values such that  $a$  values became progressively more negative is not consistent with Herrnstein's proposal.

In quantitative terms, the results of the experiments in this thesis cannot be explained purely in terms of changes in  $m$ . Regardless of the initial or subsequent value, no change in  $m$  would result in a change from positive to negative values of  $a$  as seen in five hens' data in Experiment 2, and one hen's data in Experiment 3. Even where  $a$  values remain positive, as seen in all hens' data in Experiment 1 and for some hens' data in Experiments 2 and 3, the changes observed as a function of blackout or component duration can be shown to be incompatible with changes in  $m$ .

As  $m$  becomes closer to 1.0 the bottom line of Equation 9 for both component schedules would increase and thus response rates on both schedules must decrease. Matching between relative response rates and relative reinforcement rates would obtain because the response rate on the schedule with the leaner reinforcement rate would decrease more. As values of  $m$  decrease absolute response rates would change in the opposite direction with the greatest change again occurring in the leaner schedule. The behaviour of some hens across some conditions in Experiment 2 may be seen as consistent with these predictions. That is, for some hens' data, as blackout duration was increased,  $a$  values decreased and absolute response rates in both schedules increased with the increase being greater on lean schedule (e.g., Hen 64, Figure 2.1). The increase in response rates on both components of the equal schedule pair, as a function of blackout duration, may also be seen as consistent with the proposition that  $m$  decreased as blackout duration increased. These effects were not however noted in all hens' data across all blackout durations in Experiment 2 (e.g., Hen 66 Figure 2.1) and were not observed in Experiment 3.

Similarly, the changes in absolute response rates evident when  $a$  values increased in Experiment 1 were inconsistent with this proposition. That is, response rates in both schedules did not decrease when  $a$  values increased. The change in the degree to which relative response rates 'matched' relative response rates seen in these experiments cannot therefore be attributed to changes in  $m$ .

This finding is not however surprising in that previous studies which have found increases in the degree to which relative response rates matched relative reinforcement rates, also did not show

corresponding decreases in response rates. Edmon (1978) re-analysed the data from Shimp and Wheatley (1971) and Todorov (1972) and reported that as component duration was reduced, response rates on the richer schedules increased, while little change was observed on the leaner schedules. Similar changes in rich schedule versus lean schedule response rates with increases in the degree to which animals' relative response rates matched relative reinforcement rates were reported by Charman and Davison (1982), Silberberg and Schrot (1974), Mackintosh, Little and Lord (1972) and others.

### Changes in $R_e$

If  $R_e$  is the same for both components as initially proposed by Herrnstein (1970), and  $m$  is equal to 1.0, then the relation between relative response and reinforcement rates would remain the same regardless of the value of  $R_e$ . If  $m$  is less than one, and  $R_e$  is the same in both components, then as  $R_e$  increases relative response rates will more closely approximate relative reinforcement rates. That is, values of the parameter  $a$  in the GML will become closer to 1.0. These features of Equation 9 may be seen to be of particular interest. If, as suggested by Herrnstein, the value of  $m$  for concurrent-schedule performance will be 1.0 while for multiple schedule performance values of  $m$  will be less than 1.0 then any variable which will affect  $R_e$  will influence the degree to which relative response rates match relative reinforcement rates on multiple schedules but not on concurrent schedules. In as far as changing the temporal proximity of reinforcements involves changes in  $R_e$  this proposition can be seen to support the suggestion that multiple schedule performance may be influenced by temporal proximity of alternative reinforcement rates while concurrent schedules may not. In the discussion of Experiment 2 it was suggested that as the duration of blackout increased, more reinforcers for other behaviour may be 'moved' into the blackout period such that  $R_e$  would become lower with increases in blackout duration. If this did occur, then at least in Experiment 2, the changes in  $a$  values may be related to changes in  $R_e$ . However, as with changes in  $m$ , Equation 9 implies specific changes in absolute response rates with changes in  $R_e$  and these predictions are also inconsistent with the changes in absolute response rates observed. Regardless of the value of  $m$ , Equation 9 predicts that response

rates on both rich and lean schedules, would decrease as a function of increases in  $R_e$ . If  $m$  is less than one, then closer matching between relative response rates and relative reinforcement rates would obtain because the proportional decrease on the lean schedule would be greater. Thus changes in the  $a$  values as a result of changes in  $R_e$  would require the same direction of change in absolute response rates as that predicted by increases in  $m$ . As discussed the changes in absolute response rates in these experiments were not consistent with this prediction.

In general, while the changes in  $a$  values in as far as they remained positive, observed in this dissertation may be seen as qualitatively consistent with Herrnstein's formulation of multiple-schedule performance, the data from the experiments were not consistent with the quantitative predictions of his equations. This finding supports the results of a number of other experiments which have found other discrepancies between the predictions of Equation 9 and changes in absolute response rates observed (e.g. Charman & Davison, 1983; Hinson & Staddon, 1978; McSweeney, 1980; Spealman & Gollub, 1974). Previous writers have also pointed out that Herrnstein's equations are logically inconsistent (Davison & McCarthy, 1988).

Given that response rate for both other behaviour and the operant behaviour in each component of a multiple schedule are described by Equation 9 then the total responses in a component may be described by Equation 10.

$$B_1 + B_{e1} = \frac{k(R_1 + R_{e1})}{R_1 + mR_2 + R_{e1} + mR_{e2}} \quad (10)$$

If  $k$  is a measure of total behaviour in each component then  $B_1 + B_{e1}$  must equal  $k$ . If this is so, then Equation 10 implies that  $R_1 + R_{e1}$  equals  $R_1 + mR_2 + R_{e1} + mR_{e2}$  and this can only be true if  $m$  is 0. If  $k$  is a measure of total behaviour across components, then for a two component multiple schedule with equal component lengths  $B_1 + B_{e1} + B_2 + B_{e2}$  must equal  $k$ . Thus  $R_1 + R_{e1} + R_2 + R_{e2}$  must equal  $R_1 + mR_{e1} + R_2 + mR_{e2}$ . For this to be true  $m$  must equal 1.0. Thus if  $k$  is assumed to be a measure of total behaviour, either within or across components, in a given time period,  $m$  can be only 0.0 or 1.0. The parameter  $m$  therefore cannot be a measure of the extent to which

reinforcements in one component influence behaviour in another component as it was intended to be by Herrnstein.

A number of other models have been proposed which, while sharing several features of Herrnstein's model, have attempted to eliminate some of the problems faced by his equations both in terms of the logical inconsistency and their incompatibility with a number of experimental results.

#### Williams' Averaging Model

Williams (1983) proposed that performance on a two-component multiple schedule could be described by Equation 11, given below, where  $R_1$ ,  $R_2$ ,  $R_e$ ,  $B$ , and  $m$  are as defined as in Equation 9.

$$B_1 = k \frac{R_1}{\frac{R_1 + mR_2}{1 + m} + R_e} \quad (11)$$

In this equation response rate on each component of a multiple schedule can be predicted on the basis of the rate of reinforcement in that component, relative to the average rate of reinforcement for the two components and the rate of reinforcement for other behaviour. Williams states that in this model  $k$  is not a measure of total behaviour and thus the logical inconsistency described above may not apply. Williams does not, however, define what  $k$ , as it is used in Equation 11, does measure.

Unlike Equation 9, Williams' equation predicts that, where reinforcement rates in the two components differ, as  $m$  becomes closer to 1.0, response rates on the richer schedule will increase while response rates on the leaner schedule will decrease. If reinforcement rates on the component schedules are equal, response rates will decrease as a function of increases in  $m$ . The changes in absolute response rates as a function of component duration seen in Experiment 1 are, in general more consistent with these predictions than those of Equation 9. However the data from all birds across all component durations are not consistent with these predictions. For example, for Hen 53's data  $a$  values increased when component duration was reduced from 30 s to 15 s and response rates on the rich schedules increased but response rates on the lean schedules either also increased or did not change. Similarly changes in some

birds' response rates across some blackout durations may be seen as consistent with the proposition that changes in  $a$  values result from changes in the values of  $m$  in Equation 11. For example, for Hen 62's data when blackout duration was increased from 1 s to 10 s the values of  $a$  obtained decreased. Response rates generally increased on the lean schedules and decreased on the rich schedules as would be expected if this change in  $a$  values related to a decrease in  $m$ . However, changes in response rates that were previously noted to be consistent with Herrnstein's equations are not consistent with changes in  $m$  in Equation 11.

While changes in absolute response rates implicit in Equation 11, when  $m$  changes are different from those implied by Equation 9, both equations predict the same changes in behaviour with changes in  $R_e$ . As the results of the three experiments reported in this dissertation cannot be explained in terms of changes in  $R_e$  in Equation 9 nor can they be described in terms of changes in  $R_e$  in Equation 11.

Given that no hen's data were entirely consistent with the predictions of Equation 9 or 11, such instances where behaviour did change as would be predicted by changes in  $m$  or  $R_e$  in these equations may be regarded as coincidental. Charman (1983) also reports that neither Herrnstein's nor Williams' equations could accommodate the data from a series of experiments examining the effects of a number of variables on multiple schedule performance.

In the preceding discussion of Herrnstein's and Williams' equations  $R_e$  has been assumed to be equal in both components. Herrnstein however indicated that future research may reveal this assumption to be incorrect. Three other theories of multiple schedule performance while sharing some features of Herrnstein's model have explicitly suggested that  $R_e$  may differ across components.

#### Staddon - Behavioural Competition

Staddon (1982) offers an alternative model of multiple-schedule performance which maintains the notion that relative reinforcement rate is the major controlling variable underlying multiple-schedule and concurrent-schedule performance. Essentially, Staddon's model

states that; 1) the defined operant responses and other behaviours will take up all available time and thus behaviours compete for this time, and 2) reinforcements for a particular behaviour will suppress other behaviours in direct proportion to their rate of occurrence. Given equal sensitivity to the alternative reinforcers, these two assumptions imply that behaviour will be allocated such that the number of any particular response made per reinforcer is the same as the number of any other response per reinforcer. Thus, performance on a two-component concurrent schedule can be described by Equation 12

$$\frac{R_x}{x} = \frac{R_y}{y} = \frac{R_e}{e} \quad (12)$$

In this equation  $R_x$  and  $R_y$  refer to reinforcement rate in the two components,  $R_e$  the reinforcement rate for other behaviour and  $x$ ,  $y$  and  $e$  the corresponding response rates. This equation implies strict matching. Staddon suggests that the same principles apply in multiple-schedule performance, but that such performance will be influenced by time constraints. Staddon suggests that these time constraints are responsible for the undermatching typically observed on multiple schedules.

In concurrent schedules the time allocated to any one response is limited only by the total session time. In multiple schedules the total time that can be allocated to other behaviour is limited only by the total session time but the maximum time that can be allocated to behaviours associated with  $R_x$  or  $R_y$  is the time that a component is available. For Equation 12 to be true, when  $R_x$  is greater than  $R_y + R_e$  then more than 50 per cent of the time available must be allocated to the response associated with  $R_x$ , (X). However, on multiple schedules with equal component durations the maximum time that can be allocated to that response will be 50 percent of the total time, in Staddon's terminology, X has saturated. A similar situation will apply if  $R_y$  is greater than  $R_x + R_e$ . It follows from this analysis that matching between relative response and reinforcement rates can occur on multiple schedules only when reinforcement rates in both components are less than the sum of the reinforcement rate in the other component and the reinforcement rate for other behaviours. In all other situations undermatching will obtain.

One of the implications of this model is that, provided reinforcement rate in one component is greater than the sum of  $R_e$  and the reinforcement rate in the other component, then increases in  $R_e$  will result in relative response rates becoming closer to relative reinforcement rates. In terms of the GML  $a$  values will become closer to one as  $R_e$  increases.

The fundamental difference between Staddon's and Herrnstein's model is in the mechanism by which undermatching or matching is assumed to be obtained. Herrnstein assumes that the degree to which matching occurs is primarily related to the extent to which reinforcement rate in one component influences behaviour in another component. In Staddon's model the influence of relative reinforcement rates for the defined operant responses is seen as being constant, while the degree to which matching occurs is related to the rate of reinforcement for other behaviour relative to the rates of reinforcement for the operant behaviour. However, as discussed, Herrnstein's model also predicts changes in the extent to which relative response rates match relative reinforcement rates with changes in  $R_e$ . Analysis of the absolute response rate changes predicted by Herrnstein's model revealed that the results of the experiments in this thesis could not be explained in terms of changes in  $R_e$  in Equation 9. The effect on absolute response rates of changes in  $R_e$  within the context of Staddon's model were also examined.

If total output of behaviour in a given time period is constant and behaviour is related to reinforcement rates as in Equation 12, then increases in  $R_e$  in both components while both  $R_x$  and  $R_y$  are constant will lead to decreases in  $x$  and  $y$ . That is, because  $R_e$  increases relative to  $R_x$  and  $R_y$ ,  $e$  must increase relative to  $x$  and  $y$ . However if the time period in which responses can occur remains constant, this increase in  $e$  must be offset by decreases in  $x$  and  $y$ . Thus with increases in  $R_e$  absolute response rates in both components may be expected to decrease. This prediction is the same as Herrnstein's and, as discussed, the results of the present series of experiments are not consistent with this.

However Staddon's model also predicts that  $e$  and therefore  $R_e$  will differ across components. This situation is clear if, for example,

behaviour in a one hour session on a two component multiple schedule is examined where  $R_e$  is 50 reinforcers per hour,  $R_x$  is 40 reinforcers per hour,  $R_y$  is 10 reinforcers per hour and total output per hour in units of the operant response is 400. In this situation X must equal 160, Y must equal 40 and E must equal 200. However, as behaviour takes up all available time, then more of the 200 units of other behaviour must be allocated to the component associated with Y and less to the component associated with X. That is, the amount of other behaviour in each component will be inversely proportional to the relative reinforcement rate in each component. When considered in isolation, this aspect of Staddon's model does not substantially alter predictions relating to absolute response rates, but when combined with what Staddon terms the dynamic aspects of his model it may.

Staddon proposed that changes in  $R_e$ , within the context of his model, can account for both the changes in absolute response rates and  $a$  values typically observed within-components, and the increases in the magnitude of contrast and  $a$  values for overall responding found with short components. Specifically, Staddon argues that reinforcers for the operant response are typically food and that, as animals are usually food-deprived, they will not satiate with respect to these reinforcers over the duration of components. Other reinforcers are seen to be less important and argued to be subject to relatively rapid deprivation and satiation effects such that  $R_e$  may change over the duration of a component. As explained above, more other behaviour will occur during a leaner component than in a richer component. However if  $R_e$  changes as a function of the rate of other behaviour (i.e.,  $R_e$  satiates) then  $R_e$  will decrease as a function of time in the lean component and increase as a function of time in the rich. The effects of such changes in  $R_e$ , if  $R_x$  and  $R_y$  remain constant, will be a decrease in the rate of the defined operant in the rich component as a function of time since component alternation and an increase in the rate of the operant in the lean component as a function of time since component alternation.

Staddon argues that satiation and deprivation is more likely to affect  $R_e$  given long components and the changes in other behaviour associated with changes in  $R_e$  are incompatible with overall matching. That is response rate would be higher at the end of a

lean component and lower at the end of a rich component than would be predicted by matching. Thus, in qualitative terms Staddon's model predicts that values of  $\alpha$  will be higher with short components and this effect is related to within-component response rate changes.

Several aspects of the data obtained in the Experiment 1 cannot be accommodated by Staddon's analyses. Firstly, while Staddon presumes that changes within components as a result of deprivation and satiation would be more likely to occur with longer components, the changes in response rates as a function of time since component alternation were generally greater when component duration was short. Moreover, as the magnitude of changes within components differed with component duration, it would have to be assumed that the deprivation-satiation process also varied with component duration. It may also be argued that the magnitude of changes in response rates over periods as short as 3 s may be difficult to explain in terms of satiation or deprivation. However, as the nature of any 'other' behaviours and their reinforcers are largely unknown it may be possible that they can satiate within such a time frame.

Secondly, although response rates within components for three of the four hens did change in the predicted direction, for one hen (Hen 54) the change in absolute response rates in some conditions was in the opposite direction from that predicted by Staddon.

Thirdly, if the data from the three birds, whose behaviour may be considered more consistent with Staddon's predictions, are examined it can be seen that for these hens changes in absolute response rates within components were also variable. That is, in some conditions for some birds, response rates on a lean schedule decreased as a function of time since component alternation while response rates on the rich schedule remained at a similar level throughout a component. For the same birds in other conditions or for different birds in the same condition the opposite pattern was observed.

In general, therefore, the data from Experiment 1 are consistent with Staddon's model only if the satiation-deprivation process

varies considerably across hens and as a function of component duration. As no attempt to measure 'other' behaviour was undertaken it may be possible that the changes observed in Experiment 1 were the result of changes in  $R_e$  consistent with a satiation-deprivation process but this possibility may be regarded as unlikely.

The changes in  $a$  values for overall responding in Experiment 2 are also difficult to explain in terms of Staddon's model. The decrease in  $a$  values could be expected if  $R_e$  in both components was decreased. This could occur as a result of progressively more other behaviour occurring in the blackout period as suggested earlier. It may also be argued that as the blackout duration was increased that all  $R_e$  may be allocated into the blackout. Given that components were of equal duration and behaviour is presumed to take up all available time then the observed response rates on the two components would be expected to become closer together. That is  $a$  values would approach zero. However, as discussed, this effect would also require that response rates in both components increased as  $a$  values decreased and such increases were not observed consistently in Experiment 2, and rarely in Experiment 3. For example, for Hen 66 response rates increased as component duration was initially increased but values of  $a$  for overall responding increased. In later conditions response rates for this bird decreased while overall  $a$  values decreased.

The results of Experiment 2 are not easily compatible with differential changes in  $R_e$  within components as a function of satiation or deprivation cycles. For example, if other behaviour occurred primarily in the blackout, then  $R_e$  might be expected to be low at the beginning of both components and then increase. This would imply that response rates at the beginning of both components would be high and then decrease. However, in general in this experiment, response rates on both rich and lean schedules were initially low and then increased. Alternatively, it may be argued that  $R_e$  would change within a component as a result of satiation and deprivation effects when blackout duration was short, but that with increases in blackout duration all reinforcers for  $R_e$  may be obtained during the blackout, so that  $R_e$  did not change at all during a component. This would imply that within-component changes in absolute response rates would be eliminated by increases in

blackout duration. While such effects were observed in some hens' data other patterns, as described above, were observed in other hens' data. For two hens data in Experiment 3, the within-component changes in responding were eliminated by a 1 s period of blackout. It is unlikely that all reinforcement for other behaviour could be obtained in this time.

Finally, even if the changes in  $a$  values such that  $a$  values became closer to zero could be understood in terms of other behaviour occurring in the blackout period, it is difficult to explain how the negative  $a$  values might be obtained. Negative  $a$  values could be accommodated only if the rate of other behaviour was higher in the rich component than in the lean, so that response rate for the operant response was lower in the rich component than the lean. However, such behaviour would be contrary to the predictions of Equation 12 which Staddon suggests underlies performance. That is, Staddon suggests that relative response rates will match relative reinforcement rates. Deviations from matching will occur only through the constraints of time and through changes in  $R_e$  that result from a satiation-deprivation process, which is related to the allocation of more 'other' behaviour to a component with the leaner reinforcement rate. In general, the changes in  $a$  values observed may be predicted by differential changes in  $R_e$  in the component schedules. However, the nature of the changes in the allocation of other behaviour required to explain these results are not entirely consistent with the mechanisms proposed by Staddon to explain such variations.

#### McLean and White - Successive Independence

More recently another model of multiple schedule performance has been suggested by McLean and White (1983). Using a procedure where a single VI schedule was available concurrently with each component of a multiple schedule Mclean and White (1983) demonstrated that behaviour on each component of a multiple schedule could be described as a power function of the reinforcement rate in that component, relative to reinforcement rate in the concurrently available VI. They further showed that behaviour in one component was independent of relative reinforcement rates on the schedules in the other component. Assuming that the concurrently available VI

schedule is analogous with  $R_e$ , McLean and White concluded that that responding in each component of a multiple schedule may be described in terms of the relative reinforcement rates available for the operant response and 'other' behaviour in that component.

Responding in one component is thus predicted to be independent of reinforcement rates in another component. Operant responding in one component of a multiple schedule is thus described by Equation 13:

$$\frac{B_{m1}}{B_{m1} + B_{e1}} = \frac{R_{m1}^a}{R_{m1}^a + cR_{e1}^a} \quad (13)$$

This equation represents a generalised form of Herrnstein's equation for single schedules.  $B$  is response rate in component 1,  $R$  reinforcement rate in component 1 and the subscripts  $m$  and  $e$  refer to the operant and other behaviours respectively. The exponent  $a$  is a measure of concurrent schedule sensitivity, the parameter  $c$  reflects bias between the operant and other behaviours.

The studies of behavioural contrast outlined in the general introduction of this thesis which indicated a relation between responding on one schedule and reinforcement rate on another, appear inconsistent with this proposition. However Mclean and White (1983) demonstrate that their model can, in some circumstances, predict a relation between response rates on component schedules and the relative reinforcement rate for these.

If  $B_{m1} + B_{e1}$  is defined as  $k$  then Equation 13 can be written as

$$B_{m1} = \frac{k R_{m1}^a}{R_{m1}^a + cR_{e1}^a} \quad (14)$$

Similar equations may be derived to describe  $B_{e1}$ ,  $B_{m2}$  and  $B_{e2}$ , where  $B_{m2}$  and  $B_{e2}$  refer to rates of the operant and other behaviours on the second component of a two-component multiple schedule. If, for each of these derived equations  $k$  is the same, then behaviour in both components of a two component multiple schedule can be described by Equation 15.

$$\frac{B_{m1}}{B_{m2}} = \left[ \frac{R_{m1}^a}{R_{m2}^a} \right] \times \left[ \frac{R_{m2}^a + cR_{e2}^a}{R_{m1}^a + cR_{e1}^a} \right] \quad (15)$$

McLean and White refer to the second term on the right hand side of this equation as multiple schedule bias. They suggest that the

apparent relation between response rates in the component schedules and reinforcement rates in the other components (i.e., the relation between  $B_{m1}/B_{m2}$  and  $R_{m1}/R_{m2}$ ), is mediated by this bias term, and in particular the parameter  $R_e$ . It should be apparent that this bias term differs from concurrent schedule bias which is represented as  $c$  in Equation 15.

