CHANGEOVER DELAY
AND CONCURRENT SCHEDULES

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ABSTRACT

Domestic hens served as subjects in a series of three experiments investigating the effects of changeover delay (COD) on concurrent variable-interval schedule performance. The first experiment involved manipulations of the relative reinforcement rates on the two schedules presented on two separate keys while holding the COD constant over a series of COD durations from no COD to 15-sec. Sensitivity to reinforcement as measured by a in the generalised matching law was, for both response and time measures, less than unity and least at no COD. Generally it increased with the introduction of any COD but did not change systematically with COD length. Responding during the COD was found to be insensitive to changes in reinforcement rate ratios. The second experiment manipulated the stimuli presented on the main key during the COD (CO-key procedure). Adding distinctive key-colours during the COD increased sensitivity to reinforcement while the addition of blackout decreased time (but not response) sensitivity. Both effects carried over into following (non-stimulus) conditions but this did not survive a change in the schedules. The third experiment held the schedule values constant (two-key procedure) while the COD values were varied from no COD to 12-sec (thrice). Measures of behaviour changed with COD value although generally the a values were similar to those of the first experiment. Overall the changes were recoverable although individual point estimates of a were shown not to be reliable. The findings from the three experiments support the use of the generalised matching law to describe performance on concurrent schedules of reinforcement. They also question the common use of changeover delays in concurrent schedules in that they appear to do more than simply separate the schedules in time.

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CONTENTS

Behaviour has consequences. If, when a particular event reliably follows a behaviour, the behaviour becomes more likely the event is termed a reinforcer and the behaviour is said to have been reinforced. If the behaviour becomes less likely the event is termed a punisher and the behaviour is said to have been punished. Thorndike (1911) in his formulation of the law of effect proposed that the operation(s) of reinforcement and punishment acted to strengthen (or weaken) the connections between particular setting stimuli and particular behaviours (responses). Skinner (1938), however, proposed that reinforcement acted not on particular responses but on sets of responses. He argued that all responses which had a common effect on the environment (termed an operant class) were more (or less) likely as a result of reinforcement or punishment of a particular member. Although both Thorndike and Skinner later repudiated the negative form of the law of effect it is generally accepted by more recent authors (e.g., Premack, 1971).

Generally not all occurrences of a behaviour will be followed by the particular consequence(s) it produces. An arrangement which specifies the relation(s) between the occurrences of members of the operant class and the delivery of consequences is termed a schedule of reinforcement (Skinner, 1938). The effects of various intermittent schedules of food delivery on single behaviours under controlled conditions have been investigated by Ferster and Skinner (1957). Most intermittent schedules of reinforcement are based either on the occurrence of a number of responses (ratio schedules) or on the occurrence of the first response after a specified period of time has elapsed from the last reinforcement delivery (interval schedules). It is an explicit assumption of behavioural psychology that intermittent schedules of reinforcement exist outside the controlled conditions of the laboratory (Schwartz & Lacey, 1982). It is also assumed that an

organism chooses among several behaviours at any time (Herrnstein, 1970).

Choice may be investigated by presenting two (or more) schedules of reinforcement concurrently. It is usual to arrange the schedules so that the organism is free to respond on either schedule, but not on both simultaneously, and therefore is required to choose between them. Commonly one of two procedures is used to arrange concurrent schedules. In the simpler two-key procedure the two schedules are each presented on separate manipulanda (usually perspex keys when the subjects are pigeons). The changeover-key procedure (Findley, 1958) presents both schedules on a single manipulandum (the main key), each in the presence of a discriminative stimulus. Responses on a second manipulandum (the changeover key) change the schedule and the stimulus in effect on the main key. These two procedures generate apparently equivalent patterns of behaviour on various pairs of schedules (Catania, 1966; de Villiers, 1977; Findley, 1958). If the two schedules are not equal then it is a common finding that an animal's behaviour is distributed unequally between them. Generally, the greater the rate of reinforcement provided on one schedule, as compared to the other, the greater the proportion of responses made on that schedule. The proportion of responses made on a schedule (responses on Schedule 1 / total responses) or the ratio of the responses made on the two schedules (occasionally the logarithms of the ratios) are taken as measures of the organism's choice or preference between the alternatives (de Villiers, 1977).

Models of Choice

There have been various attempts to fit mathematical functions to the data to describe concurrent-schedule performance. Among the most prominent of these are those of Herrnstein (1961, 1970), Baum and Rachlin (1969), and Baum (1974b, 1979). Most authors have attempted to find a simple relation between the measures of behaviour and the reinforcement rates. Logically it would be better to use the programmed

reinforcement rates (Fantino, Squires, Delbrück, & Peterson, 1972; Killeen, 1972) but more recent practice (after Herrnstein, 1961) has been to use the obtained reinforcement rates since these can deviate markedly from those programmed (e.g., Shull & Pliskoff, 1967) and they are what the animal experiences. Another approach to this particular problem has been to prevent the obtained reinforcement rates moving away from those programmed (Stubbs & Pliskoff, 1969). This is done by making the two concurrent schedules dependent in that when reinforcement becomes available on one schedule no reinforcement will become available on the other schedule until the reinforcement on the first has been collected. This is commonly arranged in one of two ways. Either the second variable-interval generator stops timing while a reinforcer is available on the first schedule or a single variable-interval generator determines reinforcement availability and the reinforcement is then allocated, with a predetermined probability, to either of the schedules. In both cases the organism is forced to respond on both schedules to obtain reinforcement.