A number of predictions can be made from Equation 15. Where  $R_{e1}$  and  $R_{e2}$  are zero response rates in both components will be equal. When both  $R_{e1}$  and  $R_{e2}$  increase, then the bias term will become closer to one and  $B_{m1}/B_{m2}$  will become closer to  $R_{m1}/R_{m2}$ . If analysed using the generalised matching law,  $a$  values will become closer to 1.0 as  $R_e$  increases. If  $R_{e1}$  and  $R_{e2}$  remain constant but unequal while  $R_{m1}$  and  $R_{m2}$  change, then behaviour will be biased toward responding in the component with the smaller  $R_e$ . If analysed in terms of the GML this distribution of  $R_{e1}$  and  $R_{e2}$  would lead to non-zero values of  $\log c$ .

The results of a number of experiments by Mclean and White (1983) and McLean (1988) where pigeons were exposed to a multiple concurrent schedule confirm these predictions. Specifically, when the reinforcement rate in the VI schedules available concurrently with the multiple schedules were increased, values of  $a$  for the multiple schedule performance when analysed in terms of the GML increased. When the reinforcement rate on a VI schedule available concurrently with one component schedule was higher than the reinforcement rate of a VI schedule available concurrently with the other component, animals were biased toward responding on the multiple schedule associated with the leaner VI. These results may therefore be seen as further support for Mclean and White's model and suggest one mechanism by which a relation between response rates on one component of a multiple schedule and reinforcement rate on another may be apparent. That is, where  $R_e$  is high  $B_{m1}/B_{m2}$  will approximate  $R_{m1}/R_{m2}$ . In this respect Mclean and White's model makes the same predictions as those of Staddon and Herrnstein. However, Mclean and White suggest that effects such as behavioural contrast may be described in terms of reallocation of  $R_e$  across components.

In the derivation of Equation 15 it was assumed that  $B_1 + B_{e1} = B_2 + B_{e2} = k$ . This implies that any change in  $B_1$  will result in  $B_e$

changing to the same degree but in the opposite direction. Given Equation 14 such a change in allocation of behaviour within a component will occur only if the ratio of  $R_1/R_e$  has changed, and changes in the ratio  $B_2/B_{e_2}$  will not be directly influenced by this change. In a standard contrast experiment behaviour in both components change when reinforcement rates for the defined operant response changes in only one component. In an altered component (1) the change in response rates is easily understood in terms of Equation 14 as the ratio of  $R_1/R_e$  has changed. In the constant component the change in  $B_2$  can only be predicted by Equation 14 if the ratio of  $R_2/R_{e_2}$  has changed. As  $R_2$  has remained constant it must be assumed that  $R_{e_2}$  changed inversely with changes in  $R_1$ . Mclean and White (1983) suggest that this is what happens. The relation between the operant response rates in one component with reinforcement rates in another is therefore seen to occur as the result of a relation between  $R_1$  and  $R_{e_2}$ .

This suggestion appears to be inconsistent with Mclean and White's (1983) and McLean's (1988) own findings that behaviour on a concurrent schedule available concurrently with a multiple schedule during one component of a multiple schedule was not related to the reinforcement rate in the other component of the multiple schedule. That is their analogue of  $B_{e_2}$  did not change with changes in  $R_1$ . However Mclean and White suggest that this occurs because contrast effects are related to the change in  $R_e$  rather than in the redistribution of  $B_e$ . In their experiment as each component was associated with different VI schedules  $R_e$  could not be re-allocated and hence  $B_{e_2}$  did not change with changes in  $R_1$ . McLean and White suggest that other behaviours which typically constitute  $B_e$  may be more similar in form to ratio schedules than interval schedules such that  $R_e$  can be reallocated.

Examination of Equation 15 reveals that a number of different effects would be predicted if  $R_e$  differs across components. For example, if  $R_e$  was distributed such that  $R_e$  was greater in a lean component than in a rich component, then closer matching between  $B_1/B_2$  and  $R_1/R_2$  may occur with a lower total  $R_e$  than would be required for the same degree of matching if  $R_{e_1}$  and  $R_{e_2}$  were equal. If the allocation of other reinforcers was in this direction, but more extreme, then overmatching could occur.

In summary McLean and White's model predicts that behaviour on each component of multiple schedules may be described in terms of the reinforcement rate for the defined response and the rate and distribution of reinforcers for other behaviour. The results of the experiments presented in this dissertation were examined in terms of these variables.

The changes in  $a$  values as a function of component duration seen in Experiment 1 would require that either  $R_e$  increased or that the distribution of  $R_e$  across components changed as a function of component duration. For example, if  $R_e$  was equally distributed across components when component duration was long, but as component duration became shorter  $R_e$  was distributed more in the lean component,  $a$  values would become closer to one. McLean and White suggest this could occur and invoke the possible satiation-deprivation process suggested by Staddon to account for such changes. However, as discussed, changes in  $R_e$  as a result of such deprivation-satiation processes seems unlikely. Nevertheless, it is possible that the distribution of reinforcers for other behaviours may have changed as a result of some other unknown process.

The changes in  $a$  values in the GML observed in Experiments 2 and 3 may also be predicted by Equation 15 if it is assumed that  $R_e$  changes. For example, the decrease in positive  $a$  values may be predicted if  $R_e$  decreased as a function of blackout duration, or if the distribution of  $R_e$  changed such that  $R_e$  was initially higher in a lean component but that as blackout duration increased  $R_e$  in both components became more similar. Interestingly Equation 15 will predict that if the relation between  $B_1/B_2$  and  $R_1/R_2$  is analysed in terms of the GML  $a$  values can become negative if  $R_e$  on the lean component is considerably less than  $R_e$  on the rich component. That is, if the ratio of  $R_{e1}/R_{e2}$  is directly proportional to but more extreme than the ratio of  $R_1$  to  $R_2$  negative  $a$  values may obtain.

Thus Equation 15 could describe all the changes in  $a$  values observed in the three experiments of this thesis. However, finding that data may fit a particular equation for given values of its parameter is only useful in as far as the values of the parameters are consistent with the theory underlying it. For example, finding that any of the above equations could account for 99 % of the variance in a set of

data would be meaningless if the fitted values of  $R_e$  were negative (Davison & McCarthy, 1988). Similarly while negative  $a$  values could be predicted if  $R_e$  was greater in the rich component given that  $R_e$  was not measured, this proposition may only be considered reasonable if some mechanism by which such a distribution of  $R_e$  might be obtained is identified.

As already discussed, it may be intuitively reasonable to assume that with initial increases in blackout duration many of the reinforcers for other behaviour may have been reallocated to the blackout periods. However, it is also possible that some of the reinforcers for other behaviour may not be re-allocatable. If the rate of these reinforcers is directly proportional to the rates of the reinforcement for the defined operant response then as the re-allocatable reinforcers are moved to the blackout then the  $R_e$  remaining will be greater in the rich component.

It is conceivable that some behaviours and hence the reinforcement for those behaviours may be related to the programmed food reinforcer. For example, scratching around the magazine area may be reinforced by the animal locating the occasional piece of spilled wheat. As the amount of spilled wheat will relate to the number of times the magazine operates, the rate of reinforcement for such behaviour will be directly proportional to the programmed rates of reinforcement. While this proposition may be regarded as speculative, previous studies provide some support for this. Matthews and Temple (1979) found that cows behaviour on concurrent VI schedules were described by low  $a$  values. In a later experiment Nair (1981) observed cows' behaviour on such schedules and reported that the cows engaged in a considerable amount of other behaviours, but that these were mainly food related and directly proportional to the operant reinforcement rates.

Alternatively the programmed food reinforcers may be the reinforcers for some other behaviours. In a typical operant experiment reinforcers are contingent on a particular response, such as a peck of a specified force to a lighted key. Past research suggests that in the process of shaping that response, other behaviours which occur in close proximity to the specified response may also be strengthened by the same reinforcer (Herrnstein, 1966). The rate of

any such 'superstitious' behaviour may arguably be proportional to the rate of reinforcement for that behaviour (Pear, 1988) and therefore proportional to the reinforcement rate for the defined operant. However, if  $R_1$  and  $R_2$  were the same as  $R_{e1}$  and  $R_{e2}$  respectively, Equation 15 predicts that the ratio of  $B_1$  to  $B_2$  will be 1.0 and in terms of the GML  $a$  values would be zero. To obtain negative  $a$  values the ratio of  $R_{e1}$  to  $R_{e2}$  must be in the same direction but more extreme than the ratio of  $R_1$  to  $R_2$  or the values of  $c$  the concurrent schedule bias, must be greater than 1.0. It would seem reasonable that values of  $c$  could be greater than 1 in this context as the superstitious behaviour represents a different response topography. When concurrent schedule performance is analysed in terms of the GML the use of different response typographies in the component schedules can lead to non-zero values of  $\log c$  (Davison & McCarthy, 1988).

The proposition that some  $R_e$  may be related in some way to the defined operant reinforcers so that some  $R_e$  is not re-allocatable may be seen as particularly appealing, as it may be consistent with the apparent relation between the magnitude of positive and negative  $a$  values obtained. That is, Equation 15 implies that if the amount of the total  $R_{e1}$  and  $R_{e2}$  that is proportional to  $R_1$  and  $R_2$  increases, greater undermatching will obtain. If increasing the duration of blackout results in increasingly more re-allocatable  $R_e$  being 'moved' to the blackout, then the proportionally greater amounts of  $R_e$  in a component would be  $R_e$  that is proportional to the operant reinforcement rate. Moreover, initial  $a$  values and the extent to which these would decrease must both be influenced by the initial proportion of  $R_e$  that is related to the reinforcement rate for the defined operant.

The previous paragraphs outlined several ways in which the changes in values of  $a$  observed in this study may be predicted on the basis of changes in the distribution or size of  $R_e$  in Equation 15. While such possibilities may appear plausible but speculative, as no measure of  $R_e$  was undertaken, other aspects of the data seriously question this proposal. Although Equation 15 describes behaviour in the two components in relative terms, this equation derives from Equation 14, and is valid only if the assumption that  $R_1 + R_e = R_2 + R_e = k$  is true. Given this assumption, changes in  $R_e$  imply specific

changes in absolute response rates. As has already been discussed, changes in absolute response rates varied across birds even where changes in overall  $a$  values were similar. Thus, if the changes in overall  $a$  values obtained relate to changes in  $R_e$  these changes must have varied across birds. Similarly, the changes within components may relate to changes in  $R_e$ , but again, given the changes in absolute response rates underlying these the changes in  $R_e$  would again have to differ across birds.

Charman and Davison and McCarthy.

One other model which has recently been proposed to describe multiple schedule performance may be seen as similar to that offered by Mclean and White (1983). Charman (1983) and Davison and McCarthy (1988) proposed that response rates in each component of multiple schedules may be described by Equations 16 and 17 where the terms are as defined in Equation 9.

$$B_1 = \frac{k(R_1 + mR_2)}{R_1 + mR_2 + R_{e1} + mR_{e2}} \quad (16)$$

and

$$B_2 = \frac{k(R_2 + mR_1)}{R_2 + mR_1 + R_{e2} + mR_{e1}} \quad (17)$$

In these equations response rate in each component is described as a function of the rate of reinforcement for that response in the component of interest and to some extent the reinforcement rate for the same response in the other component relative to the total reinforcement rate available. Assuming that  $k$  is equal in both components then behaviour on a two component multiple schedule can be described as:

$$\frac{B_1}{B_2} = \left[ \frac{R_1 + mR_2}{R_2 + mR_1} \right] \times \left[ \frac{R_2 + mR_1 + R_{e2} + mR_{e1}}{R_1 + mR_2 + R_{e1} + mR_{e2}} \right] \quad (18)$$

This model differs from Herrnstein's in that, to the extent that reinforcement rate in one component influences behaviour in another, the reinforcements available in the one component will reinforce responding in the other component. The predictions of this model with changes in  $m$  therefore differ from those of Herrnstein's. If  $m$  equals 1.0, then response rate in the two components will be equal.

proportional to the rate of reinforcement for the operant response, then as  $m$  approaches 1.0 response rates on the rich schedule will decline while response rates on the lean schedule will increase. The increase on the lean schedule would be greater than the decrease on the rich schedule. This model therefore suffers much the same difficulty in accommodating the results of the three experiments reported here as the others examined.

The preceding discussion outlined five models of multiple schedule performance. Three of these imply that changes in  $a$  values in the GML may result from the extent to which reinforcement rate in one component influences performance on another component, that is, on the value of the interaction term  $m$ . For a number of reasons the usefulness of this term in explaining the results of the experiments reported here is limited. In particular, the negative  $a$  values observed in Experiments 2 and 3 cannot be predicted on the basis of any change in this term.

All five models discussed can be shown to predict that multiple schedule performance will be influenced by reinforcers available for other behaviours. As such these models are all consistent with the suggestion made in the discussion of Experiment 2, that the changes in  $a$  values observed in these experiments may relate to the relative influence and/or the rate of reinforcement for other behaviour. However, detailed examination of the equations which describe performance under Herrnstein's, William's, Mclean & White's and McCarthy and Davison's models revealed that none of these can easily accommodate the results of the three experiments presented in this dissertation. This situation arises as all these models assume that the sum of behaviour in a given time period equals a constant  $k$ . As a consequence of this assumption, changes in the reinforcement rate for other behaviour,  $R_e$ , imply specific changes in the operant response rates,  $B_1$  and  $B_2$ .

It is possible to speculate that the changes in  $a$  values observed may be attributable to changes in  $R_e$ . Various reasons why  $R_e$  may change as a function of reducing component or blackout duration may be postulated. However, the variability in absolute response rates question the validity of such explanations. Although some aspects of Staddon's model were not quantified, as he also assumes that

total output of behaviour in a given time period will be constant, and this is a crucial feature of the model, the usefulness of this model may be similarly questioned.

Given this analysis two possibilities are apparent. Changes in the distribution and/or rate of reinforcement for other behaviours as a function of changes in component or blackout duration which contributed to the  $a$  values obtained, varied across birds. Alternatively the data obtained in the experiments reported in this dissertation were not explicable in terms of any of these models. Although the relative merits of these two possibilities cannot be assessed in terms of the data obtained in these experiments, a number of other studies have examined the effect of other reinforcers and behaviours on multiple schedule performance.

The results of the experiments reported above (McLean & White, 1983 and McLean, 1988) on the effects of a VI schedule being available concurrently with a multiple schedule supported the suggestion that the rate of reinforcement for other behaviour will affect the apparent relation between behaviour in one component and reinforcement available in another. However, to account for the data in the three experiments of this dissertation the distribution of  $R_e$  across components would have to change. The procedures used in McLean and White and McLean where separate interval schedules in each component were used as an analogue for  $R_e$  do not allow  $R_e$  to be reallocated and thus cannot be used to assess this aspect of  $R_e$ . As suggested by McLean (1988) the provision of a concurrent FR schedule common across components may provide a better analogue of  $R_e$ . Davison and McCarthy (1988) reported that in unpublished research from their laboratory, reinforcers available on FR schedules available concurrently with multiple schedules were reallocated between components when reinforcement rates were changed. Even this however may be considered inadequate to assess these models if the reinforcer available on the FR schedule was also food.

Another method of assessing the time allocated to other behaviour used in the literature has been to assess the time spent engaged in the operant behaviour on each component of a multiple schedule. For example, White (1978) examined the behaviour of rats in a contrast experiment where the manipulanda for the two components of the

multiple schedules were located at opposite ends of a chamber. The time spent at each end of the chamber in each component was measured. White reported that when one component was changed to a leaner schedule both the response frequency and time spent on that component were reduced, and that the time spent on the constant component was increased. On the other hand, local response rates (that is the number of response made to the response manipulandum in the time the animal was on the side of the chamber associated with that component) did not change as a function of changing the relative reinforcement rates. In a second experiment, response-independent reinforcement was employed and similar changes in time allocation were observed. Similar results were also reported in an experiment by Bouzas and Baum (1976) and Charman (1983). These results may be seen as consistent with changes in multiple schedule performance occurring through reallocation of  $R_e$ . However as no attempt to identify or measure any particular 'other' behaviours or reinforcers for these were made they do not constitute proof of this proposition.

An alternative method of examining the effect of other reinforcers on behaviour in multiple schedules has been to provide access to some other reinforcer and measure the time spent engaging in behaviour presumably related to this reinforcer. The results of these studies are equivocal. For example, Hinson & Staddon (1978) provided animals working on a multiple VI VI schedules with access to a running wheel. When one component schedule was changed to extinction Hinson & Staddon reported that the magnitude of contrast evident was greater than that obtained in similar conditions where the running wheel was absent. Hinson and Staddon also report that the allocation of wheel running between components was redistributed in the contrast phase, such that more wheel running occurred in the component with the lower rate of reinforcement.

On the other hand Dougan, McSweeney and Farmer (1985) found that, while contrast was obtained when access to water was concurrently available with a multiple schedule, water drinking was not differentially allocated across the components. Dougan, McSweeney and Farmer-Dougan, (1986) carried out a series of experiments which attempted to clarify the differences between the results of Hinson

and Staddon's study and those of Dougan et al. (1985). Dougan et al. (1986) found that the presence of a water bottle decreased the magnitude of contrast obtained when animals were not water deprived but increased the magnitude of contrast when animals were water deprived and the baseline VI schedules were comparatively rich. In the experiment where the animals were water deprived, it appeared that water drinking in the constant component during baseline conditions was re-allocated into the extinction component.

Thus the results of Hinson and Staddon and Dougan et al. (Exp 2, 1986) are consistent with the proposal that  $R_e$  may be redistributed across components in some situations. However the results of Dougan et al (1985) and Dougan et al. (Exp 1 and 3, 1986) indicate that such reallocation of  $R_e$  may not occur. Given that it is assumed that reinforcers for other behaviour are available even when access to other behaviour is not specifically programmed, it may be argued that, in instances where a measured response is not re-allocated, animals may have re-allocated reinforcements for other unobserved behaviours. Alternatively, the inconsistencies in the studies reported may be regarded as tentative support for the proposition that animals may vary in the extent to which they redistribute  $R_e$ . Support for this interpretation is gained from the results of an experiment carried out by Dougan and McSweeney (1985) on the effect of water availability on single VI schedule performance. In this study response and licking rates varied considerably across subjects.

The above discussion generally suggests that  $R_e$  may change with changes in reinforcement rate for the defined operant behaviour. Thus, changes in  $R_e$  may have occurred in these studies. These studies do not however indicate whether  $R_e$  will change with changes in component or blackout duration. They simply suggest that  $R_e$  can change and that these changes can result in changes in the extent to which relative response rates on component schedules of a multiple schedule will match relative reinforcement rates.

One other aspect of the theories discussed above also needs consideration. That is, the assumption that  $k$  or total output in a period of time will remain the same regardless of changes in reinforcement rates. Davison and McCarthy (1988) suggest that,

although some studies have reported that  $k$  in Herrnsteins equation for single schedule performance is independent of reinforcement rate, in general, analysis of single schedule performance show that  $k$  and  $R_e$  are not independent. This finding has major implications for the theories outlined above. If  $k$  is not constant, then the models do not necessarily require specific changes in absolute response rates with changes in the parameters  $m$  or  $R_e$ , and thus the difficulties in accommodating the results of the experiments in this thesis are diminished. However, the theoretical concepts underlying the models and the derivations of the equations are also dependent on  $k$  being constant. Mclean and White (1983) suggest that apparent changes in  $k$  with changes in reinforcement rates, may, however, reflect changes in  $a$  and  $c$  in Equation 14.

In summary, data obtained in the three experiments of this thesis cannot be predicted on the basis of changes in  $m$  or in changes in  $R_e$ , if  $R_e$  remains the same across components. Models which explicitly allow changes in  $R_e$  across components may be considered most appropriate. These models cannot account for the data obtained without a number of assumption about the allocation of  $R_e$ . In particular negative  $a$  values could be predicted by these models only if  $R_e$  was distributed such that more  $R_e$  was allocated to the richer component. Such possibilities were not explicitly suggested by the proponents of these theories. Further experimental work where some measure of  $R_e$  is included may validate such assumptions. The usefulness of these models is also questioned by results of other studies which appear to show that  $k$  does not remain constant when reinforcement rate is varied. In general, therefore, the usefulness of all models discussed in interpreting the data may be seen as questionable. Unfortunately, examination of other models which do not specifically incorporate reinforcers for other behaviour are no more successful in accommodating the results of this dissertation.

#### Williams (1983)

Williams, also noting the difficulties associated with the possible non-independence of  $k$  and  $R_e$  in Herrnstein's model, suggested an alternative interpretation of his equations. Specifically, Williams suggested that the parameter  $k$  and  $R_e$  could be replaced respectively by  $kC$  and  $C$  where  $C$  is a measure of the inhibitory effects of

reinforcement. The equations derived by this substitution are thus related to Catania's (1973) description of single schedule performance. According to Catania, reinforcers have two effects, an excitatory effect whereby reinforcers strengthen the behaviour on which they are contingent, and an inhibitory effect where reinforcers also inhibit the behaviour on which they are contingent. These effects are presumed to interact multiplicatively so that behaviour on a single schedule can be described by the Equation 19

$$B_1 = kC \left[ \frac{R_1}{(R_1 + C)} \right] \quad (19)$$

This equation can be seen to be similar to Equation 7, although the terms are interpreted differently. This equation implies that the excitatory effect of a reinforcer is stronger than its' inhibitory effect and thus response rates are predicted to increase as the reinforcement rate for that behaviour increases.

A number of studies which have shown that response rates on a single schedule will increase when some reinforcers are replaced by periods of timeout (e.g., Carr & Reynolds, 1974; McMillan, 1971; Starr & Staddon, 1974 and others) provide support for the proposition that reinforcers can inhibit responding. This interpretation of parameters may therefore have merit.

The use of the parameters  $kC$  and  $C$  to replace  $R_e$  and  $k$ , in Equation 9, does not improve its ability to account for the data in this dissertation. Regardless of the value of  $C$  response rate in a rich schedule will be higher than response rates in the lean schedule and as already discussed no values of  $m$  can be predict negative  $a$  values. Thus this equation clearly cannot account for the data in Experiments 2 and 3.

Williams (1983) also provides another equation to describe multiple-schedule performance. This new equation includes separate parameters to represent the relative influence on behaviour, in one component, of reinforcement rate in the preceding and following components. Williams and Wixted (1986) analysed data obtained on an experiment involving three component multiple schedules using this new equation and reported that it fitted the data well. However, as the equation has four free parameters such fits might be expected. In terms of

the experiments reported here, this equation is limited, as it simply involves splitting  $m$  up into two parts. As variations in  $m$  cannot lead to negative  $a$  values, nor can the two parameters which represent the relative influence on behaviour in one component of the reinforcement rates in the preceding and following schedule.

### McSweeney

Another model of multiple-schedule performance was recently advanced by McSweeney (1987). This model can be seen to have some similarity to Williams' model in that it also relies on the proposition that reinforcers can inhibit responding. McSweeney argues that reinforcers increase behaviour they follow immediately, and suppress behaviours they follow after a delay. It is assumed that this inhibitory effect of reinforcers can influence the class of responses on which they are contingent. The excitatory function is again considered to be greater than the inhibitory function, so that behaviour will increase as a function of reinforcement rate. McSweeney further suggests that the suppressive effect of reinforcers on behaviour they follow after a delay will diminish with time.

Although no attempt to quantify the model was made, McSweeney suggests that her model can accommodate many of the findings relating to behavioural contrast. However the usefulness of this model in describing performance in the experiments in this dissertation is limited. This is because the theory is specifically concerned with changes in absolute response rates and as already discussed the changes in absolute responses observed varied considerably across hens. For example, Mcsweeney suggests that separating components in time should increase response rates, in both components, and that this increase should be greater in the lean component. This would occur as the suppressive effects of reinforcers obtained in one component, on behaviour in another, as they diminish over time, would be removed. The increases in response rates seen in Experiment 2 for some birds is consistent with this proposition. However, as already noted, this effect of blackout duration was not consistent across birds. Furthermore, this model cannot account for the increases in response rate on a lean schedule to a level higher than the response rates on the rich schedule.

### Conclusions

The data from the three experiments in this thesis are not easily accommodated by any of the theories of multiple-schedule performance outlined above. It may be argued that the results obtained were different from those reported in other studies and thus may reflect some peculiar and unimportant procedural artifact. If this were so then the results of these experiments may be considered outside the bounds of typical multiple-schedule performance and thus are beyond the concern of the theories examined. It is this author's opinion that such a conclusion is unwarranted and that an adequate theory of multiple-schedule performance should accommodate such results.

The results of Experiment 1, in general, replicated those of the majority of previous studies examining the short component effect. The results of Experiment 2 were unusual as negative  $a$  values were obtained. However, this effect was evident in five of the six hens' data. The general form of the relation between  $a$  values and blackout duration was also replicated in two of three hens' data in Experiment 3. Although the data from one bird in Experiment 3 was different from that of Experiment 2, given that Experiment 3 used a different and more complex procedure, the extent to which results of Experiment 2 were replicated may be seen as more important than the extent to which they were not. Furthermore, the results of Experiment 2 and 3 are not entirely unsupported by past research.

As stated in the discussion of Experiment 3, negative  $a$  values have been reported occasionally in other studies. The results of two other experiments are particularly relevant. Foster (1976) also found negative  $a$  values for two of four pigeons' data when responding on the terminal links of a concurrent-chain procedure were examined in isolation. This experiment effectively consisted of exposing pigeons to a MULT FI FI where components were separated by a period of blackout. The duration of the inter-component blackout in that experiment was variable with a mean of 30 s. This duration is comparable with the blackout duration at which negative  $a$  values were obtained in this dissertation. Similar results were

evident in a study by Nevin (1983) during conditions where pigeons worked on MULT VI VI schedules separated by 30 s blackout. Although the relation between relative response rates and reinforcements rates were not reported for these conditions, examination of his Figure 2 shows that some birds response rates were higher when reinforcers were delivered at a rate of 42 per hour compared to response rates when reinforcement rate was 129 reinforcers per hour. Thus, some other studies may be seen as providing some support for the results obtained in Experiments 2 and 3.

The results of these experiments are also similar to previous studies which have found that values of  $\alpha$  and response rates for total responding were not related to particular within-component changes in sensitivity or response rates.

As discussed in the discussion of Experiment 1, while one pattern of within-component changes in behaviour may dominate, within-component changes also vary across hens. Thus identifying suitable explanations of changes in behaviour within components is difficult. It is possible that they are influenced by the same variables as affect overall responding in that within-component behaviour also changed as a function of the variables manipulated. However, given the weak relation between the overall and within-component changes, they may also relate to different processes.

Thus in conclusion the results of the experiments in thesis suggest that the GML is inadequate as a descriptor of multiple-schedule performance. Although fits to the data were reasonable, the values of the parameter  $\alpha$  were not consistent with the theoretical interpretation of this parameter. The results of Experiments 2 and 3 in particular, represent a serious challenge to other theoretical formulations proposed to explain multiple-schedule performance. Of the theories examined, those proposed by McLean and White (1983) and Davison and McCarthy (1988) may be considered most promising. However, the usefulness of these theories can only be assessed by further experiments which manipulate blackout duration and also include suitable measures of other behaviours.

In general, however, the results were most consistent if viewed in terms of relative response rates for overall responding, and future

research may find that behaviour on multiple schedules may only be predictable in terms of this measure. That is, relative response rates may vary as an orderly function of a number of variables. The absolute response rates within and across components, and the relative response rate changes within components which contribute to these, however, may vary across subjects. Such a proposal may be particularly appropriate where the availability of reinforcers is determined by VI schedules. Under these schedules, behaviour can vary considerably without changing the reinforcement rate obtained. This proposition may be seen as analogous to a situation where a number of people set out from the same place for the same destination, for example a rock concert. Each person may take a different route but arrive at the designated place at about the same time. The method of arriving at that place may be viewed as unimportant in that it does not effect any rewards or punishers associated with the arrival.

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## APPENDIX 1

The data from the last five days in each condition of Experiment 1.

Appendix 1a: The condition (COND), hen number, total number of responses (Resp) and reinforcers obtained (Rfts) in S1 (O) and S2 (Y), and the total time the components were available.

Appendix 1b: The condition (COND), hen number and number of responses on S1 (O) and S2 (Y) in each 15-s subinterval.

## APPENDIX 1a

4

COND	HEN	RESP		RFTS		TIME		COND	HEN	RESP		RFTS		TIME	
		O	Y	O	Y	O	Y			O	Y	O	Y	O	Y
1	51	541	412	26	09	840	840	04	51	489	385	26	08	840	840
1	51	546	407	25	09	840	840	04	51	504	400	26	09	840	840
1	51	500	413	25	09	840	840	04	51	573	462	26	09	840	840
1	51	472	391	26	09	840	840	04	51	714	560	26	08	840	840
1	52	565	478	25	08	840	840	04	52	658	491	26	05	840	840
1	52	464	373	25	08	840	840	04	52	455	304	26	05	840	840
1	52	532	433	25	08	840	840	04	52	662	565	26	05	840	840
1	52	556	460	25	08	840	840	04	52	648	572	26	09	840	840
1	52	503	419	25	08	840	840	04	52	740	592	26	05	840	840
1	53	339	304	24	05	840	840	04	53	317	238	25	08	840	840
1	53	238	170	24	05	840	840	04	53	361	310	25	08	840	840
1	53	387	270	25	05	840	840	04	53	350	268	25	08	840	840
1	53	382	332	24	05	840	840	04	53	311	232	25	08	840	840
1	53	382	338	24	05	840	840	04	53	216	107	19	07	840	840
1	54	324	282	25	06	840	840	04	54	414	294	26	08	840	840
1	54	344	299	22	06	840	840	04	54	360	309	27	08	840	840
1	54	326	271	25	06	840	840	04	54	318	287	25	07	840	840
1	54	328	287	24	06	840	840	04	54	354	334	26	06	840	840
1	54	313	291	24	06	840	840	04	54	415	363	24	07	840	840
2	51	429	557	08	26	840	840	05	51	586	421	26	08	840	840
2	51	496	579	09	26	840	840	05	51	534	332	26	08	840	840
2	51	534	627	09	26	840	840	05	51	417	349	26	09	840	840
2	51	513	595	09	26	840	840	05	51	490	335	26	09	840	840
2	51	454	567	09	26	840	840	05	51	562	379	26	08	840	840
2	52	334	477	07	24	840	840	05	52	641	306	26	06	840	840
2	52	388	488	05	27	840	840	05	52	468	245	26	05	840	840
2	52	505	566	05	26	840	840	05	52	666	283	26	05	840	840
2	52	515	598	05	26	840	840	05	52	561	272	26	04	840	840
2	52	482	606	05	26	840	840	05	52	476	222	26	06	840	840
2	53	345	422	08	26	840	840	05	53	175	111	17	06	840	840
2	53	364	451	07	25	840	840	05	53	096	061	17	05	840	840
2	53	399	492	08	25	840	840	05	53	202	136	17	04	840	840
2	53	353	500	08	25	840	840	05	53	202	135	17	05	840	840
2	53	354	453	08	25	840	840	05	53	158	078	16	07	840	840
2	54	197	300	08	25	840	840	05	54	390	208	25	05	840	840
2	54	291	344	04	26	840	840	05	54	406	229	26	06	840	840
2	54	319	437	08	27	840	840	05	54	425	275	26	07	840	840
2	54	285	266	06	20	840	840	05	54	518	284	25	05	840	840
2	54	242	246	06	21	840	840	05	54	416	269	26	06	840	840
03	51	451	571	08	26	840	840	06	51	409	316	09	26	840	840
03	51	508	699	09	26	840	840	06	51	458	479	08	26	840	840
03	51	528	707	09	26	840	840	06	51	396	423	08	26	840	840
03	51	493	597	08	26	840	840	06	51	338	346	09	26	840	840
03	51	510	604	09	26	840	840	06	51	249	290	08	26	840	840
03	52	490	563	05	26	840	840	06	52	649	831	05	27	840	840
03	52	496	581	05	26	840	840	06	52	702	861	05	26	840	840
03	52	442	554	05	26	840	840	06	52	754	888	05	26	840	840
03	52	435	534	05	26	840	840	06	52	684	840	05	26	840	840
03	52	468	559	05	26	840	840	06	52	698	825	05	26	840	840
03	53	270	374	08	25	840	840	06	53	180	208	07	20	840	840
03	53	247	328	08	25	840	840	06	53	312	355	08	26	840	840
03	53	266	352	08	25	840	840	06	53	338	447	08	25	840	840
03	53	278	377	08	25	840	840	06	53	143	182	07	15	840	840
03	53	255	351	08	25	840	840	06	53	225	297	08	19	840	840
03	54	404	399	08	27	840	840	06	54	404	485	05	25	840	840
03	54	358	354	08	27	840	840	06	54	305	390	05	24	840	840
03	54	341	385	08	27	840	840	06	54	271	368	05	25	840	840
03	54	348	441	08	27	840	840	06	54	189	300	08	24	840	840
03	54	394	385	08	26	840	840	06	54	275	376	05	26	840	840

07 51	476	567	09 26	840	840	09 51	529	295	20 07	594	594
07 51	388	900	08 26	840	840	09 51	579	357	21 06	594	594
07 51	339	453	08 26	840	840	09 51	520	289	20 06	594	594
07 51	339	433	08 26	840	840	09 51	539	279	21 07	594	594
07 51	373	441	08 26	840	840	09 51	467	310	21 07	594	594
07 52	509	751	05 26	840	840	09 52	517	272	18 04	594	594
07 52	467	765	06 27	840	840	09 52	160	091	17 04	594	594
07 52	404	634	05 26	840	840	09 52	240	106	17 04	594	594
07 52	524	751	06 26	840	840	09 52	464	218	18 04	594	594
07 52	613	874	06 26	840	840	09 52	545	313	18 04	594	594
07 53	366	610	08 25	840	840	09 53	308	193	17 03	594	594
07 53	261	473	08 22	840	840	09 53	565	384	30 07	594	594
07 53	278	541	08 25	840	840	09 53	324	197	18 03	594	594
07 53	278	508	08 25	840	840	09 53	388	233	18 03	594	594
07 53	299	534	08 25	840	840	09 53	398	245	17 03	594	594
07 54	374	528	04 24	840	840	09 54	512	161	18 05	594	594
07 54	302	493	05 26	840	840	09 54	529	160	18 04	594	594
07 54	304	424	05 24	840	840	09 54	471	129	18 04	594	594
07 54	285	420	05 25	840	840	09 54	404	108	19 05	594	594
07 54	289	423	05 25	840	840	09 54	508	147	18 05	594	594
08 51	709	482	25 08	840	840	10 51	350	379	06 19	594	594
08 51	635	456	26 09	840	840	10 51	361	397	07 21	594	594
08 51	670	463	26 09	840	840	10 51	367	367	07 21	594	594
08 51	610	434	26 08	840	840	10 51	314	333	06 20	594	594
08 51	538	389	26 08	840	840	10 51	380	395	07 20	594	594
08 52	725	547	26 06	840	840	10 52	361	490	03 18	594	594
08 52	768	556	26 05	840	840	10 52	323	481	04 18	594	594
08 52	807	579	26 05	840	840	10 52	373	525	04 18	594	594
08 52	784	559	26 06	840	840	10 52	334	528	04 18	594	594
08 52	707	511	26 06	840	840	10 52	290	458	04 18	594	594
08 53	395	337	25 08	840	840	10 53	229	386	03 17	594	594
08 53	408	380	25 08	840	840	10 53	228	355	05 18	594	594
08 53	475	353	25 08	840	840	10 53	195	319	03 17	594	594
08 53	333	256	25 08	840	840	10 53	215	307	03 18	594	594
08 53	200	191	22 08	840	840	10 53	206	368	03 17	594	594
08 54	482	208	25 05	840	840	10 54	295	323	05 18	594	594
08 54	433	208	24 05	840	840	10 54	173	254	05 16	594	594
08 54	350	258	24 05	840	840	10 54	132	262	05 17	594	594
08 54	493	150	24 05	840	840	10 54	133	250	05 17	594	594
08 54	481	156	26 05	840	840	10 54	192	286	05 18	594	594

## APPENDIX 1b

## RESPONSES IN SUCCESSIVE 15-S SUBINTERVALS

COND	HEN	O	Y	O	Y	O	Y	O	Y	O	Y	O	Y	O	Y	O	Y	
1	51	68	45	65	43	65	56	68	47	71	58	69	58	66	54	69	51	
1	51	80	38	73	48	63	58	68	55	71	56	70	58	62	63	67	59	
1	51	75	42	64	46	74	54	72	46	72	46	67	55	58	59	64	59	
1	51	77	38	68	38	63	54	62	51	61	49	54	59	60	62	55	62	
1	51	66	33	55	41	62	44	53	46	60	53	61	56	61	59	54	59	
1	52	73	34	70	58	81	66	65	62	74	65	67	63	61	66	74	64	
1	52	71	26	65	50	64	47	60	45	57	57	49	50	44	44	54	50	
1	52	69	37	75	46	67	49	75	63	68	59	76	60	42	59	60	61	
1	52	75	33	68	49	79	59	75	59	66	66	62	70	56	61	75	63	
1	52	65	36	49	49	62	56	69	51	70	66	61	56	70	51	57	54	
1	53	40	20	40	34	48	37	39	42	51	42	38	37	42	46	41	46	
1	53	32	14	27	23	27	24	31	19	33	16	26	24	31	21	31	31	
1	53	57	16	44	20	41	33	53	45	56	42	45	39	40	38	51	39	
1	53	50	17	53	34	48	40	50	46	46	45	44	40	52	54	39	56	
1	53	53	23	53	34	50	38	40	52	43	51	51	45	47	43	45	53	
1	54	38	08	44	37	41	33	42	40	36	42	41	44	42	39	40	39	
1	54	41	22	45	36	49	44	45	37	47	43	53	32	33	45	31	41	
1	54	34	12	45	38	38	33	45	41	42	34	38	34	41	38	43	45	
1	54	36	18	36	31	36	39	43	40	47	34	40	41	44	39	46	45	
1	54	36	16	38	40	43	51	37	36	41	40	43	33	36	37	39	38	
2	51	40	79	43	80	53	67	56	71	54	70	57	62	64	63	62	65	
2	51	52	87	56	76	70	69	64	75	65	77	65	79	65	61	59	55	
2	51	47	89	51	76	77	86	71	81	76	74	77	79	72	74	63	69	
2	51	41	78	55	79	60	69	73	83	65	69	76	81	76	63	67	73	
2	51	40	85	44	72	60	69	57	69	60	71	67	74	67	70	59	58	
2	52	16	69	33	66	41	59	48	61	47	66	51	56	48	48	50	52	
2	52	25	68	35	73	50	64	44	70	48	62	63	54	59	43	64	55	
2	52	54	87	47	80	68	69	68	70	68	57	67	61	69	71	64	71	
2	52	50	90	56	78	63	70	65	66	66	63	74	73	77	81	64	78	
2	52	38	85	54	83	53	87	61	65	58	66	76	66	70	74	72	80	
2	53	30	58	43	53	40	52	53	49	45	53	45	51	36	57	53	49	
2	53	41	65	40	57	38	56	46	57	53	63	47	55	52	48	47	52	
2	53	32	77	49	60	48	45	51	69	53	72	51	52	59	58	56	59	
2	53	43	74	43	53	47	66	50	59	53	66	54	65	34	55	29	62	
2	53	33	62	38	55	48	58	49	60	51	61	44	54	51	53	40	50	
2	54	12	44	22	36	27	39	30	39	25	37	29	39	25	34	27	32	
2	54	18	45	34	42	38	41	45	47	43	45	44	49	33	42	36	33	
2	54	28	51	39	56	55	54	45	49	41	61	27	52	42	65	42	49	
2	54	24	31	38	39	35	29	43	35	32	34	35	31	37	33	41	34	
2	54	17	32	26	36	30	29	37	31	34	29	30	35	33	30	35	26	
		O	Y	O	Y	O	Y	O	Y		O	Y	O	Y	O	Y	Y	
03	51	100	165	114	139	121	135	117	132	04	51	119	086	115	096	128	162	105
03	51	110	208	124	167	141	171	133	153	04	51	170	095	172	142	163	133	143
03	51	142	212	115	173	142	165	137	158	04	51	142	076	132	092	121	111	122
03	51	115	166	121	141	128	140	130	150	04	51	136	100	142	108	151	136	120
03	51	118	162	127	150	137	147	129	145	04	51	172	115	190	121	175	163	161
03	52	099	160	125	147	132	136	134	122	04	52	177	076	177	127	154	140	149
03	52	093	169	130	150	130	137	145	126	04	52	120	043	095	079	123	088	094
03	52	081	160	107	135	122	137	132	122	04	52	159	101	189	128	165	166	170
03	52	037	148	103	139	120	131	125	117	04	52	173	097	155	111	172	128	138
03	52	091	152	112	135	125	151	140	122	04	52	195	110	199	152	175	168	167
03	53	042	101	077	106	079	076	072	092	04	53	092	050	084	060	072	062	066
03	53	047	096	066	086	062	074	072	072	04	53	101	062	086	077	091	083	089
03	53	053	095	067	099	076	075	070	083	04	53	090	054	092	078	085	068	069
03	53	052	100	077	102	072	089	077	086	04	53	086	052	078	059	067	062	059
03	53	053	097	071	093	059	083	072	078	04	53	077	023	061	024	047	026	034
03	54	088	090	106	109	112	099	098	102	04	54	099	064	111	080	102	076	087
03	54	073	080	100	091	092	094	093	089	04	54	074	061	100	078	097	088	082
03	54	065	094	098	097	088	100	090	094	04	54	078	063	080	076	083	076	072
03	54	083	105	091	111	085	111	089	114	04	54	088	075	089	086	091	085	088
03	54	081	092	098	096	115	100	101	098	04	54	105	084	083	096	111	094	089

		RESPONSES IN SUCCESSIVE 5-S SUBINTERVALS											
COND	HEN	O	Y	O	Y	O	Y	O	Y	O	Y	O	Y
05	51	102	051	099	058	084	078	088	073	092	081	121	082
05	51	105	046	077	050	081	052	075	067	106	055	090	062
05	51	077	053	073	049	062	065	074	056	060	059	074	067
05	51	101	047	070	056	083	061	077	050	075	061	085	060
05	51	102	049	079	063	080	075	084	070	097	057	122	067
05	52	111	020	114	037	107	051	112	066	104	067	095	065
05	52	094	016	073	043	066	044	076	044	084	049	077	050
05	52	120	033	106	043	108	057	123	049	104	050	106	051
05	52	100	028	087	039	090	054	085	057	103	051	097	045
05	52	078	019	077	043	076	038	077	041	089	041	079	041
05	53	037	011	018	019	027	021	037	025	026	016	032	020
05	53	019	001	014	017	013	010	021	011	015	011	014	011
05	53	044	016	035	025	029	026	034	020	028	022	033	029
05	53	038	014	035	021	039	024	027	025	038	022	025	029
05	53	031	005	028	010	027	018	026	010	020	021	026	014
05	54	066	039	048	032	067	044	066	026	068	029	078	038
05	54	046	039	049	047	079	043	082	038	073	032	079	030
05	54	054	047	069	050	076	059	075	046	070	044	083	031
05	54	069	046	074	054	095	054	091	044	093	045	097	041
05	54	048	041	068	050	074	054	077	051	072	038	078	036
06	51	077	057	071	053	077	048	095	052	054	051	056	055
06	51	080	079	083	069	082	093	078	072	068	083	070	083
06	51	057	085	067	063	073	067	074	068	057	071	069	072
06	51	053	058	064	053	066	061	049	057	055	055	052	063
06	51	038	060	040	048	047	046	045	046	037	051	044	040
06	52	071	167	095	142	108	139	122	136	124	127	135	122
06	52	072	174	110	154	136	145	127	139	130	123	129	129
06	52	077	166	122	160	131	155	141	149	143	134	142	129
06	52	075	159	116	147	118	137	127	144	125	136	126	119
06	52	082	156	099	146	124	145	133	142	121	116	140	123
06	53	029	043	025	034	030	032	036	034	028	035	032	031
06	53	038	078	052	057	051	054	059	056	058	056	055	066
06	53	044	090	058	075	061	075	058	076	057	064	060	068
06	53	015	048	018	026	028	028	026	025	030	029	026	026
06	53	030	051	041	046	037	047	046	046	038	057	035	042
06	54	064	105	064	076	082	081	063	087	060	077	072	065
06	54	036	078	051	072	061	060	049	056	054	066	056	061
06	54	035	067	047	065	053	062	042	057	052	058	042	060
06	54	030	056	025	046	025	043	036	049	039	051	035	056
06	54	036	082	053	061	050	051	054	061	043	062	042	059

## RESPONSES IN SUCCESSIVE 5 S SUBINTERVALS

COND	HEN	O	Y	O	Y	O	Y	O	Y	O	Y	O	Y		
07	51	163	203	165	179	150	186	08	51	242	155	245	176	223	152
07	51	126	177	129	165	134	159	08	51	227	158	194	151	217	147
07	51	106	169	116	149	117	136	08	51	242	159	219	159	211	145
07	51	105	162	118	128	117	144	08	51	211	144	180	148	223	144
07	51	118	160	130	138	125	145	08	51	174	143	184	132	181	114
07	52	138	273	177	239	196	242	08	52	270	137	221	201	235	210
07	52	113	257	162	247	193	261	08	52	280	120	243	216	245	228
07	52	114	228	127	195	165	211	08	52	295	138	268	206	251	237
07	52	135	281	191	242	198	234	08	52	272	138	261	210	252	213
07	52	158	313	223	284	233	278	08	52	262	149	222	175	223	190
07	53	091	232	140	192	136	188	08	53	144	101	126	122	127	114
07	53	061	185	101	163	099	130	08	53	149	113	142	133	118	136
07	53	063	209	095	170	121	165	08	53	193	110	158	113	124	130
07	53	082	193	101	162	095	155	08	53	133	071	108	084	093	102
07	53	079	200	101	174	119	162	08	53	072	060	062	069	066	062
07	54	120	196	133	166	121	167	08	54	157	086	168	067	158	055
07	54	078	192	114	153	112	153	08	54	141	091	147	068	145	049
07	54	086	164	111	127	110	133	08	54	156	188	105	080	089	089
07	54	091	160	084	143	111	117	08	54	144	066	170	049	181	035
07	54	091	167	110	131	089	128	08	54	151	064	175	047	155	046

## RESPONSES IN SUCCESSIVE 3 S SUBINTERVALS

COND	HEN	O	Y	O	Y	COND	HEN	O	Y	O	Y
09	51	272	150	257	151	10	51	162	190	188	191
09	51	299	184	281	175	10	51	182	201	179	198
09	51	266	147	254	143	10	51	183	193	184	176
09	51	292	140	250	141	10	51	152	181	162	154
09	51	240	149	231	162	10	51	184	209	197	193
09	52	266	100	253	174	10	52	150	253	213	239
09	52	087	031	074	060	10	52	143	263	180	218
09	52	136	046	105	060	10	52	178	265	196	261
09	52	232	085	232	134	10	52	123	278	214	254
09	52	285	144	264	172	10	52	127	234	163	225
09	53	179	089	129	104	10	53	115	222	115	166
09	53	326	159	242	225	10	53	108	189	120	166
09	53	199	094	125	104	10	53	079	161	117	158
09	53	223	094	166	140	10	53	100	160	115	147
09	53	229	091	170	154	10	53	087	215	119	154
09	54	199	088	317	073	10	54	141	187	154	138
09	54	220	093	312	068	10	54	085	128	088	128
09	54	179	078	293	051	10	54	062	143	070	121
09	54	165	070	239	038	10	54	065	127	070	123
09	54	209	065	249	082	10	54	091	146	101	143

Appendix 2.1 The condition, hen, number of responses, reinforcers and time with reinforcement time removed and the number of responses in each 15-s subinterval of each component in the last five days of all conditions.

C	Hen	Resp		Rfts				Time				Responses in Successive 15-s Subintervals															
		G	R	G	R	G	R	G	R	G	R	G	R	G	R	G	R	G	R	G	R						
01	61	376	352	8	27	811	756	39	68	47	53	61	45	52	41	53	55	61	52	63	38						
01	61	450	457	9	27	806	755	45	68	72	64	62	59	67	61	67	71	66	72	72	62						
01	61	487	469	9	27	807	757	56	69	77	58	67	63	77	73	64	73	69	69	77	65						
01	61	387	390	8	27	810	755	42	73	61	58	53	50	50	45	51	59	52	55	80	51						
01	61	367	369	8	28	809	754	35	59	48	55	55	45	53	52	52	58	58	57	66	43						
01	62	479	791	5	27	819	752	50	122	25	128	36	113	78	128	93	103	95	105	102	95						
01	62	512	868	4	27	822	753	62	135	32	153	30	112	55	126	111	112	116	120	106	111						
01	62	523	840	4	26	822	756	64	115	34	130	42	108	69	124	100	115	104	125	110	123						
01	62	510	862	5	27	822	755	55	113	29	119	46	128	76	133	92	115	102	128	111	126						
01	62	338	812	5	27	817	754	53	100	22	122	17	105	33	132	63	112	74	117	76	124						
01	63	480	509	8	28	810	749	45	92	68	92	68	70	75	53	66	71	74	82	84	51						
01	63	576	556	7	28	810	752	51	105	80	93	85	68	89	65	83	73	91	75	97	78						
01	63	528	511	8	28	806	751	42	97	69	77	78	64	81	59	84	74	86	72	89	68						
01	63	501	538	9	28	806	751	46	100	64	83	85	61	75	59	77	73	77	87	77	76						
01	63	503	519	9	28	807	751	51	91	65	78	74	69	83	55	74	66	76	92	82	70						
01	64	187	557	5	28	817	756	27	98	29	81	28	73	22	83	23	80	25	75	33	69						
01	64	241	546	5	28	817	756	33	80	37	77	36	89	28	71	27	77	38	82	43	69						
01	64	203	489	4	28	818	753	32	76	30	63	25	66	26	72	21	74	33	77	37	63						
01	64	160	500	4	28	820	753	23	79	22	71	23	67	20	76	16	69	23	73	33	67						
01	64	175	453	4	28	822	753	30	65	31	59	22	60	13	77	25	66	23	73	31	60						
01	65	436	549	9	27	809	755	55	93	66	76	65	78	66	62	65	86	56	78	63	77						
01	65	485	583	9	27	807	757	55	100	61	80	68	75	75	76	71	89	80	85	76	78						
01	65	477	550	9	27	808	753	53	87	69	78	63	77	76	69	73	83	74	77	69	81						
01	65	417	520	9	27	809	759	50	88	63	75	55	63	65	67	65	74	64	77	56	76						
01	65	375	531	8	27	809	756	43	104	52	73	61	70	56	70	55	68	61	79	48	70						
01	66	532	691	4	28	822	748	74	122	67	109	54	101	86	86	74	101	100	94	77	81						
01	66	644	846	4	28	822	750	118	145	69	132	78	130	75	115	101	117	108	110	98	98						
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01	66	597	741	4	26	821	755	86	130	65	118	71	113	102	86	86	105	96	101	94	90						
01	66	576	659	5	28	818	752	82	109	72	90	61	90	64	77	109	100	99	105	89	88						
02	61	333	264	28	8	754	808	52	25	51	35	41	38	48	46	51	36	42	43	49	41						
02	61	328	312	28	8	752	810	45	31	45	46	45	39	46	51	49	37	44	54	54	54						
02	61	374	391	27	8	758	809	63	51	52	53	46	61	54	61	55	48	46	61	58	57						
02	61	342	332	28	7	751	812	49	43	46	49	50	46	48	47	55	43	44	53	51	52						
02	61	343	408	28	8	751	811	50	52	46	66	48	68	43	58	53	52	54	58	50	54						
02	62	868	541	27	5	754	817	139	70	130	64	120	57	123	62	113	75	131	110	113	105						
02	62	789	434	27	4	758	819	126	54	122	42	104	51	116	56	102	61	120	81	101	89						
02	62	787	338	27	5	756	817	117	56	122	28	116	21	131	33	91	46	114	68	97	87						
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03	61	263	342	17	17	783	789	41	71	52	59	46	35	29	45	21	41	35	48	40	43						
03	61	226	235	17	18	787	780	40	38	20	30	36	31	30	42	34	37	29	30	37	27						
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03	63	464	397	18	18	782	785	51	56	72	57	52	55	73	56	71	56	61	62	76	56						
03	63	344	311	17	17	788	782	49	50	47	43	55	45	54	53	44	41	48	50	48	49						

03 63	165	90	15	15	794	790	13	08	29	21	25	10	30	13	28	13	21	14	20	11
03 64	316	315	18	17	783	783	44	44	53	43	40	47	53	58	48	51	38	44	40	48
03 64	278	261	16	18	789	782	41	35	39	38	45	38	41	34	37	35	35	42	40	39
03 64	206	215	17	16	787	790	31	30	26	30	26	35	33	29	34	29	30	35	28	27
03 64	187	182	15	17	793	782	33	25	35	21	34	29	23	28	20	21	31	29	21	29
03 64	92	86	15	16	790	789	20	11	13	10	14	10	12	11	14	19	07	13	12	12
03 65	473	483	17	16	787	791	71	78	71	75	61	64	70	66	66	62	81	66	73	67
03 65	438	465	18	18	781	782	60	65	66	68	58	74	62	75	60	55	59	66	74	60
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03 65	289	274	16	19	790	777	50	47	39	32	35	33	40	45	38	38	47	39	40	41
03 65	280	228	16	15	789	792	30	30	30	35	44	28	34	36	49	40	42	28	51	32
03 66	183	101	10	9	804	807	32	36	27	10	24	12	34	15	28	11	20	05	19	12
03 66	396	511	15	17	793	785	66	89	55	102	64	67	58	71	60	67	51	75	42	46
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03 66	120	138	15	16	791	786	17	36	22	20	14	13	22	18	12	17	21	18	12	16
04 61	331	256	4	26	821	761	38	31	52	30	60	32	58	36	46	44	43	36	34	47
04 61	325	292	3	25	824	748	34	40	51	48	46	46	51	48	49	35	42	39	43	36
04 61	328	214	4	27	821	754	35	37	57	31	56	27	57	30	45	31	44	27	35	31
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04 61	339	323	5	29	819	755	40	49	48	43	64	52	56	50	47	40	44	44	41	45
04 62	739	800	3	32	825	740	75	135	103	126	100	106	114	102	118	106	116	114	115	113
04 62	695	778	4	28	821	753	92	122	93	122	84	124	104	114	105	112	111	100	107	85
04 62	753	841	4	29	820	751	72	133	94	116	139	116	108	126	123	132	102	127	117	94
04 62	771	826	2	29	827	750	88	155	109	129	103	134	121	104	118	93	117	107	117	104
04 62	764	833	4	30	820	753	81	123	94	120	109	132	119	127	110	128	129	107	122	97
04 63	473	437	4	36	823	730	46	70	60	74	67	61	69	65	75	63	74	57	82	47
04 63	519	519	2	38	827	724	47	83	74	89	70	72	78	65	87	59	80	70	84	77
04 63	545	481	4	29	821	757	45	80	82	84	86	72	90	64	80	62	82	68	80	52
04 63	574	515	5	29	820	749	54	86	87	80	82	77	88	65	86	64	89	72	90	71
04 63	538	594	5	30	817	757	39	87	74	88	86	91	83	83	82	86	88	78	86	82
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04 64	267	381	4	29	823	751	29	59	34	54	45	56	41	58	40	55	34	52	45	49
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04 64	291	401	5	29	820	752	31	58	48	59	41	55	47	56	41	60	41	56	43	56
04 65	412	450	4	35	822	734	53	69	60	61	61	66	57	64	62	63	58	64	62	63
04 65	402	533	4	29	821	749	48	81	61	70	62	75	61	82	53	75	59	77	58	75
04 65	380	535	4	32	822	745	47	78	58	72	55	73	50	70	58	87	61	78	52	78
04 65	405	507	4	32	821	749	49	86	61	69	59	65	59	71	66	73	59	67	52	72
04 65	341	531	3	30	825	750	54	89	47	75	47	75	55	75	44	71	45	70	49	76
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04 66	398	765	3	34	720	737	46	147	46	119	52	96	58	109	52	103	81	88	65	107
04 66	562	715	4	36	821	732	58	121	69	97	82	102	86	96	88	110	91	96	88	93
04 66	512	919	6	30	896	744	54	149	55	140	65	144	70	116	87	113	88	120	93	138
05 61	358	334	30	3	753	822	51	28	50	55	53	52	54	58	53	52	53	45	44	44
05 61	387	281	30	6	749	815	49	27	59	42	58	51	56	48	59	48	60	40	47	31
05 61	312	221	27	4	755	822	41	28	54	24	45	27	47	35	52	42	36	32	40	35
05 61	344	298	27	6	762	813	45	36	45	42	49	44	56	48	51	38	49	47	50	43
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05 62	856	621	29	3	755	823	153	63	134	84	146	91	138	93	104	87	87	100	96	103
05 62	783	575	29	3	751	824	138	67	107	82	140	81	111	81	103	82	84	87	100	98
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05 63	553	345	29	6	752	816	64	21	87	46	90	54	88	58	83	59	77	49	64	58
05 63	506	388	30	3	748	823	61	24	76	49	89	55	68	65	71	62	66	66	78	67
05 63	563	401	28	4	755	820	71	24	80	52	85	61	90	68	77	69	88	63	73	64
05 63	588	424	28	3	752	823	83	21	90	55	75	64	79	75	85	66	87	69	91	74
05 63	538	431	31	7	743	813	77	30	72	56	77	67	72	62	80	77	85	77	76	63
05 64	322	269	28	3	751	824	51	18	46	35	46	41	46	43	46	46	42	45	46	43
05 64	385	204	29	6	752	817	67	18	55	18	51	31	50	33	55	29	51	36	57	39
05 64	355	268	27	5	755	818	58	18	53	28	47	45	54	45	49	41	46	48	49	43
05 64	302	258	36	6	735	815	46	21	44	28	45	41	48	41	42	45	42	42	36	40
05 64	304	242	37	3	733	823	45	17	47	38	45	39	44	33	44	30	37	43	42	42
05 65	501	372	33	2	744	826	67	35	76	45	72	53	71	52	77	56	72	66	67	67
05 65	538	378	29	3	752	824	66	33	72	58	79	51	75	53	85	58	81	61	81	64
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05 65	553	386	40	3	721	824	83	39	75	48	78	61	83	61	82	60	70	63	83	54
05 65	517	346	37	3	726	824	78	42	70	45	71	50	72	52	73	56	84	48	70	53
05 66	520	411	33	4	739	819	91	15	73	39	72	54	67	54	89	74	59	85	69	90
05 66	384	510	28	3	756	823	62	37	59	46	59	64	54	80	52	93	45	83	53	108
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06 61	418	377	17	17	792	795	50	51	60	54	61	55	65	56	54	58	63	46	65	57
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06 62	727	769	16	18	793	790	107	129	108	103	109	104	90	112	103	97	106	109	104	117
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07 62	461	660	27	5	768	827	47	77	56	75	64	98	91	102	64	107	78	105	62	97
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07 65	527	222	29	4	766	828	75	26	68	29	74	29	72	32	83	41	83	30	78	36
07 65	533	360	28	5	761	827	75	51	77	65	80	46	79	48	73	46	72	48	78	57
07 65	498	416	28	4	766	828	68	50	69	64	68	59	68	66	70	60	75	59	80	59
07 66	901	709	29	5	756	825	113	89	158	91	133	97	133	111	133	110	140	119	93	95
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16	61	172	161	13	13	589	588	28	25	20	20	21	18	27	21	22	23	17	20	37	34
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16	62	674	621	11	13	595	588	65	80	106	101	107	72	94	102	112	84	94	85	97	98
16	62	513	557	13	14	588	586	53	70	71	78	65	76	85	83	66	63	87	94	86	95
16	62	501	560	13	14	589	584	49	67	71	98	80	79	85	95	73	79	68	82	76	61
16	63	339	352	13	13	589	585	32	36	32	45	48	44	56	53	56	67	62	58	52	61
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16	63	265	307	13	13	588	587	29	30	39	36	40	53	38	52	36	42	38	53	46	41
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19	61	157	378	19	3	569	615	30	54	21	54	31	45	20	55	22	62	16	55	18	55
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19	61	150	351	20	4	568	612	27	54	20	53	22	39	20	48	20	44	17	58	24	55
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19	62	269	455	22	2	564	618	24	63	43	73	46	65	33	65	45	62	39	62	40	66
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19	64	283	214	22	2	562	618	41	15	45	31	40	30	45	38	41	34	37	30	35	36
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38 62	371	406	11	3	284	309	17	42	63	55	63	55	52	60	82	64	64	71	30	59
38 62	177	194	11	4	285	301	13	17	22	25	23	33	33	26	33	36	31	28	22	32
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42	65	549	559	29	4	651	717	64	65	78	91	74	96	76	90	90	78	88	69	80	71
42	65	554	559	28	3	650	719	67	70	62	88	79	82	73	86	91	75	104	80	78	78
42	66	418	366	24	5	663	713	39	51	59	48	69	56	49	56	64	49	77	51	61	55
42	66	396	359	29	3	650	719	41	54	56	57	63	52	44	52	68	45	69	52	56	48
42	66	413	258	29	3	652	719	41	47	63	39	63	33	52	28	75	31	64	38	55	43
42	66	410	319	28	2	652	724	44	43	50	49	59	49	61	43	72	45	63	38	62	52
42	66	408	318	29	4	649	717	37	61	55	47	66	39	56	39	68	31	74	46	53	55
43	61	371	303	29	4	754	820	56	17	51	40	56	50	56	62	61	45	46	47	46	42
43	61	363	294	29	7	754	812	50	25	56	43	56	57	55	50	53	44	47	37	47	41
43	61	378	379	29	2	753	825	61	38	54	68	59	78	54	75	52	49	48	38	50	35
43	61	388	397	29	4	750	820	56	40	60	84	54	66	48	56	53	58	56	52	61	41
43	61	367	347	29	5	753	817	49	39	51	66	53	65	47	58	58	47	57	32	52	40
43	62	789	560	29	4	752	821	89	41	92	53	118	88	117	86	119	107	119	95	136	90
43	62	720	477	28	3	758	825	54	24	113	52	104	91	120	82	106	89	116	68	111	72
43	62	642	443	29	3	752	823	57	23	103	48	90	75	100	90	108	78	112	61	76	64
43	62	823	466	29	3	753	823	108	24	131	73	136	85	129	96	125	64	110	63	85	61
43	62	730	509	29	4	749	820	72	12	120	42	111	97	102	98	88	93	119	83	119	84
43	63	360	387	29	4	748	821	47	28	55	52	55	49	45	52	55	76	49	66	54	64
43	63	353	331	29	3	752	824	51	29	54	36	55	43	44	54	47	50	55	55	48	64
43	63	360	389	28	3	753	825	46	29	57	49	49	63	53	66	47	61	47	53	61	69
43	63	327	344	29	7	754	811	47	27	53	45	41	57	37	48	50	59	48	54	51	56
43	63	348	264	27	4	761	821	48	15	46	28	51	39	51	40	57	53	40	46	55	43
43	64	429	242	29	4	749	821	46	25	54	37	66	38	68	41	70	29	60	34	65	38
43	64	441	252	29	5	755	819	45	23	61	30	59	45	72	48	66	43	69	31	70	33
43	64	399	286	27	5	759	817	51	26	63	39	47	53	55	52	64	48	63	37	56	32
43	64	456	275	30	3	756	823	51	26	61	45	67	44	70	40	75	37	61	39	72	44
43	64	498	289	29	5	749	819	53	21	66	38	80	49	68	48	69	45	85	40	78	48
43	65	640	496	28	4	751	820	84	49	71	49	94	69	83	86	101	69	103	84	104	90
43	65	655	514	29	4	751	822	86	52	85	71	90	68	100	81	92	84	108	79	95	79
43	65	632	469	30	4	750	819	87	45	84	55	91	73	90	73	88	72	108	66	85	85
43	65	592	530	28	3	757	824	75	42	86	73	84	88	88	83	89	76	96	80	76	88
43	65	666	518	28	3	760	823	94	45	108	73	97	80	84	80	87	79	98	82	100	75
43	66	281	358	28	4	753	821	40	40	44	49	36	51	35	65	46	54	48	49	34	50
43	66	295	353	27	3	756	825	35	20	46	33	36	33	42	56	49	73	43	66	44	73
43	66	268	287	27	4	760	820	40	17	44	21	38	37	38	44	40	37	31	64	37	67
43	66	195	251	27	5	756	821	26	20	35	33	27	29	30	35	28	44	21	49	29	41
43	66	171	205	28	3	759	823	26	18	36	18	18	23	18	32	25	32	25	34	23	50
44	61	500	290	5	29	818	749	74	46	99	43	77	41	68	43	77	41	53	36	53	40
44	61	429	255	3	29	825	753	31	36	72	41	91	35	72	36	63	40	55	35	46	32
44	61	397	217	3	29	825	750	31	33	81	23	76	33	60	34	54	33	53	30	43	32
44	61	513	248	3	27	825	758	43	44	76	27	96	37	93	26	71	34	69	37	66	44
44	61	430	225	6	29	817	756	30	36	71	33	89	34	80	28	56	25	54	35	50	34
44	62	603	598	4	27	820	760	57	69	97	93	115	85	89	92	90	86	64	79	84	94
44	62	817	571	4	28	821	753	74	99	121	68	127	61	132	95	120	77	112	83	133	88
44	62	646	548	2	27	827	759	32	69	101											

44	63	439	287	3	29	824	750	36	50	56	47	65	42	71	39	72	40	66	36	74	33
44	64	293	279	5	28	818	754	37	38	40	45	40	41	42	44	44	38	45	34	45	36
44	64	253	309	3	29	824	752	24	43	34	49	41	44	38	53	40	46	36	40	40	34
44	64	198	292	5	28	820	748	19	42	28	48	31	43	28	44	34	35	31	41	28	40
44	64	262	305	3	28	823	755	27	43	42	45	47	40	43	42	33	44	34	45	36	46
44	64	285	341	5	30	820	750	33	52	36	49	38	47	36	41	46	47	49	50	47	55
44	65	515	480	4	28	822	751	72	87	84	67	73	69	74	81	72	69	68	61	72	46
44	65	650	473	3	28	824	753	67	63	106	71	106	72	93	76	104	64	95	73	82	55
44	65	552	478	4	29	821	752	72	78	98	63	79	73	87	83	76	66	69	56	71	59
44	65	649	474	3	29	824	750	95	79	100	68	94	59	99	58	87	68	89	69	87	74
44	65	583	493	4	29	827	753	61	77	93	82	91	69	73	68	86	61	97	69	85	68
44	66	285	353	4	29	822	751	33	58	32	34	39	45	41	50	45	51	43	62	52	55
44	66	248	321	5	28	820	753	31	40	25	42	32	38	39	48	31	49	34	54	56	52
44	66	260	333	2	29	826	752	16	52	25	42	37	54	34	47	41	52	49	49	58	37
44	66	274	340	5	28	819	756	23	52	27	62	49	62	52	40	48	47	33	41	42	39
44	66	512	438	4	30	821	750	52	66	77	69	77	85	86	72	65	61	77	38	79	47
45	61	513	326	7	26	814	758	69	47	80	39	74	45	74	48	73	53	75	43	69	51
45	61	533	341	6	26	815	758	57	47	88	44	94	49	73	41	68	49	79	49	75	57
45	61	502	268	5	26	819	761	55	46	86	37	82	41	73	38	71	39	70	34	66	33
45	61	523	311	7	28	814	755	62	57	94	47	89	31	73	49	68	38	63	47	74	42
45	61	479	259	6	26	818	757	58	42	87	33	82	34	59	33	72	42	67	35	54	40
45	62	530	569	4	26	820	757	44	59	87	85	91	88	70	88	72	84	83	92	84	75
45	62	630	512	9	27	810	754	52	61	101	69	125	82	90	70	90	77	85	66	88	88
45	62	630	511	7	26	815	759	74	64	122	69	97	83	96	84	96	61	77	75	72	78
45	62	662	521	7	27	814	759	79	42	106	78	113	89	121	77	81	78	80	80	84	78
45	62	616	508	8	27	810	757	74	49	123	64	101	83	95	84	79	63	82	78	65	87
45	63	526	294	9	28	807	754	65	38	86	34	91	41	69	47	74	39	72	47	71	48
45	63	576	343	7	28	811	756	71	58	82	54	97	51	89	48	84	39	86	47	67	46
45	63	437	328	9	27	806	756	47	45	72	60	68	45	75	44	58	45	84	46	51	43
45	63	617	334	5	28	820	753	66	63	103	48	99	53	97	52	87	32	91	42	74	45
45	63	536	296	6	27	815	756	61	48	91	53	85	42	81	39	81	43	70	35	67	36
45	64	280	303	6	28	816	755	27	32	41	46	41	53	40	43	43	47	46	43	43	40
45	64	282	302	7	27	814	757	32	37	43	45	48	46	40	49	38	42	42	40	41	45
45	64	296	358	7	27	813	759	29	41	43	52	51	53	48	51	45	58	37	50	44	53
45	64	349	351	7	26	814	761	47	44	41	44	49	51	46	57	53	49	56	51	56	56
45	64	298	320	8	28	812	754	34	42	40	48	51	56	52	42	44	46	39	42	39	45
45	65	551	534	8	27	812	761	63	77	81	60	82	82	88	82	75	54	87	73	76	107
45	65	564	561	8	26	810	760	69	90	79	74	83	97	79	70	83	65	93	98	78	68
45	65	524	468	7	28	813	752	67	91	84	70	82	51	78	72	80	67	74	57	59	51
45	65	543	498	7	24	814	757	58	65	87	75	90	80	84	60	75	84	78	87	71	47
45	65	496	531	5	27	819	754	58	83	69	74	81	82	75	64	68	55	68	97	77	77
45	66	369	497	7	29	813	756	36	82	48	74	59	68	58	61	48	64	57	84	64	65
45	66	408	527	6	27	815	753	48	83	66	78	59	85	55	66	47	66	67	89	67	60
45	66	365	477	7	26	811	762	41	83	51	68	56	57	50	75	53	69	54	71	60	54
45	66	231	306	7	27	813	757	24	37	20	43	29	53	33	56	33	30	36	34	50	55
45	66	392	446	9	26	808	757	43	60	41	67	50	58	58	78	67	79	67	59	66	45
46	61	309	304	26	8	762	811	53	40	36	45	41	48	45	43	46	39	40	38	48	51
46	61	387	399	26	7	762	813	59	38	66	59	47	66	55	68	57	58	53	57	50	53
46	61	420	461	27	6	751	817	73	61	63	90	63	84	60	68	59	64	50	51	53	45
46	61	417	413	27	7	758	814	70	36	59	60	57	66	56	73	62	62	53	62	60	54
46	61	408	449	28	5	753	819	55	62	62	83	56	77	48	67	64	58	63	55	61	48
46	62	796	752	28	5	751	817	101	86	131	119	112	113	107	108	110	100	122	117	115	110
46	62	675	620	28	8	755	811	71	68	107	107	98	109	86	75	90	98	88	109	83	
46	62	808	576	29	8	751	807	99	60	114	88	125	86	128	77	89	96	126	84	127	84
46	62	698	582	26	9	757	805	93	62	135	86	103	85	83	87	105	83	86	90	95	90
46	62	777	749	29	8	749	808	90	59	139	109	116	119	133	97	105	118	90	137	105	111
46	63	404	542	27	9	757	806	47	77	68	93	72	76	50	76	62	70	57	81	41	70
46	63	428	395	26	5	762	820	69	57	72	52	60	65	65	61	58	64	52	47	49	50
46	63	253	397	27	4	758	820	40	49	35	52	41	46	31	64	30	60	39	71	38	59
46	63	521	535	27	5	757	818	44	59	70	79	91	76	65	80	77	79	81	74	94	88
46	63	308	477	27	6	759	816	44	46	48	79	58	80	42	75	35	79	44	60	35	60
46	64	513	338	29	5	750	818	56	42	82	55	83	42	65	46	70	57	84	48	74	48
46	64	425	284	26	8	764	808	54	34	54	49	63	37	77	43	61	43	61	36	55	42
46	64	397	353	26	9	759	805	55	44	66	49	50	52	56	43	53	59	55	58	62	48
46	64	385	295	27	5	758	818	44	40	51	43	57	38	60	45	63	42	62	38	49	50
46	64	384	297	26	9	760	807	39	30	49	40	54	45	62	48	52	48	65	40	64	43
46	65	513	507	28	9	759	805	89	60	66	63	73	68	75	75	70	81	69	78	71	82
46	65	451	478	28	8	755	809	70	50	51	74	67	68	83	68	59	76	58	73	63	70
46	65	536	572	29	5	750	818	85	63	58	90	84	72	71	90	76	75	95	90	67	93
46	65	508	509	29	6	750	814	88	54	79	62	67	69	70	78	60	82	79	81	65	83
46	65	454	512	28	8	745	810	68	73	77	73	67	75	60	78	71	72	61	73	57	72
46	66	469	609	28	5	752	817	75	37	80	78	67	85	60	92	68	107	62	108	68	104
46	66	508	590	28	5	753	818	68	68	74	81	82	95	62	100	75	82	75	78	74	86
46	66	462	486	27	6	764	815	73	31	77	58	65	65	52	84	74	91	64	90	58	71
46	66	366	482	27	8	758	811	58	54	42	66	44	62	64	60	54	80	44	75	60	85
46	66	419	479	26	8	761	808	62	45	58	58	60	77	67	79	67	77	50	76		

47	62	638	580	19	18	781	784	90	92	97	73	107	86	85	78	105	83	87	85	67	85
47	62	599	569	17	17	788	783	71	75	98	80	93	79	89	91	62	78	89	82	97	86
47	62	558	537	19	19	781	780	80	83	100	71	86	84	74	67	83	74	67	89	68	71
47	62	588	508	19	19	778	782	87	71	79	63	103	78	74	59	99	79	76	82	72	78
47	63	422	375	18	19	787	780	62	66	73	54	64	43	66	52	55	53	54	57	50	52
47	63	444	425	17	18	785	783	66	66	80	60	68	57	70	64	46	62	56	54	58	57
47	63	593	626	17	16	783	787	95	97	86	97	86	94	85	84	86	78	83	88	73	92
47	63	487	427	17	17	784	787	68	54	83	67	72	61	82	75	61	61	57	59	54	52
47	63	437	364	17	17	787	785	59	52	59	62	63	45	66	61	65	47	62	56	65	41
47	64	465	389	17	17	785	786	60	53	66	56	63	49	80	59	76	69	65	57	58	48
47	64	444	364	17	17	786	783	59	50	56	47	64	46	76	63	59	58	66	48	65	52
47	64	523	438	17	16	788	787	70	50	85	71	91	69	77	69	81	61	70	69	49	49
47	64	425	393	17	17	784	787	58	55	60	55	56	60	67	62	66	61	56	53	64	47
47	64	476	411	17	17	786	784	66	56	69	62	80	49	63	70	68	72	62	49	61	54
47	65	530	551	16	17	786	788	73	82	79	89	90	73	76	84	80	68	60	74	73	84
47	65	507	502	17	16	797	787	67	66	73	71	74	80	79	76	68	78	68	64	78	67
47	65	482	450	19	19	786	781	67	66	80	55	66	59	62	61	69	69	69	66	69	75
47	65	501	494	16	17	787	785	73	67	69	78	77	73	74	91	74	53	65	68	70	67
47	65	508	504	17	17	786	785	76	69	72	62	81	74	67	85	66	74	77	65	70	75
47	66	515	567	17	16	786	785	77	63	76	86	77	101	64	86	81	76	72	73	68	83
47	66	548	558	17	17	788	783	70	81	84	87	77	96	65	74	76	60	92	85	87	76
47	66	560	548	16	17	790	786	71	85	81	83	79	83	65	87	85	64	92	70	88	77
47	66	502	529	18	18	781	784	64	77	82	77	75	70	78	82	57	71	80	69	66	84
47	66	544	571	17	16	783	785	74	88	91	90	82	82	84	66	61	74	70	95	83	78

## APPENDIX 2.2

The intercepts ( $\log c$ ), slopes ( $a$ ), standard errors and variance accounted for by the fitted lines to data for each 15-s subinterval of components for all conditions at each blackout duration in the descending series.

Appendix 2.2.1 - Intercepts of the fitted lines

Appendix 2.2.2 - Slopes of the fitted lines

Appendix 2.2.3 - Standard errors of the fitted lines

Appendix 2.2.4 - Variance accounted for by the fitted lines

## Appendix 2.2.1 Intercepts (log c of the fitted lines

HEN	BIN	BLACKOUT DURATION (in SECONDS)						
		1	10	30	60	120	180	297
61	1	0.02	0.07	0.11	0.02	0.06	0.03	-0.01
61	2	0.05	0.08	0.12	-0.04	0.06	0.00	-0.10
61	3	0.07	0.10	0.12	-0.00	0.07	0.07	-0.11
61	4	0.03	0.09	0.07	0.01	0.05	0.03	-0.10
61	5	0.04	0.10	0.05	0.01	0.07	0.02	-0.08
61	6	0.02	0.08	0.06	-0.00	0.11	0.04	-0.06
61	7	0.07	0.07	0.05	0.03	0.08	0.08	-0.04
62	1	0.00	-0.11	-0.07	-0.11	-0.02	-0.01	-0.02
62	2	-0.04	-0.07	-0.05	-0.02	-0.02	-0.06	-0.01
62	3	-0.02	-0.08	-0.06	-0.04	-0.01	-0.01	-0.05
62	4	0.01	-0.07	-0.02	-0.03	0.03	-0.00	-0.04
62	5	0.04	-0.03	-0.03	0.03	0.01	0.03	-0.06
62	6	0.01	-0.03	-0.07	-0.01	0.02	0.07	-0.04
62	7	0.01	-0.06	-0.05	-0.05	0.02	0.06	-0.04
63	1	0.05	0.03	-0.03	0.03	-0.04	0.01	-0.02
63	2	0.09	0.08	-0.02	-0.01	-0.03	0.00	-0.03
63	3	0.11	0.05	-0.01	0.00	-0.02	0.01	-0.00
63	4	0.11	0.04	0.00	0.02	-0.07	0.04	-0.00
63	5	0.10	0.06	0.00	-0.00	-0.04	0.00	0.00
63	6	0.10	0.08	-0.01	0.02	-0.03	0.07	0.03
63	7	0.10	0.08	0.02	0.01	-0.04	0.03	0.02
64	1	0.03	0.02	0.07	0.03	0.01	0.01	-0.02
64	2	0.02	0.03	0.05	0.01	-0.02	-0.04	-0.06
64	3	-0.02	0.03	0.03	-0.03	-0.04	-0.04	-0.06
64	4	-0.06	0.02	0.06	-0.02	-0.06	-0.03	-0.01
64	5	-0.08	-0.00	0.07	0.00	-0.04	0.07	-0.07
64	6	-0.10	0.00	0.02	-0.05	-0.08	0.03	-0.08
64	7	-0.06	-0.03	0.02	-0.03	-0.10	-0.03	-0.03
65	1	-0.01	0.06	-0.09	-0.03	0.01	0.03	0.05
65	2	0.01	0.07	-0.03	0.00	0.02	0.03	0.04
65	3	0.01	0.08	-0.05	0.02	-0.01	0.01	0.05
65	4	0.00	0.07	-0.04	0.02	0.00	0.03	0.05
65	5	0.00	0.06	-0.05	0.01	0.01	0.02	0.05
65	6	0.00	0.06	-0.06	0.01	0.01	0.02	0.00
65	7	0.00	0.05	-0.05	0.03	-0.01	0.05	0.04
66	1	0.03	-0.03	-0.14	-0.14	-0.16	-0.06	-0.05
66	2	0.01	-0.05	-0.10	-0.14	-0.08	-0.14	-0.07
66	3	-0.02	-0.03	-0.06	-0.12	-0.06	-0.10	-0.08
66	4	0.00	-0.02	-0.02	-0.13	-0.06	-0.11	-0.11
66	5	-0.02	-0.01	-0.06	-0.06	-0.02	-0.06	-0.09
66	6	-0.01	-0.05	-0.07	-0.07	-0.02	-0.07	-0.09
66	7	-0.05	-0.04	-0.02	-0.12	-0.06	-0.04	-0.06

Appendix 2.2.2. Slopes ( $\alpha$ ) of the fitted lines.

HEN	BIN	BLACKOUT DURATION (in SECONDS)						
		1	10	30	60	120	180	297
61	1	0.21	-0.10	-0.06	-0.33	-0.22	-0.17	-0.24
61	2	0.02	-0.25	-0.18	-0.44	-0.35	-0.30	-0.36
61	3	-0.04	-0.22	-0.17	-0.41	-0.40	-0.30	-0.24
61	4	-0.02	-0.20	-0.27	-0.45	-0.45	-0.32	-0.29
61	5	0.05	-0.18	-0.24	-0.38	-0.34	-0.27	-0.18
61	6	0.02	-0.14	-0.21	-0.41	-0.32	-0.25	-0.13
61	7	0.02	-0.15	-0.22	-0.37	-0.34	-0.32	-0.22
62	1	0.35	0.11	0.09	-0.07	0.16	0.26	0.17
62	2	0.41	0.09	0.06	-0.06	0.14	0.13	0.05
62	3	0.36	0.03	0.03	-0.05	0.12	0.12	-0.04
62	4	0.26	0.05	-0.03	-0.19	0.05	0.11	-0.07
62	5	0.16	0.01	-0.02	-0.15	0.03	0.04	0.02
62	6	0.10	-0.08	0.01	-0.11	0.03	-0.03	-0.10
62	7	0.05	0.06	-0.02	-0.15	-0.08	-0.04	-0.08
63	1	0.47	0.04	-0.17	-0.06	-0.05	-0.02	-0.06
63	2	0.23	-0.06	-0.32	-0.19	-0.22	-0.14	-0.07
63	3	0.13	-0.07	-0.35	-0.19	-0.20	-0.18	-0.10
63	4	0.04	-0.10	-0.32	-0.19	-0.23	-0.13	-0.07
63	5	0.07	-0.09	-0.32	-0.19	-0.26	-0.10	-0.10
63	6	0.10	-0.14	-0.33	-0.22	-0.23	-0.13	-0.04
63	7	0.03	-0.13	-0.31	-0.24	-0.13	-0.10	-0.11
64	1	0.49	0.12	0.06	0.22	0.10	0.18	0.16
64	2	0.32	0.09	0.12	0.11	0.10	0.21	0.19
64	3	0.29	0.10	0.07	0.11	0.07	0.18	0.11
64	4	0.31	0.09	0.03	0.09	0.08	0.13	0.07
64	5	0.29	0.09	0.05	0.03	0.07	0.13	0.10
64	6	0.22	0.08	0.03	0.05	0.07	0.10	-0.04
64	7	0.17	0.05	-0.01	0.08	0.03	-0.05	-0.02
65	1	0.34	0.13	-0.16	-0.14	-0.12	-0.09	0.07
65	2	0.20	0.03	-0.23	-0.18	-0.19	-0.15	-0.31
65	3	0.17	0.07	-0.23	-0.19	-0.19	-0.18	-0.07
65	4	0.17	0.04	-0.26	-0.17	-0.15	-0.13	-0.09
65	5	0.19	0.07	-0.24	-0.17	-0.11	-0.12	-0.10
65	6	0.16	0.06	-0.20	-0.18	-0.05	-0.12	-0.08
65	7	0.18	0.07	-0.23	-0.17	-0.09	-0.10	-0.08
66	1	0.39	0.33	0.25	0.09	0.10	-0.08	-0.07
66	2	0.33	0.25	0.21	0.07	0.07	0.02	0.06
66	3	0.24	0.14	0.16	-0.05	0.01	0.08	-0.01
66	4	0.14	0.17	0.10	-0.10	-0.01	-0.07	-0.01
66	5	0.14	0.14	0.15	-0.11	-0.07	-0.08	-0.10
66	6	0.01	0.14	0.13	-0.12	-0.16	-0.12	-0.03
66	7	0.01	0.14	0.15	-0.19	-0.11	-0.08	-0.05

## Appendix 2.2.3. Standard errors of the fitted lines.

HEN	BIN	BLACKOUT DURATION (in SECONDS)						
		1	10	30	60	120	180	297
61	1	0.128	0.174	0.136	0.079	0.078	0.118	0.153
61	2	0.125	0.153	0.114	0.112	0.141	0.146	0.146
61	3	0.105	0.150	0.139	0.152	0.160	0.176	0.151
61	4	0.098	0.132	0.122	0.119	0.170	0.178	0.156
61	5	0.117	0.106	0.131	0.128	0.175	0.200	0.163
61	6	0.083	0.109	0.115	0.184	0.175	0.212	0.172
61	7	0.092	0.079	0.128	0.107	0.176	0.206	0.140
62	1	0.086	0.080	0.106	0.104	0.100	0.106	0.158
62	2	0.266	0.113	0.093	0.105	0.132	0.162	0.107
62	3	0.258	0.113	0.141	0.144	0.112	0.124	0.122
62	4	0.203	0.087	0.121	0.141	0.124	0.151	0.107
62	5	0.118	0.101	0.098	0.138	0.152	0.176	0.135
62	6	0.100	0.133	0.135	0.111	0.140	0.163	0.171
62	7	0.089	0.101	0.155	0.115	0.125	0.141	0.146
63	1	0.123	0.083	0.064	0.073	0.104	0.095	0.121
63	2	0.075	0.072	0.086	0.104	0.088	0.093	0.152
63	3	0.090	0.073	0.091	0.106	0.112	0.086	0.131
63	4	0.081	0.072	0.084	0.105	0.099	0.108	0.123
63	5	0.086	0.095	0.080	0.146	0.100	0.086	0.111
63	6	0.095	0.103	0.101	0.124	0.104	0.123	0.124
63	7	0.070	0.080	0.091	0.096	0.105	0.098	0.144
64	1	0.133	0.102	0.079	0.090	0.086	0.103	0.109
64	2	0.154	0.061	0.063	0.080	0.105	0.127	0.131
64	3	0.167	0.089	0.071	0.093	0.118	0.150	0.175
64	4	0.193	0.070	0.082	0.097	0.128	0.121	0.163
64	5	0.176	0.067	0.080	0.110	0.129	0.154	0.133
64	6	0.147	0.057	0.083	0.134	0.139	0.113	0.190
64	7	0.094	0.056	0.087	0.071	0.115	0.130	0.185
65	1	0.104	0.109	0.061	0.043	0.101	0.070	0.087
65	2	0.056	0.092	0.064	0.051	0.066	0.083	0.089
65	3	0.062	0.115	0.058	0.057	0.066	0.105	0.066
65	4	0.058	0.112	0.068	0.069	0.082	0.104	0.092
65	5	0.081	0.083	0.058	0.052	0.072	0.101	0.120
65	6	0.075	0.117	0.079	0.064	0.069	0.094	0.081
65	7	0.076	0.086	0.064	0.094	0.092	0.087	0.086
66	1	0.165	0.095	0.094	0.126	0.154	0.191	0.192
66	2	0.140	0.110	0.083	0.164	0.128	0.142	0.208
66	3	0.109	0.119	0.101	0.194	0.113	0.116	0.189
66	4	0.138	0.085	0.164	0.265	0.103	0.129	0.178
66	5	0.133	0.080	0.198	0.146	0.104	0.153	0.201
66	6	0.163	0.086	0.092	0.159	0.130	0.167	0.187
66	7	0.114	0.089	0.105	0.167	0.126	0.167	0.179

Appendix 2.2.4 The percentage of variance accounted for by the fitted lines.

HEN	BIN	BLACKOUT DURATION (in SECONDS)						
		1	10	30	60	120	180	297
61	1	53.2	14.4	8.6	90.4	78.4	54.3	59.1
61	2	1.4	59.2	56.2	89.2	74.6	71.0	77.1
61	3	5.0	54.6	43.4	79.0	75.0	62.4	58.0
61	4	1.7	53.3	70.9	88.5	76.8	64.7	66.1
61	5	7.4	57.2	63.6	82.0	63.7	50.9	41.2
61	6	2.2	47.3	63.3	72.1	60.8	44.5	23.5
61	7	1.3	65.3	61.0	86.3	63.4	58.5	57.9
62	1	91.8	50.0	31.7	20.5	58.0	78.2	32.9
62	2	60.6	20.1	21.4	16.2	38.5	28.0	8.0
62	3	55.8	3.8	2.7	6.5	39.2	34.6	4.3
62	4	52.1	14.1	4.4	49.6	7.1	23.9	13.9
62	5	54.1	0.7	3.1	37.8	1.6	3.6	1.4
62	6	40.7	0.1	0.1	33.1	2.5	2.6	12.4
62	7	19.3	0.1	1.2	47.4	18.9	4.3	11.3
63	1	87.7	11.6	77.4	29.0	11.0	2.3	9.8
63	2	82.0	27.0	87.9	63.6	78.0	52.6	9.5
63	3	49.1	35.3	88.0	62.5	64.8	47.9	24.0
63	4	11.0	53.6	88.3	64.8	75.9	40.7	15.2
63	5	24.6	35.8	89.2	47.8	79.7	39.8	27.9
63	6	33.2	52.0	84.6	61.7	74.2	36.0	5.2
63	7	9.6	60.1	85.4	76.3	48.0	33.5	22.4
64	1	89.3	45.0	20.4	77.5	47.8	62.4	51.7
64	2	73.0	53.1	61.2	52.8	35.0	59.0	52.7
64	3	66.8	41.7	29.5	42.2	19.4	43.5	17.0
64	4	61.7	49.4	4.9	31.7	21.4	37.1	8.1
64	5	62.1	49.5	14.7	3.8	14.4	26.7	23.3
64	6	58.3	52.2	7.0	7.8	12.6	30.1	2.0
64	7	66.2	29.7	1.1	39.6	4.7	8.4	0.7
65	1	86.1	41.4	76.1	85.4	47.2	46.8	26.2
65	2	87.2	7.0	85.8	86.8	84.3	65.8	6.1
65	3	80.9	17.2	88.5	85.8	84.5	61.8	37.8
65	4	82.0	6.6	87.1	78.1	70.0	48.3	32.3
65	5	75.5	29.6	89.2	85.1	60.7	43.9	25.4
65	6	72.1	14.2	76.0	81.6	28.5	49.6	36.2
65	7	75.6	24.8	86.0	64.0	38.2	43.7	32.8
66	1	79.0	86.5	80.0	19.9	18.1	8.5	6.2
66	2	78.8	73.8	78.1	9.5	13.6	1.2	3.6
66	3	76.2	43.7	58.4	3.6	0.2	18.9	0.0
66	4	39.6	68.1	16.7	7.2	0.5	12.7	0.1
66	5	41.1	62.8	23.4	23.7	17.8	11.4	10.9
66	6	0.4	60.1	54.0	22.0	42.8	20.1	1.3
66	7	0.7	55.6	55.4	39.6	26.8	10.1	4.1

## APPENDIX 2.3

The intercepts ( $\log c$ ), slopes ( $a$ ), standard errors (S.E), and variance accounted for by the lines fitted to data for each 15 s subinterval (bin) of conditions at each condition in the ascending series.

BLACKOUT (s)	INTERCEPT		SLOPE		S.E		VAC	
	30	1	30	1	30	1	30	1
HEN BIN								
61 1	0.09	0.12	-0.31	0.14	0.140	0.112	73.4	45.1
61 2	0.00	0.13	-0.24	-0.23	0.133	0.103	64.6	71.1
61 3	-0.02	0.12	-0.23	-0.24	0.147	0.079	57.4	81.8
61 4	0.02	0.10	-0.18	-0.20	0.113	0.085	58.7	73.0
61 5	0.03	0.12	-0.17	-0.09	0.144	0.067	42.9	45.4
61 6	0.06	0.12	-0.18	-0.07	0.135	0.078	49.0	26.6
61 7	0.00	0.11	-0.24	-0.01	0.156	0.067	56.5	0.8
62 1	-0.09	0.10	0.04	0.33	0.128	0.174	3.9	65.3
62 2	-0.01	0.16	0.10	0.11	0.113	0.109	27.1	34.7
62 3	-0.02	0.09	0.07	0.03	0.136	0.074	9.2	6.5
62 4	-0.04	0.08	0.04	0.06	0.111	0.084	6.2	19.7
62 5	0.04	0.07	-0.04	0.02	0.122	0.101	4.3	2.5
62 6	0.00	0.07	0.03	0.09	0.120	0.114	2.3	23.1
62 7	-0.02	0.06	-0.05	0.07	0.119	0.102	6.6	21.6
63 1	0.00	0.06	0.02	0.11	0.122	0.148	1.9	23.5
63 2	-0.03	0.11	0.01	-0.09	0.116	0.130	0.5	19.8
63 3	-0.03	0.11	-0.03	-0.11	0.103	0.088	4.0	46.0
63 4	0.01	0.06	-0.07	-0.16	0.090	0.096	29.4	58.8
63 5	0.06	0.06	-0.09	-0.18	0.079	0.115	44.6	55.9
63 6	0.02	0.07	-0.02	-0.16	0.101	0.085	2.2	64.6
63 7	0.03	0.06	-0.13	-0.16	0.106	0.100	48.2	55.7
64 1	-0.06	0.05	0.15	0.30	0.117	0.090	47.1	83.6
64 2	-0.08	0.04	0.27	0.22	0.152	0.064	62.6	84.0
64 3	-0.06	0.07	0.32	0.18	0.148	0.092	71.6	62.8
64 4	-0.08	0.05	0.22	0.20	0.162	0.070	49.5	78.1
64 5	-0.02	0.06	0.17	0.19	0.183	0.077	30.6	74.3
64 6	-0.00	0.09	0.29	0.22	0.154	0.081	65.2	77.6
64 7	0.03	0.07	0.23	0.19	0.123	0.080	64.7	73.0
65 1	0.04	0.05	-0.01	0.21	0.090	0.083	0.6	77.5
65 2	0.05	0.06	-0.01	0.02	0.080	0.102	0.9	1.8
65 3	0.03	0.05	0.01	0.03	0.094	0.075	0.7	5.4
65 4	0.05	0.02	0.05	0.01	0.059	0.077	24.7	0.5
65 5	0.08	0.04	0.04	0.00	0.100	0.084	7.4	0.0
65 6	0.03	0.04	0.05	0.05	0.063	0.090	19.7	11.5
65 7	0.03	0.02	-0.02	-0.02	0.086	0.087	2.0	2.0
66 1	0.00	-0.05	0.16	0.33	0.142	0.110	37.1	80.0
66 2	-0.00	-0.05	0.26	0.21	0.121	0.120	69.3	56.7
66 3	-0.01	-0.08	0.25	0.07	0.209	0.070	40.9	33.6
66 4	-0.06	-0.10	0.13	-0.01	0.149	0.101	25.7	0.3
66 5	-0.03	-0.07	0.01	0.02	0.148	0.091	0.3	3.0
66 6	-0.06	-0.09	0.00	-0.04	0.156	0.137	0.0	5.1
66 7	-0.03	-0.04	0.01	-0.12	0.166	0.079	0.1	54.9

## APPENDIX 3.1

The data from the last five days in each condition of Experiment 3. The first set of columns show: The hen number, condition (Cond), total number of responses (Resp) and reinforcers obtained (Rfts) in S1 (R) and S2 (G) and the total time the components were available less reinforcement time. The data in the second set of columns are the number of responses in S1 and S2 in each 15-s sub-interval. Data from each multiple schedule of conditions using the multiple-multiple procedure are indicated in the condition column as decimal points.

Hen	Cond	Resp		Total Time		Rfts		15-s Sub-intervals							
		R	G	R	G	R	G	First		Second		Third		Fourth	
Phase	I							R	G	R	G	R	G	R	G
21	1.1	249	221	2913	2691	2	11	58	57	61	59	66	54	64	51
21	1.2	218	191	2674	2879	11	4	54	40	59	42	59	55	46	54
21	1.3	216	181	2821	2822	6	6	58	55	46	35	62	42	50	49
21	1.4	196	132	2732	2970	9	1	68	33	37	30	40	33	51	36
21	1.5	158	150	2960	2682	1	11	34	43	39	37	33	35	52	35
21	1.1	184	199	2970	2696	1	10	39	63	44	57	53	40	48	39
21	1.2	213	209	2674	2880	11	4	58	46	57	49	53	58	45	56
21	1.3	206	178	2822	2821	6	6	49	47	57	55	48	39	52	37
21	1.4	209	165	2700	2971	10	1	51	35	47	41	60	46	51	43
21	1.5	199	188	2970	2671	1	11	45	50	53	41	43	53	58	44
21	1.1	183	215	2875	2789	3	8	33	66	41	54	60	53	49	42
21	1.2	186	182	2700	2881	10	4	44	50	38	34	53	46	51	52
21	1.3	169	117	2880	2822	4	6	51	35	38	34	49	20	31	28
21	1.4	145	70	2702	2970	10	1	38	18	32	25	39	21	36	26
21	1.5	94	90	3000	2821	0	6	31	22	30	15	17	25	16	28
21	1.1	208	174	2941	2665	2	11	46	52	61	47	53	31	48	44
21	1.2	177	191	2672	2881	11	4	43	42	51	47	50	49	33	53
21	1.3	192	145	2823	2821	6	6	56	49	43	28	52	36	41	32
21	1.4	95	95	2761	2970	8	1	17	15	30	17	19	30	29	33
21	1.5	177	144	2970	2701	1	10	38	45	45	39	47	29	47	31
21	1.1	189	193	2960	2641	2	11	38	49	40	52	54	46	57	46
21	1.2	169	184	2671	2880	11	4	49	36	41	54	48	40	31	54
21	1.3	186	141	2820	2820	6	6	51	42	38	28	51	36	46	35
21	1.4	162	89	2730	2970	9	1	41	23	37	18	35	26	49	22
21	1.5	112	118	2971	2671	1	11	30	31	31	27	28	31	23	29
22	1.1	179	169	2940	2787	2	7	36	48	41	23	50	42	52	56
22	1.2	119	97	2697	2918	11	2	36	15	28	14	30	40	25	28
22	1.3	128	109	2851	2850	5	5	30	33	32	32	27	18	39	36
22	1.4	85	59	2733	2971	9	1	31	7	21	10	21	25	12	17
22	1.5	19	44	2968	2764	1	8	4	17	5	11	3	9	7	7
22	1.1	241	238	2940	2785	2	7	40	62	59	54	70	61	72	61
22	1.2	162	152	2671	2941	11	2	42	25	43	20	36	52	41	55
22	1.3	201	177	2880	2851	4	5	47	42	49	51	45	38	60	46
22	1.4	87	58	2700	2970	10	1	25	13	20	17	22	12	20	16
22	1.5	92	115	2970	2700	1	10	14	41	24	27	29	32	25	15
22	1.1	213	229	2942	2721	2	9	34	55	45	67	75	62	59	45
22	1.2	175	157	2763	2940	8	2	54	29	33	28	42	45	46	55
22	1.3	196	154	2849	2824	6	5	55	32	42	39	49	40	50	43
22	1.4	198	169	2707	2995	10	0	49	25	44	41	51	42	54	61
22	1.5	101	113	2982	2690	0	11	13	38	18	30	34	21	36	24
22	1.1	222	232	2942	2787	2	7	40	60	50	51	66	58	66	63
22	1.2	163	187	2668	2945	11	2	31	31	52	48	51	50	29	58
22	1.3	187	169	2850	2851	5	5	44	41	51	48	43	31	49	49
22	1.4	170	193	2703	2970	10	1	53	31	39	59	44	55	34	48
22	1.5	154	129	2970	2733	1	9	18	47	41	35	46	19	49	28
22	1.1	230	233	2940	2788	2	7	41	62	54	49	68	56	67	66
22	1.2	202	180	2644	2960	12	2	52	38	49	31	46	53	55	58
22	1.3	205	178	2851	2850	5	5	50	42	52	50	47	37	56	49
22	1.4	247	140	2672	3000	11	0	74	18	65	32	52	37	56	53
22	1.5	102	191	2996	2705	0	10	6	54	9	56	42	45	45	36
23	1.1	121	83	2970	2751	1	8	26	20	32	17	33	25	30	21
23	1.2	132	123	2705	2880	10	4	28	23	34	28	37	31	33	41
23	1.3	136	130	2782	2800	7	7	36	31	42	34	28	38	30	27
23	1.4	112	70	2745	3000	9	0	27	12	34	18	25	17	26	23
23	1.5	53	94	3000	2703	0	10	8	17	9	21	11	25	25	31
23	1.1	83	77	2970	2756	1	8	12	18	17	20	28	22	26	17

23	1.2	75	44	2731	2881	9	4	16	6	16	9	19	13	24	16
23	1.3	100	88	2812	2801	7	6	27	22	22	18	25	28	26	20
23	1.4	74	65	2729	2972	10	0	23	13	14	14	19	13	18	25
23	1.5	68	71	2970	2761	1	8	5	18	10	15	27	18	26	20
23	1.1	27	70	2955	2710	1	10	1	17	7	16	10	16	9	21
23	1.2	17	5	2850	2910	5	3	2	3	1	1	6	0	8	1
23	1.3	118	85	2820	2794	6	7	26	21	31	16	31	19	30	29
23	1.4	98	60	2672	2970	11	1	22	8	24	14	25	16	27	22
23	1.5	66	117	2943	2728	1	10	8	34	12	26	17	25	29	32
23	1.1	127	160	2971	2755	1	8	11	47	34	41	44	40	38	32
23	1.2	166	90	2775	2837	9	4	51	12	36	19	52	32	27	27
23	1.3	150	144	2791	2790	7	7	44	44	34	37	37	34	35	29
23	1.4	127	96	2733	3000	9	0	42	26	28	24	25	26	32	20
23	1.5	67	101	2941	2762	2	8	10	19	13	29	25	27	19	26
23	1.1	93	130	2941	2697	2	10	17	26	26	38	19	35	31	31
23	1.2	155	102	2751	2862	9	4	32	19	45	28	44	23	34	32
23	1.3	133	124	2820	2820	6	6	42	32	32	25	24	35	35	32
23	1.4	143	55	2732	2970	9	1	37	10	37	16	33	11	36	18
23	1.5	55	108	3000	2701	0	10	9	26	11	22	19	23	16	37
24	1.1	166	187	2910	2697	3	10	28	43	43	47	45	54	50	43
24	1.2	143	100	2672	2880	11	4	29	24	32	32	41	21	41	23
24	1.3	139	147	2822	2822	6	6	37	42	28	32	34	36	40	37
24	1.4	157	138	2732	3000	9	0	42	36	29	30	40	31	46	41
24	1.5	184	158	3000	2701	0	10	16	43	42	39	51	40	75	36
24	1.1	186	181	2940	2670	2	11	34	40	41	42	65	45	46	54
24	1.2	126	93	2673	2880	11	4	28	12	27	28	43	24	28	29
24	1.3	143	133	2820	2820	6	6	33	42	39	31	39	35	32	25
24	1.4	150	134	2732	3000	9	0	35	14	41	51	37	36	37	33
24	1.5	97	217	3000	2673	0	11	3	70	23	52	39	49	32	46
24	1.1	178	187	2890	2681	3	11	21	42	43	30	56	49	58	66
24	1.2	141	101	2673	2882	11	4	33	29	34	22	41	23	33	27
24	1.3	154	154	2827	2815	6	6	47	45	39	38	37	34	31	37
24	1.4	151	130	2730	2970	9	1	41	15	41	39	36	37	33	39
24	1.5	130	109	2872	2730	0	10	15	46	26	18	42	19	47	26
24	1.1	175	266	2900	2929	3	11	25	57	43	54	53	66	54	89
24	1.2	127	90	2673	2881	11	4	31	13	30	29	35	26	31	22
24	1.3	108	110	2841	2800	6	6	26	28	24	27	19	32	39	23
24	1.4	174	106	2734	2970	9	1	46	9	45	17	33	32	50	48
24	1.5	117	164	2974	2698	0	11	12	42	25	35	41	45	39	42
24	1.1	171	211	2890	2681	3	11	25	48	45	45	46	56	55	62
24	1.2	144	101	2673	2880	11	4	41	21	35	26	34	28	34	26
24	1.3	158	158	2830	2811	6	6	44	33	39	45	37	49	38	31
24	1.4	150	154	2750	2925	9	2	36	23	37	41	32	54	45	36
24	1.5	91	87	3000	2821	0	6	8	26	22	19	36	15	25	27
25	1.1	151	174	2940	2781	2	7	40	42	31	43	40	47	40	42
25	1.2	150	139	2646	2969	11	2	37	29	41	30	37	40	35	40
25	1.3	144	151	2850	2852	5	50	40	41	36	38	26	33	42	39
25	1.4	152	116	2686	2957	11	1	45	22	34	25	42	31	31	38
25	1.5	111	170	2970	2733	1	9	13	46	31	42	31	42	36	40
25	1.1	175	180	2944	2781	2	7	42	52	44	38	48	44	41	46
25	1.2	169	160	2670	2940	11	2	40	35	47	35	43	44	39	46
25	1.3	138	139	2870	2850	5	50	39	35	36	41	31	29	32	34
25	1.4	159	143	2700	2913	11	2	53	26	40	40	34	42	32	35
25	1.5	106	161	2962	2738	1	9	15	47	27	41	31	35	33	38
25	1.1	180	181	2941	2784	2	7	43	43	44	45	45	47	48	46
25	1.2	169	146	2673	2940	11	92	44	30	42	41	39	40	44	35
25	1.3	155	142	2851	2850	5	5	43	36	35	40	31	28	46	38
25	1.4	153	130	2700	2971	11	0	46	21	38	35	37	38	32	36
25	1.5	132	177	2970	2932	1	9	19	42	32	48	37	43	44	44
25	1.1	183	178	2947	2773	2	7	37	45	35	45	53	38	58	50
25	1.2	165	148	2693	2917	11	2	42	29	39	35	39	43	45	41

25	1.3	170	160	2868	2851	5	5	42	34	44	44	44	45	40	37
25	1.4	164	134	2672	2999	11	0	44	22	40	36	40	40	40	36
25	1.5	103	152	3000	2700	0	10	8	44	22	40	32	42	41	26
25	1.1	187	188	2941	2778	2	7	37	52	50	41	52	46	48	49
25	1.2	177	148	2672	2940	11	2	47	29	43	38	37	38	50	43
25	1.3	169	173	2881	2850	4	5	39	41	36	48	47	48	47	36
25	1.4	186	147	2732	2940	9	2	51	27	50	32	43	41	42	47
25	1.5	110	169	2955	2686	1	11	15	50	25	39	35	44	35	36
26	1.1	113	140	2991	2732	1	8	21	40	19	39	36	35	37	26
26	1.2	127	117	2732	2880	9	4	31	22	35	32	34	27	27	36
26	1.3	123	119	2790	2793	7	7	32	33	30	33	35	25	26	28
26	1.4	96	102	2763	3000	8	0	32	22	18	25	22	23	24	32
26	1.5	94	114	2970	2701	1	10	17	28	22	33	27	20	28	33
26	1.1	127	140	2985	2735	1	8	24	35	24	33	32	34	47	38
26	1.2	144	120	2733	2880	9	4	36	32	35	28	39	35	34	37
26	1.3	142	126	2820	2822	6	6	38	33	33	27	34	35	37	31
26	1.4	145	136	2761	2970	1	10	17	28	22	33	27	20	28	33
26	1.5	121	161	3000	2731	0	9	21	45	27	40	37	42	36	34
26	1.1	131	179	2980	2744	1	8	28	50	32	51	31	40	40	38
26	1.2	176	151	2731	2881	9	4	48	34	41	43	46	38	41	36
26	1.3	170	184	2790	2790	7	7	41	51	38	46	46	45	45	42
26	1.4	156	165	2731	2999	9	0	56	41	41	40	29	46	30	38
26	1.5	167	139	2970	2733	1	9	26	39	35	32	53	33	53	35
26	1.1	141	169	2970	2754	1	8	28	46	30	37	41	44	42	42
26	1.2	202	145	2732	2880	10	4	51	35	47	38	54	38	50	34
26	1.3	172	169	2791	2792	7	7	43	39	39	44	47	46	43	40
26	1.4	172	136	2698	2918	11	2	50	33	43	34	45	29	34	40
26	1.5	129	141	2982	2718	0	10	19	34	35	26	37	39	38	42
26	1.1	139	150	2993	2730	1	8	28	34	30	45	47	33	34	38
26	1.2	167	143	2714	2882	10	4	42	35	38	39	45	32	42	37
26	1.3	157	155	2792	2791	7	7	42	42	38	36	42	35	35	42
26	1.4	138	136	2687	2956	11	1	41	33	30	30	34	28	33	35
26	1.5	106	150	2983	2719	0	10	20	40	26	38	30	37	30	35
21	2.0	338	596	8710	8141	9	29	82	157	62	149	95	141	99	149
22	2.0	456	596	8724	8134	9	29	94	147	101	150	127	157	134	142
23	2.0	361	400	8777	8203	7	27	78	114	85	101	92	96	106	89
24	2.0	556	861	8790	8186	7	27	112	215	139	225	154	199	151	222
25	2.0	303	409	8789	8193	7	27	71	106	68	106	78	101	86	96
26	2.0	502	632	8705	8187	9	28	116	167	119	158	136	145	131	162
21	2.0	408	561	8783	8106	8	29	86	136	95	143	106	133	121	149
22	2.0	411	547	8761	8184	7	28	103	144	112	140	103	127	93	136
23	2.0	302	369	8759	8219	7	27	53	92	78	98	90	92	81	87
24	2.0	514	740	8789	8188	7	27	105	187	120	205	153	172	136	176
25	2.0	235	429	8769	8206	7	27	58	122	48	107	68	103	61	97
26	2.0	447	653	8743	8141	9	28	103	167	99	158	125	164	120	164
21	2.0	382	568	8757	8130	8	29	93	142	87	155	97	133	105	138
22	2.0	524	615	8785	8182	7	28	134	152	129	150	120	164	141	149
23	2.0	280	355	8786	8197	7	27	61	93	61	94	87	80	71	88
24	2.0	672	836	8791	8187	7	27	154	217	166	216	180	193	172	210
25	2.0	280	457	8772	8201	7	27	66	126	66	113	68	115	80	103
26	2.0	428	631	8743	8204	7	28	100	157	101	149	116	154	111	171
21	2.0	345	618	8761	8193	8	27	74	162	67	147	90	162	114	147
22	2.0	597	724	8759	8189	7	28	142	189	146	178	149	184	160	173
23	2.0	363	428	8749	8173	8	28	68	130	81	101	93	101	121	96
24	2.0	671	858	8821	8128	6	29	136	217	163	215	186	213	186	213
25	2.0	198	346	8765	8299	7	24	45	91	42	78	55	83	56	94
26	2.0	426	620	8763	8240	6	27	100	162	100	154	102	153	124	151
21	2.0	406	476	8729	8131	9	29	81	141	97	123	115	113	113	99
22	2.0	312	444	8789	8165	7	28	92	116	90	109	70	109	60	110
23	2.0	409	472	8774	8168	7	28	72	127	113	103	100	128	124	114
24	2.0	602	828	8792	8183	7	27	109	227	152	195	170	217	171	189

25	2.0	370	529	8713	8276	8	26	96	130	92	125	87	125	95	149
26	2.0	499	679	8730	8125	9	29	115	185	119	164	135	167	130	163
21	3.0	548	456	8164	8731	28	9	136	98	125	122	133	111	154	125
22	3.0	451	337	8166	8816	28	6	116	46	110	88	110	95	115	108
23	3.0	368	341	8194	8749	27	8	103	70	89	89	95	94	81	88
24	3.0	700	558	8202	8780	27	7	200	126	175	129	158	154	167	149
25	3.0	515	271	8228	8759	27	7	127	54	134	67	121	76	133	74
26	3.0	487	406	8153	8793	28	7	122	98	118	103	123	108	124	97
21	3.0	562	477	8197	8749	27	8	155	115	128	121	142	112	137	129
22	3.0	448	338	8165	8810	28	6	116	67	114	83	114	101	104	87
23	3.0	342	335	8204	8775	27	7	90	86	82	83	91	77	79	89
24	3.0	690	593	8229	8758	27	7	205	112	172	148	157	158	156	175
25	3.0	520	307	8215	8759	27	7	129	59	127	72	123	86	141	90
26	3.0	463	383	8163	8781	28	7	128	89	106	80	115	100	114	114
21	3.0	634	587	8136	8753	29	8	168	134	160	164	149	146	157	143
22	3.0	434	375	8179	8764	28	7	112	81	111	97	105	83	106	114
23	3.0	389	361	8195	8781	27	7	105	82	93	95	99	98	92	86
24	3.0	676	549	8182	8805	27	7	188	115	170	141	159	146	159	147
25	3.0	550	368	8184	8795	27	7	140	73	139	78	133	102	138	115
26	3.0	545	497	8187	8702	28	9	140	116	134	120	131	134	140	127
21	3.0	611	480	8160	8752	28	8	152	95	151	124	157	131	151	130
22	3.0	482	325	8175	8775	28	7	114	72	133	77	115	89	120	87
23	3.0	360	377	8192	8782	27	7	104	87	77	97	96	94	83	99
24	3.0	687	544	8196	8722	27	9	194	107	170	133	156	146	167	158
25	3.0	505	327	8192	8821	27	6	125	70	124	73	128	90	128	94
26	3.0	554	390	8198	8729	28	8	135	85	143	101	137	100	139	104
21	3.0	623	487	8171	8715	28	9	171	114	139	121	153	124	160	128
22	3.0	469	334	8166	8812	28	6	138	60	105	84	115	94	111	96
23	3.0	361	329	8207	8745	27	8	104	72	84	80	94	91	79	86
24	3.0	619	489	8191	8791	27	7	169	102	159	123	148	124	143	140
25	3.0	501	295	8197	8781	27	7	120	62	126	62	123	86	132	85
26	3.0	483	400	8191	8700	28	9	132	89	126	106	122	95	103	110
21	4.0	581	484	8403	8361	20	21	146	120	138	118	150	125	147	121
22	4.0	356	354	8506	8387	18	19	89	85	87	88	86	94	94	87
23	4.0	326	356	8477	8437	18	18	88	83	85	90	70	85	83	98
24	4.0	667	672	8453	8401	18	20	173	172	165	177	159	165	170	158
25	4.0	514	519	8390	8382	21	20	142	133	117	128	134	127	121	131
26	4.0	479	533	8436	8455	19	18	128	138	105	138	122	133	124	124
21	4.0	501	431	8390	8386	20	21	130	102	118	100	119	108	134	121
22	4.0	393	390	8477	8412	18	19	109	85	87	103	112	103	85	99
23	4.0	298	289	8477	8445	18	18	71	71	68	67	87	69	72	82
24	4.0	342	345	8477	8472	17	18	86	74	84	92	90	89	82	90
25	4.0	462	449	8399	8396	20	20	127	117	122	116	107	112	106	104
26	4.0	433	443	8433	8416	19	19	115	124	101	107	107	107	110	105
21	4.0	642	561	8389	8383	20	21	166	154	149	140	156	137	171	130
22	4.0	458	441	8452	8412	19	19	133	109	90	112	117	112	118	108
23	4.0	335	380	8412	8523	18	18	78	90	79	98	99	91	79	101
24	4.0	684	610	8422	8382	20	20	174	139	172	164	165	149	173	158
25	4.0	535	487	8404	8393	20	20	129	118	135	123	135	126	136	120
26	4.0	486	450	8428	8463	19	18	111	115	118	120	115	99	142	116
21	4.0	564	536	8372	8393	21	20	143	145	138	125	143	134	140	132
22	4.0	393	406	8444	8442	19	18	112	92	92	105	95	101	94	108
23	4.0	361	325	8445	8441	19	18	79	79	96	72	86	83	100	91
24	4.0	680	637	8356	8391	21	21	169	148	168	154	172	171	171	164
25	4.0	556	501	8432	8428	19	19	145	113	131	133	133	129	147	126
26	4.0	507	466	8492	8400	18	19	123	131	130	110	135	108	119	117
21	4.0	528	531	8373	8398	21	20	144	138	117	117	137	132	130	144
22	4.0	404	407	8418	8437	19	19	110	93	93	105	95	102	106	107
23	4.0	383	392	8470	8449	18	18	107	90	79	88	95	103	102	111
24	4.0	621	597	8384	8410	20	20	174	138	153	153	152	154	142	152
25	4.0	538	557	8403	8422	20	19	155	128	130	152	130	137	123	140

26	4.0	493	419	8435	8450	18	19	104	122	118	96	140	97	131	104
21	5.0	601	486	8035	8827	32	6	150	123	133	111	156	119	162	133
22	5.0	471	291	8071	8850	32	4	123	73	107	93	124	66	117	59
23	5.0	308	261	8082	8872	31	4	84	54	70	58	74	68	80	81
24	5.0	415	498	8070	8815	31	6	85	106	113	128	113	127	104	137
25	5.0	572	427	8092	8850	31	4	138	73	144	123	144	115	146	116
26	5.0	557	361	8076	8869	31	4	129	73	138	85	148	101	142	102
21	5.0	571	367	8042	8814	32	6	161	78	116	95	157	93	137	101
22	5.0	402	210	8100	8853	32	4	96	42	96	62	111	58	99	48
23	5.0	308	172	8147	8894	28	4	90	21	80	38	70	52	68	61
24	5.0	425	394	8100	8752	31	7	97	77	111	120	106	90	111	107
25	5.0	516	366	8052	8859	32	4	132	50	127	109	125	98	132	109
26	5.0	538	303	8121	8858	30	4	138	56	137	73	138	89	125	85
21	5.0	554	488	8017	8900	32	4	139	80	131	136	135	133	149	139
22	5.0	397	250	8048	8903	31	4	101	55	88	77	115	58	93	60
23	5.0	248	202	8117	8899	30	3	65	33	71	49	56	62	56	58
24	5.0	434	404	8066	8937	31	2	104	53	108	106	113	122	109	123
25	5.0	518	375	8074	8868	31	4	131	58	117	105	131	106	139	106
26	5.0	503	275	8056	8875	32	4	139	51	121	70	124	68	119	86
21	5.0	517	432	8095	8882	30	4	136	74	126	127	118	121	137	110
22	5.0	414	220	8129	8880	30	3	91	30	110	63	96	62	117	65
23	5.0	277	206	8178	8892	30	2	83	37	68	55	56	50	70	64
24	5.0	458	446	8089	8862	31	4	124	83	126	120	106	122	102	121
25	5.0	427	274	8109	8877	30	4	112	49	106	70	108	78	101	77
26	5.0	231	386	8301	8883	24	3	78	100	61	93	48	95	44	98
21	5.0	550	507	8046	8815	32	6	154	96	124	131	130	143	142	137
22	5.0	421	323	8063	8836	33	4	88	64	104	89	115	87	114	83
23	5.0	306	239	8100	8878	31	3	78	38	84	58	74	65	70	78
24	5.0	421	435	8096	8794	31	6	94	87	107	108	111	120	109	120
25	5.0	524	359	8138	8840	30	4	140	57	126	88	140	121	118	93
21	6.0	378	397	8818	8073	6	31	87	102	84	94	101	109	106	92
22	6.0	334	348	8867	8084	4	31	89	74	86	87	74	95	85	92
23	6.0	185	275	8863	8140	3	30	34	72	45	67	53	63	53	73
24	6.0	569	871	8843	8020	6	32	128	218	149	223	155	223	137	207
25	6.0	433	602	8861	8063	4	32	76	157	105	144	125	147	127	154
26	6.0	309	457	8278	8007	3	31	70	127	72	112	77	108	90	110
21	6.0	396	456	8823	8130	6	29	109	128	92	118	98	105	97	105
22	6.0	321	343	8874	8072	3	32	73	79	84	88	84	90	80	86
23	6.0	266	236	8881	8096	4	30	58	66	76	53	64	64	68	53
24	6.0	480	815	8777	8044	7	32	111	215	135	210	115	216	119	174
25	6.0	363	586	8880	8037	4	32	58	139	86	156	112	142	107	149
26	6.0	323	436	8837	8108	4	31	69	119	77	102	84	108	93	107
21	6.0	465	414	8786	8070	6	32	97	99	117	94	122	120	129	101
22	6.0	251	318	8885	8060	3	32	47	81	58	76	76	82	70	79
23	6.0	160	209	8882	8126	4	29	41	61	27	49	39	53	53	46
24	6.0	414	762	8793	8071	7	31	82	205	111	176	109	177	112	204
25	6.0	316	517	8875	8076	4	31	48	135	73	122	93	127	102	133
26	6.0	346	401	8853	8099	4	31	61	116	92	95	91	105	102	85
21	6.0	502	430	8818	8045	6	32	105	102	133	105	133	123	131	100
22	6.0	249	349	8806	8117	4	32	49	81	56	85	68	85	76	98
23	6.0	150	211	8877	8100	4	30	36	54	35	52	43	53	36	52
24	6.0	445	747	8851	8068	4	32	81	167	106	188	124	211	134	181
25	6.0	368	654	8847	8072	5	31	54	150	90	164	108	166	116	174
26	6.0	256	405	8894	8149	2	30	54	123	51	103	75	96	76	83
21	6.0	401	395	8822	8096	6	30	94	99	96	98	104	98	107	100
22	6.0	310	304	8880	8097	4	31	75	75	86	74	65	78	84	77
23	6.0	141	195	8866	8143	4	29	27	62	38	47	38	41	38	45
24	6.0	412	779	8749	8111	6	32	50	191	121	205	113	188	128	195
25	6.0	457	615	8868	8052	4	32	77	165	106	140	138	157	136	153
26	6.0	246	381	8854	8097	4	31	43	111	64	97	61	86	78	87

21	7.1	150	357	2961	2661	01	06	24	82	31	92	49	92	46	91
21	7.2	247	215	2641	2910	12	03	39	50	72	42	71	57	65	66
21	7.3	272	261	2796	2876	07	05	51	68	62	74	77	56	82	63
21	7.4	201	111	2722	2958	09	02	33	30	51	34	54	25	63	22
21	7.5	081	123	2985	2698	00	11	13	28	19	32	25	33	24	30
21	7.1	221	342	2937	2652	03	11	51	82	64	86	55	91	51	83
21	7.2	242	232	2673	2880	11	04	47	63	71	56	69	57	55	56
21	7.3	277	242	2797	2805	07	07	54	77	60	42	99	65	63	58
21	7.4	209	124	2732	2971	09	01	50	38	39	31	54	23	66	32
21	7.5	103	113	3000	2674	00	11	25	34	39	31	23	28	16	20
21	7.1	275	331	2921	2662	03	11	44	80	73	97	75	83	83	71
21	7.2	231	203	2678	2881	11	04	58	34	65	53	60	58	48	58
21	7.3	316	253	2798	2804	07	07	74	67	74	61	98	70	70	55
21	7.4	207	121	2733	3000	09	00	53	43	41	36	49	19	64	23
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21	7.1	158	316	2911	2678	03	11	26	74	40	91	44	74	48	77
21	7.2	232	255	2674	2881	11	4	46	52	54	76	66	73	66	54
21	7.3	271	256	2816	2804	7	7	68	77	41	52	85	71	77	56
21	7.4	183	206	2733	2970	9	1	36	56	40	52	50	51	57	47
21	7.5	102	118	2970	2677	1	11	12	32	33	29	31	25	26	32
21	7.1	199	297	2940	2660	02	11	42	74	52	87	52	60	53	76
21	7.2	221	193	2673	2880	11	04	44	31	53	46	78	53	46	63
21	7.3	288	253	2821	2820	06	06	65	83	61	59	92	49	70	62
21	7.4	168	099	2731	3000	09	00	32	41	36	31	39	16	61	11
21	7.5	164	093	3000	2702	00	10	18	23	49	24	41	26	56	20
22	7.1	099	149	2970	2693	01	10	23	45	25	46	29	43	22	15
22	7.2	220	103	2761	2941	08	02	41	21	57	37	59	30	63	15
22	7.3	160	146	2821	2793	06	07	35	40	40	31	39	39	46	36
22	7.4	196	099	2670	2970	11	01	56	35	45	30	52	15	43	19
22	7.5	032	199	3000	2701	00	10	05	49	09	54	11	50	07	46
22	7.1	103	156	2940	2758	02	08	23	36	27	36	30	44	23	40
22	7.2	130	071	2663	2941	12	02	20	17	35	21	41	24	34	09
22	7.3	191	183	2877	2845	05	05	43	42	57	52	48	52	43	37
22	7.4	212	090	2694	3000	11	00	52	33	49	25	57	26	54	06
22	7.5	032	197	3000	2703	00	10	05	44	16	59	04	46	07	48
22	7.1	96	121	2940	2758	02	08	26	25	26	25	19	31	25	40
22	7.2	104	078	2671	2941	11	02	26	08	23	22	23	27	32	21
22	7.3	146	161	2837	2875	05	05	30	40	44	46	32	41	40	34
22	7.5	031	160	2998	2713	00	10	05	33	15	48	08	41	03	38
22	7.4	148	097	2673	2970	11	01	42	30	32	34	37	18	37	15
22	7.1	105	165	2934	2772	02	08	25	31	31	41	29	33	20	60
22	7.2	110	69	2674	2940	11	02	22	17	35	17	27	22	26	13
22	7.3	177	151	2879	2863	05	04	40	40	47	33	49	43	41	35
22	7.4	128	095	2671	2970	11	01	39	26	36	35	31	19	22	15
22	7.5	027	138	3000	2730	00	09	08	30	11	39	07	39	01	30
22	7.1	110	169	2935	2766	02	08	21	37	29	41	28	43	32	48
22	7.2	108	077	2647	2940	12	02	24	12	20	23	30	24	34	18
22	7.3	164	162	2850	2850	05	05	35	34	40	46	45	44	44	38
22	7.4	185	085	2679	2940	11	02	52	29	33	24	51	22	49	10
22	7.5	035	170	3000	2702	00	10	13	41	09	39	08	41	05	49
25	7.1	126	157	2941	2761	02	08	37	37	26	36	31	46	32	38
25	7.2	172	086	2642	2941	12	02	44	16	35	23	51	23	42	24
25	7.3	153	122	2850	2851	05	05	34	28	45	35	35	31	39	28
25	7.4	127	113	2691	2962	11	01	36	23	33	28	28	34	30	28
25	7.5	089	145	2980	2730	01	09	17	32	21	40	27	44	24	29
25	7.1	143	142	2940	2784	02	07	37	33	29	32	40	36	37	41
25	7.2	192	093	2673	2941	12	02	47	16	53	27	45	24	47	26
25	7.3	153	122	2850	2851	05	05	34	28	45	35	35	31	39	28
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25	7.1	140	135	2958	2749	02	08	33	32	31	31	38	32	38	40

25	7.2	177	106	2668	2924	12	02	45	12	44	26	43	35	45	33
25	7.3	151	140	2851	2850	05	05	36	34	38	36	40	32	37	38
25	7.4	133	106	2703	2970	10	01	39	20	29	27	33	29	32	30
25	7.5	080	164	3000	2674	00	11	04	42	17	38	27	45	32	39
25	7.1	142	130	2967	2674	01	11	35	37	35	30	37	33	35	30
25	7.2	151	117	2659	2933	11	03	36	27	48	32	42	32	25	26
25	7.3	130	141	2836	2876	05	05	31	37	37	36	32	29	30	39
25	7.4	111	108	2675	2970	11	01	34	19	26	22	29	29	22	38
25	7.5	047	115	3000	2701	00	10	06	29	11	31	10	31	20	24
25	7.1	161	155	2923	2756	02	09	41	38	41	32	41	38	38	47
25	7.2	158	104	2745	2917	10	02	36	19	44	26	36	34	42	25
25	7.3	144	133	2851	2859	05	05	40	33	35	39	32	34	37	27
25	7.4	143	122	2670	2970	11	01	42	31	31	28	35	34	35	29
25	7.5	087	143	2971	2679	01	11	13	43	17	32	24	36	33	32
21	8.1	266	215	2940	2713	2	10	66	50	63	65	65	61	71	38
21	8.2	183	216	2753	2970	9	1	48	40	49	54	54	49	32	73
21	8.3	205	234	2850	2880	5	4	55	55	53	53	54	69	41	55
21	8.4	90	106	2777	2970	8	1	25	24	20	24	21	33	23	26
21	8.5	190	146	2970	2731	1	9	44	29	48	33	50	45	48	39
21	8.1	214	191	2940	2779	2	8	43	37	47	47	64	52	60	55
21	8.2	230	220	2760	2910	8	3	52	51	60	45	59	63	58	62
21	8.3	115	184	2826	2850	6	5	21	32	33	51	34	48	26	52
21	8.4	146	159	2760	3000	8	0	38	37	34	47	38	38	36	37
21	8.5	172	133	2940	2751	2	9	36	27	38	28	48	32	50	46
21	8.1	161	140	2910	2730	3	9	42	32	44	28	38	37	36	44
21	8.2	137	151	2700	2940	10	2	29	33	35	37	31	38	41	44
21	8.3	90	140	2820	2880	6	4	14	22	22	34	29	42	25	42
21	8.4	104	136	2789	3000	8	0	21	25	25	41	27	37	29	33
21	8.5	179	137	2970	2760	1	8	46	32	42	31	39	34	52	40
21	8.1	165	160	2940	2756	2	9	33	28	42	44	41	41	48	46
21	8.2	138	162	2788	2940	8	2	27	37	30	39	41	39	40	47
21	8.3	120	170	2820	2880	6	4	28	33	32	44	27	46	31	47
21	8.4	91	126	2700	3000	10	0	29	28	26	29	20	35	16	34
21	8.5	169	150	3000	2760	0	8	40	30	34	35	43	38	52	47
21	8.1	184	191	2940	2790	2	7	40	48	53	44	43	44	47	56
21	8.2	148	156	2760	2910	9	3	30	31	40	30	33	41	45	54
21	8.3	122	166	2820	2850	6	5	30	34	27	42	35	39	29	52
21	8.4	110	112	2700	3000	10	0	24	23	25	34	30	29	30	27
21	8.5	206	149	2940	2760	2	8	47	28	58	36	51	46	49	40
22	8.1	160	130	2970	2714	1	10	41	34	46	28	37	34	36	34
22	8.2	312	242	2760	2970	8	1	76	35	83	71	75	69	78	67
22	8.3	228	194	2841	2850	6	5	58	59	49	47	59	41	62	47
22	8.4	126	54	2703	2970	11	1	35	13	30	11	30	14	31	16
22	8.5	102	104	3000	2760	0	8	24	30	24	34	21	21	31	17
22	8.1	149	129	2940	2725	2	10	35	27	45	32	26	37	42	32
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22	8.5	79	101	2970	2732	1	9	19	28	18	18	19	22	22	34
22	8.1	151	108	2910	2730	3	9	34	30	31	22	48	27	38	29
22	8.2	251	185	2730	2940	9	2	69	31	56	39	57	64	67	51
22	8.3	186	186	2790	2880	7	4	54	46	41	44	43	43	48	53
22	8.4	116	113	2774	2970	8	1	27	25	27	30	36	29	26	29
22	8.5	138	110	2970	2730	1	9	31	22	28	22	41	30	38	36
22	8.1	136	120	2940	2714	2	10	34	28	32	33	31	29	38	29
22	8.2	302	232	2760	2940	8	2	73	38	90	57	64	66	75	71
22	8.3	220	159	2840	2790	6	7	57	44	52	29	47	43	64	43
22	8.4	109	136	2760	3000	8	0	26	36	27	29	26	35	29	35
22	8.5	120	91	2970	2730	1	9	38	26	24	23	32	21	25	22
22	8.1	191	120	2970	2729	1	10	44	28	52	30	48	33	45	29
22	8.2	282	228	2760	2970	8	1	92	52	52	48	77	61	60	68

22	8.3	228	154	2880	2824	4	6	58	40	55	37	58	38	56	38
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22	8.5	119	92	2970	2700	1	10	39	28	25	19	29	27	24	20
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25	8.2	221	231	2716	2958	10	2	51	50	66	57	60	58	44	66
25	8.3	173	150	2820	2790	6	7	42	41	37	38	45	35	48	35
25	8.4	62	5	2820	3000	6	0	22	1	20	1	9	2	11	1
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25	8.1	166	180	2970	2760	1	8	33	45	42	50	44	54	46	32
25	8.2	252	253	2809	2970	7	1	61	56	73	59	52	65	66	73
25	8.3	152	143	2790	2880	7	4	43	35	33	38	44	37	31	32
25	8.4	140	41	2786	2970	8	1	43	9	41	9	32	10	24	13
25	8.5	140	132	2940	2711	2	10	35	31	32	43	28	35	43	23
25	8.1	183	172	2910	2700	3	10	37	39	45	49	50	46	50	39
25	8.2	251	254	2728	2992	10	1	59	61	66	70	64	60	62	63
25	8.3	165	153	2828	2871	6	5	45	42	45	41	43	34	32	36
25	8.4	124	56	2705	2940	11	2	35	11	32	15	30	16	27	14
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25	8.1	181	178	2970	2789	1	8	43	47	41	47	45	39	52	45
25	8.2	245	253	2717	2957	10	2	55	59	66	63	68	62	56	69
25	8.3	176	141	2850	2820	5	6	46	41	39	33	44	40	47	27
25	8.4	141	87	2760	3000	8	0	34	21	47	21	32	22	28	23
25	8.5	156	143	2970	2786	1	8	41	31	44	35	35	36	36	41
25	8.1	167	197	2940	2802	2	7	30	46	43	63	43	32	51	56
25	8.2	245	247	2809	2970	7	1	64	51	77	53	39	63	63	78
25	8.3	191	170	2850	2820	5	6	52	46	43	42	48	32	48	50
25	8.4	138	89	2760	2970	8	1	33	20	44	21	37	25	24	23
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21	9.1	184	145	2340	2179	2	8	38	30	51	46	46	37	48	33
21	9.2	155	160	2220	2370	6	1	32	27	39	39	40	43	44	51
21	9.3	120	159	2303	2310	4	3	21	19	25	34	38	52	36	54
21	9.4	66	65	2168	2370	8	1	14	14	20	20	18	11	14	20
21	9.5	148	76	2400	2220	0	6	30	18	35	19	40	20	42	18
21	9.1	157	161	2370	2250	1	5	37	46	41	36	41	42	37	36
21	9.2	130	170	2185	2340	8	2	29	36	29	47	39	35	33	52
21	9.3	110	134	2280	2250	4	5	22	30	25	34	32	40	29	30
21	9.4	53	78	2220	2400	6	0	13	19	16	13	16	21	8	25
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21	9.1	138	119	2340	2250	2	5	39	32	30	24	33	32	36	31
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21	9.5	127	91	2400	2220	0	6	35	20	31	19	31	23	30	29
21	9.1	201	172	2370	2250	1	5	49	50	58	45	49	39	45	38
21	9.2	140	197	2190	2358	7	2	35	51	31	45	42	53	32	48
21	9.3	145	146	2220	2310	6	3	19	31	44	37	38	33	42	45
21	9.4	49	79	2190	2400	7	0	10	18	24	20	13	20	1	20
21	9.5	127	85	2370	2241	1	6	33	18	27	18	34	22	33	27
21	9.1	190	123	2370	2160	1	8	55	26	45	36	41	35	49	26
21	9.2	133	157	2220	2370	6	1	31	43	36	34	32	40	34	40
21	9.3	131	157	2311	2311	3	3	20	33	39	32	36	47	36	45
21	9.4	69	67	2160	2340	8	2	13	16	20	17	17	11	19	23
21	9.5	150	93	2400	2220	0	6	33	19	42	19	39	29	35	27
22	9.1	119	83	2345	2160	2	8	19	27	31	20	38	26	31	10
22	9.2	110	132	2190	2370	7	1	14	31	29	33	32	32	35	36
22	9.3	138	145	2289	2260	4	5	39	33	36	34	32	44	31	34
22	9.4	116	49	2190	2370	7	1	32	15	33	12	38	13	13	9
22	9.5	94	180	2370	2220	1	6	24	48	27	45	22	49	20	37
22	9.1	157	202	2340	2220	2	6	47	60	51	58	30	49	27	33
22	9.2	157	172	2179	2340	8	2	35	38	39	47	47	48	35	40
22	9.3	155	173	2310	2277	3	5	33	45	34	52	44	41	43	34

22	9.4	104	95	2193	2370	7	1	39	11	29	27	18	32	18	25
22	9.5	144	151	2340	2220	2	6	41	46	38	38	34	37	30	31
22	9.1	135	204	2370	2190	1	7	40	71	28	48	33	44	34	41
22	9.2	175	153	2237	2370	7	1	38	39	46	36	50	33	41	45
22	9.3	173	168	2321	2250	3	5	47	47	50	26	36	45	40	50
22	9.4	87	144	2245	2340	6	2	28	46	20	52	22	28	17	18
22	9.5	162	128	2400	2190	0	7	24	32	34	48	54	40	49	9
22	9.1	156	165	2370	2220	1	6	26	50	37	46	41	32	51	36
22	9.2	129	112	2184	2340	8	2	32	25	33	35	39	20	25	32
22	9.3	158	183	2310	2250	3	5	51	61	48	53	25	48	33	22
22	9.4	114	92	2165	2370	8	1	32	24	35	23	26	22	21	23
22	9.5	137	142	2400	2220	0	6	32	55	33	41	33	27	39	19
22	9.1	145	170	2370	2136	1	9	31	36	33	50	47	48	34	36
22	9.2	125	124	2160	2340	8	2	40	28	40	24	13	38	32	34
22	9.3	177	179	2275	2310	5	3	46	41	44	36	46	44	41	58
22	9.4	113	128	2181	2400	8	0	31	18	34	29	23	44	23	35
22	9.5	102	138	2340	2160	2	8	19	30	34	47	25	44	24	17
25	9.1	82	130	2340	2160	2	8	22	23	21	38	18	40	21	29
25	9.2	145	143	2250	2340	5	2	39	29	34	39	36	36	36	39
25	9.3	140	140	2280	2280	4	4	39	37	29	36	37	38	34	28
25	9.4	101	22	2160	2400	8	0	31	6	24	6	23	4	23	6
25	9.5	28	141	2370	2211	1	7	3	41	8	44	10	35	7	21
25	9.1	111	149	2370	2228	1	7	27	38	27	39	27	38	30	34
25	9.2	151	168	2250	2370	5	1	32	39	46	46	34	38	39	45
25	9.3	133	125	2220	2250	6	5	36	36	30	35	35	32	32	22
25	9.4	99	58	2130	2370	9	1	31	14	31	14	24	13	13	17
25	9.5	81	139	2340	2220	2	6	17	36	22	37	15	32	27	34
25	9.1	121	144	2370	2188	1	8	25	35	30	40	33	33	33	36
25	9.2	141	154	2220	2340	6	2	34	37	38	41	48	39	20	38
25	9.3	124	145	2220	2310	6	3	31	34	30	40	29	38	34	33
25	9.4	113	56	2189	2370	8	1	30	16	26	16	29	16	28	8
25	9.5	57	117	2400	2190	0	7	13	34	16	40	15	20	13	23
25	9.1	104	120	2370	2220	1	6	22	35	29	33	27	32	25	21
25	9.2	148	151	2190	2340	7	2	32	38	33	38	45	38	37	38
25	9.3	122	121	2310	2310	3	3	34	38	35	30	31	25	21	29
25	9.4	94	24	2160	2370	8	1	30	6	21	7	23	8	20	3
25	9.5	44	89	2340	2220	2	6	9	23	8	29	8	18	19	19
25	9.1	117	137	2370	2241	1	6	25	38	25	45	32	30	35	24
25	9.2	147	177	2222	2340	6	2	34	36	39	44	35	45	38	51
25	9.3	153	142	2310	2310	3	3	35	34	45	46	42	33	31	29
25	9.4	109	66	2190	2340	7	2	24	17	30	15	31	21	24	13
25	9.5	65	129	2400	2160	0	8	19	35	15	30	16	33	14	32
21	10.1	120	160	2370	2250	1	5	28	49	33	40	29	37	30	34
21	10.2	77	118	2190	2340	7	2	17	23	18	32	22	33	20	30
21	10.3	105	118	2280	2250	4	5	30	34	18	23	26	30	31	31
21	10.4	53	34	2187	2343	8	1	9	5	10	8	17	8	17	13
21	10.5	64	69	2400	2160	0	8	13	16	12	16	21	18	18	19
22	10.1	66	124	2370	2160	1	8	10	33	21	34	21	34	14	23
22	10.2	133	113	2196	2364	7	1	28	24	32	26	40	32	33	31
22	10.3	128	119	2250	2250	5	5	30	31	31	32	28	34	39	22
22	10.4	139	136	2160	2370	8	1	30	26	25	43	34	37	50	30
22	10.5	97	106	2400	2190	0	7	22	28	29	34	25	23	21	21
25	10.1	112	120	2322	2179	2	8	23	29	31	31	31	33	27	27
25	10.2	143	140	2250	2370	5	1	30	32	32	37	37	37	44	34
25	10.3	106	101	2260	2270	5	4	23	24	30	28	27	24	26	25
25	10.4	89	51	2160	2400	8	0	22	9	27	14	18	14	22	14
25	10.5	78	102	2400	2160	0	8	14	30	24	28	21	23	18	22
21	10.1	101	122	2310	2160	3	8	20	31	27	25	28	36	26	30
21	10.2	140	139	2250	2370	5	1	30	40	36	31	36	31	38	37
21	10.3	112	127	2280	2310	4	3	27	33	30	25	21	32	34	37

21	10.4	66	58	2160	2400	8	0	13	9	15	24	20	16	18	9
21	10.5	83	72	2370	2133	1	9	11	13	25	17	26	22	21	20
22	10.1	70	147	2340	2220	2	6	20	41	19	38	14	43	16	24
22	10.2	79	59	2220	2370	6	1	19	10	16	14	26	16	18	19
22	10.3	129	138	2250	2310	5	3	40	35	28	39	33	34	28	30
22	10.4	140	89	2220	2370	6	1	42	14	34	33	30	24	33	19
22	10.5	99	117	2400	2243	0	6	13	23	38	30	27	26	21	38
25	10.1	102	143	2370	2223	1	6	31	34	19	39	28	40	24	30
25	10.2	155	148	2220	2340	6	2	36	39	40	36	38	36	41	37
25	10.3	141	134	2310	2310	3	3	35	33	34	39	35	30	37	32
25	10.4	160	79	2139	2391	9	0	37	18	38	28	38	19	47	14
25	10.5	80	136	2370	2160	1	8	18	35	21	39	21	35	20	27
21	10.1	107	197	2370	2220	1	6	23	61	29	48	26	55	29	33
21	10.2	122	160	2190	2340	7	2	34	42	24	34	31	40	33	44
21	10.3	98	107	2250	2280	5	4	28	23	18	26	22	32	30	26
21	10.4	61	47	2160	2400	8	0	15	8	14	13	13	15	19	11
21	10.5	113	81	2384	2237	0	6	20	17	32	16	32	22	29	26
22	10.1	109	161	2310	2235	3	6	19	39	24	48	29	35	37	39
22	10.2	178	139	2250	2370	5	1	44	34	47	27	41	38	46	40
22	10.3	165	138	2310	2280	3	4	37	33	41	35	40	37	47	33
22	10.4	110	97	2160	2400	8	0	34	6	19	29	22	33	35	29
22	10.5	75	102	2370	2160	1	8	11	25	13	15	29	31	22	31
25	10.1	113	138	2340	2160	2	8	31	30	28	40	25	37	29	31
25	10.2	162	149	2250	2370	5	1	37	42	37	38	38	38	50	31
25	10.3	149	131	2273	2287	5	3	42	32	36	34	35	36	36	29
25	10.4	127	59	2135	2365	9	1	29	7	33	16	34	17	31	19
25	10.5	90	137	2400	2138	0	9	14	39	20	30	30	32	26	36
21	10.1	117	116	2370	2220	1	6	20	32	34	26	32	30	31	28
21	10.2	107	153	2190	2370	7	1	26	29	30	40	28	44	23	40
21	10.3	118	131	2263	2297	5	3	28	25	27	37	30	34	33	35
21	10.4	60	55	2179	2381	8	0	15	7	13	14	16	20	16	14
21	10.5	87	63	2386	2174	0	8	17	15	21	15	26	17	23	16
22	10.1	104	130	2310	2220	3	6	22	31	18	34	30	40	34	25
22	10.2	120	95	2206	2354	7	1	34	14	23	19	30	31	33	31
22	10.3	134	129	2289	2302	3	4	29	35	37	29	36	35	32	30
22	10.4	91	102	2160	2400	8	0	27	11	18	34	6	34	40	23
22	10.5	119	113	2400	2220	0	6	23	28	34	28	31	26	31	31
25	10.1	132	156	2370	2247	1	6	31	39	36	46	30	30	34	40
25	10.2	152	161	2190	2370	7	1	32	50	44	41	35	36	41	34
25	10.3	151	139	2250	2250	5	5	36	39	44	32	38	38	33	30
25	10.4	173	90	2146	2354	9	1	44	8	47	25	37	33	45	24
25	10.5	129	166	2370	2160	1	8	23	49	36	36	31	41	39	40
21	10.1	136	179	2340	2238	2	6	23	53	37	52	36	34	40	40
21	10.2	130	150	2160	2370	8	1	34	34	35	38	37	33	24	45
21	10.3	122	149	2250	2220	5	6	26	31	30	35	39	41	27	42
21	10.4	61	54	2165	2395	8	0	13	15	19	19	15	13	14	7
21	10.5	73	72	2370	2190	1	7	15	13	15	17	22	22	21	20
22	10.1	102	113	2310	2190	3	7	24	45	21	27	28	19	29	22
22	10.2	117	67	2213	2347	7	1	32	2	26	13	36	25	23	27
22	10.3	159	137	2310	2280	3	4	42	39	46	32	42	30	28	37
22	10.4	87	79	2161	2369	8	1	25	10	29	15	25	22	8	32
22	10.5	111	80	2400	2130	0	9	18	23	27	24	39	21	27	12
25	10.1	131	161	2340	2248	2	6	31	42	34	43	34	34	31	41
25	10.2	141	149	2160	2340	8	2	30	39	35	36	40	43	36	31
25	10.3	143	144	2280	2250	4	5	35	38	34	33	38	34	35	38
25	10.4	198	96	2220	2370	6	1	44	16	47	19	54	29	52	33
25	10.5	147	162	2400	2147	0	9	32	44	35	38	35	37	45	43
21	11.1	116	147	1770	1648	1	6	22	31	30	34	33	52	30	31
21	11.2	85	123	1710	1770	4	1	15	26	15	33	27	33	28	31
21	11.3	88	152	1680	1740	4	2	16	18	23	40	23	44	24	50
21	11.4	47	77	1620	1770	6	1	6	21	10	23	17	14	13	18

21	11.5	111	54	1800	1650	0	5	25	10	33	14	23	15	29	16
21	11.1	157	143	1800	1620	0	6	26	15	46	36	40	48	45	44
21	11.2	87	117	1680	1767	4	2	17	23	17	24	20	31	33	39
21	11.3	114	126	1710	1650	3	5	22	19	26	28	40	38	25	40
21	11.4	36	31	1680	1800	4	0	8	4	10	11	6	6	12	10
21	11.5	78	52	1800	1680	0	4	15	13	24	10	19	11	20	18
21	11.1	116	92	1800	1650	0	5	15	13	27	27	29	24	45	28
21	11.2	77	136	1650	1740	5	2	12	36	14	32	23	33	28	35
21	11.3	103	106	1693	1680	4	4	19	14	26	27	25	30	33	35
21	11.4	41	51	1615	1770	7	1	9	5	9	16	10	17	13	13
21	11.5	73	48	1800	1620	0	6	8	11	23	12	20	12	21	14
21	11.1	84	73	1800	1680	0	4	10	14	20	17	21	17	32	26
21	11.2	64	117	1724	1770	3	1	12	22	15	32	19	30	18	33
21	11.3	82	94	1740	1680	2	4	11	20	15	25	28	21	28	28
21	11.4	33	71	1650	1800	5	0	5	9	12	21	9	22	6	18
21	11.5	66	44	1800	1620	0	6	8	9	24	8	20	16	14	11
21	11.1	89	81	1770	1638	1	6	18	14	21	16	23	28	27	23
21	11.2	65	112	1620	1800	6	0	11	30	12	34	17	24	24	25
21	11.3	79	129	1690	1740	4	2	10	17	16	30	28	42	25	40
21	11.4	42	87	1631	1800	6	0	7	25	9	21	14	22	12	19
21	11.5	90	66	1770	1620	1	6	25	10	20	5	22	24	23	27
22	11.1	105	134	1770	1620	1	6	22	36	21	30	28	39	34	29
22	11.2	97	96	1650	1740	5	2	35	18	32	21	11	27	19	30
22	11.3	106	131	1650	1710	5	3	32	40	31	33	15	21	26	37
22	11.4	67	62	1680	1740	4	2	15	8	17	13	17	14	17	28
22	11.5	69	77	1800	1639	0	6	8	20	18	24	20	23	23	10
22	11.1	113	120	1800	1620	0	6	23	37	28	23	29	29	32	32
22	11.2	139	95	1692	1770	4	1	34	21	38	27	34	18	33	29
22	11.3	149	156	1710	1709	3	4	33	45	33	45	43	41	40	25
22	11.4	67	86	1620	1800	6	0	20	14	21	21	23	24	3	27
22	11.5	108	78	1800	1650	0	5	26	22	26	15	28	15	27	27
22	11.1	104	111	1770	1650	1	5	27	26	28	29	26	29	22	28
22	11.2	72	95	1590	1770	7	1	20	18	20	24	22	28	10	25
22	11.3	159	152	1688	1710	4	3	49	37	41	25	31	44	38	46
22	11.4	63	53	1629	1770	6	1	22	10	13	13	19	12	9	18
22	11.5	109	93	1800	1680	0	4	13	21	28	27	32	25	34	20
22	11.1	78	123	1740	1620	2	6	13	30	19	37	21	39	23	17
22	11.2	120	122	1620	1794	6	1	25	17	31	27	33	31	31	47
22	11.3	146	133	1710	1710	3	3	31	39	32	35	40	29	43	30
22	11.4	57	55	1650	1770	5	1	16	5	17	15	15	19	9	16
22	11.5	71	58	1800	1620	0	6	4	8	21	20	24	11	22	19
22	11.1	95	143	1770	1620	1	6	22	36	22	42	27	41	24	24
22	11.2	126	133	1680	1800	4	0	35	19	33	32	38	37	20	45
22	11.3	140	173	1740	1744	2	2	29	44	35	42	37	42	38	44
22	11.4	58	67	1650	1740	5	2	19	16	16	20	9	13	14	18
22	11.5	69	87	1800	1620	0	6	9	25	20	15	20	21	20	26
25	11.1	57	57	1800	1710	0	3	14	15	15	15	14	15	14	12
25	11.2	111	102	1650	1769	5	2	30	23	31	26	18	24	32	29
25	11.3	76	70	1650	1680	5	4	18	16	17	17	20	21	20	15
25	11.4	93	51	1650	1800	5	0	29	9	20	14	23	14	21	14
25	11.5	69	84	1770	1590	1	7	15	23	17	25	13	21	24	15
25	11.1	60	67	1800	1620	0	6	13	11	16	23	15	19	16	14
25	11.2	86	91	1680	1800	4	0	21	20	18	21	25	24	22	26
25	11.3	80	70	1680	1680	4	4	16	18	22	18	24	16	17	19
25	11.4	18	10	1770	1800	1	0	4	2	5	3	6	2	3	3
25	11.5	55	89	1800	1680	0	4	12	17	14	24	15	23	13	24
25	11.1	35	53	1800	1703	0	4	6	9	13	11	8	19	8	14
25	11.2	75	71	1590	1800	7	0	15	16	23	19	22	19	15	17
25	11.3	88	86	1700	1710	4	3	22	20	25	20	17	20	24	26
25	11.4	70	14	1680	1770	4	1	16	2	20	3	17	6	17	3
25	11.5	10	47	1800	1719	0	3	0	13	4	11	3	13	3	10

25	11.1	45	45	1740	1642	2	6	5	11	13	10	14	12	13	12
25	11.2	87	72	1680	1740	4	2	22	14	19	20	27	21	19	17
25	11.3	71	69	1680	1680	4	4	16	13	18	21	25	17	12	18
25	11.5	4	18	1800	1770	0	1	0	4	1	6	1	5	2	3
25	11.1	81	84	1770	1592	1	7	16	17	23	23	22	30	20	14
25	11.2	98	97	1672	1770	5	1	10	21	24	24	30	25	34	27
25	11.3	95	94	1710	1735	3	3	22	23	24	22	24	22	25	27
25	11.4	88	56	1650	1800	5	0	26	13	18	16	21	15	22	13
25	11.5	64	101	1770	1680	1	4	16	24	14	27	14	24	19	27