The Simple Matching Law. Herrnstein (1961) investigated behaviour on concurrent variable-interval variable-interval schedules (conc VI VI schedules). Variable-interval schedules make reinforcement delivery, typically brief access to food, aperiodically contingent on responding. Herrnstein reported that the proportion of the total responses made on one schedule was equivalent to, or "matched", the proportion of the total reinforcements (obtained) on that schedule:

$$P1/(P1+P2) = R1/(R1+R2), \qquad (0.1)$$

where P is the number of responses, R the number of reinforcements, and the numbers denote the two schedules. Since on variable-interval schedules reinforcement delivery becomes available after varying periods of time (whether or not the animal has responded on the schedule) the

first response on a schedule may produce reinforcement. It is therefore possible that responding on one schedule will come under the control of reinforcement on the other. This may result in either simple alternation between the schedules or in the development of "concurrent superstitions" whereby reinforcement delivered on one schedule maintains patterns of responding which involve both schedules (as demonstrated by Catania and Cutts, 1963). To prevent this Herrnstein (1961) introduced a changeover delay (COD). This consisted of a specified period immediately following a changeover from one schedule to another during which responses could not produce reinforcement. A reinforcer that would have been available during this immediate post-changeover period was held until the first response after the COD. Herrnstein reported that such a delay was necessary if the response proportions were to "match" the reinforcement proportions. Changeover delays are now commonly programmed when conc VI VI schedules are arranged (de Villiers, 1977) and are usually timed from the first response on a key (two-key procedure) or from a response on the changeover key (Findley or CO-key procedure).

The simple "matching" model (Equation 0.1) has been reported to describe the data from a large number of studies using conc VI VI schedules (Catania, 1966; de Villiers, 1977). This applied whether the behaviour measure was either the responses made on, or the times spent responding under, each schedule (Baum, 1979; Baum & Rachlin, 1969; Brownstein & Pliskoff, 1968; de Villiers, 1977). The times spent responding under a schedule are usually measured as the cumulative totals for each schedule of the times from the first response on a key to a response on another key (or the interchangeover times).

The Multiplicative Matching Law. Behaviour under concurrent schedules has been found to vary with changes in variables other than the reinforcement rates. These have included the amount of reinforcement (Brownstein, 1971; Catania, 1963), the delay to reinforcement (Chung,

1965a; Chung and Herrnstein, 1967), the quality of the reinforcer (Hollard & Davison, 1971; Matthews & Temple, 1979; Miller, 1976) and the effort required for a response (Chung, 1965b; Hunter & Davison, 1982). Baum and Rachlin (1969) suggested that the ratios of the reinforcement rates, the amounts, and the delays (and other possible variables) might combine multiplicatively to determine the "value" of the alternatives and, therefore, the ratio of the times spent (and responses made) on the alternatives. Rachlin (1971) summarised this multiplicative "matching" law as:

$$V1/V2 = P1/P2 = T1/T2 = (R1/R2)(A1/A2)(D2/D1)...(X1/X2), \qquad (0.2)$$

where V1 and V2 are the "values" of the alternatives, P1 and P2 are the numbers of responses made, T1 and T2 the times spent, R1 and R2 the reinforcement rates, A1 and A2 the amounts of reinforcement, D1 and D2 the delays to reinforcement, and X1 and X2 any other variables that might influence the choice. Rachlin (1971) argued that in this form the law may be tautologous. If a one-to-one correspondence is not found between the ratio of responses made or of times spent and the variables manipulated (expressed as the product of the ratios) then it may be argued that some other (unmeasured) variable was also involved or that some transformation of the ratios of the independent variables was necessary.

The Generalised Matching Law. Perfect matching between the ratios of the numbers of responses made (or the ratios of the times spent) and the ratios of the numbers of reinforcements obtained has not always been found. Many authors have reported that proportionately fewer responses were made (or less time spent) on the schedule with the higher rate of reinforcement than would have been predicted by strict matching (Baum, 1979; de Villiers, 1977; Myers & Myers, 1977; Wearden & Burgess, 1982). The term "undermatching" has been used to describe these findings (Baum,

1974b). Data which show undermatching imply a power function relation between the ratios of the responses and the ratios of the reinforcements. This form of the matching law has been termed the generalised matching law (Baum, 1974b) and has been found to give good descriptions of the data from conc VI VI schedules. The equation takes the form:

$$B1/B2 = b(R1/R2)^{a}, \qquad (0.3)$$

where B1 and B2 are measures of behaviour (responses or times spent responding) on the two alternatives, and R1 and R2 are the reinforcement rates on the two schedules. The parameters a and b are expressions of the sensitivity to variations in the reinforcement rates and of bias to either alternative, respectively. Equation 0.3 reduces to the simple matching equation (Equation 0.1) when both a and b equal 1.00.

Baum (1979) suggested that time data tended to produce a values of around 1.00 while response data produced a values less than 1.00 (i.e., undermatching). However, more recent authors (e.g., Mullins, Agunwamba, & Donohoe, 1982; Wearden & Burgess, 1982) have suggested that both measures tend to show undermatching, although the a values from time data do tend to be closer to 1.00. Values of a around 0.80 are, probably, the most common (Baum, 1979; de Villiers, 1977; Lobb & Davison, 1975; Myers & Myers, 1977; Wearden & Burgess, 1982). Bias is usually assumed to be constant, affecting the preference shown across all reinforcement ratios (Baum, 1974b). It would appear as another multiplicative factor in Rachlin's (1971) equation (Equation 0.2).

If the data are transformed to the logarithms of the ratios then straight lines fit the data well (Baum, 1974b). Plotted on logarithmic coordinates a appears as the slope of the line and log b as the y-intercept and the equation becomes:

$$\log(B1/B2) = a\log(R1/R2) + \log b. \qquad (0.4)$$

Baum (1974b, 1979) pointed out that when the data are plotted as proportions values of a and b not equal to 1.00 produce curvilinear plots which are difficult to interpret. Earlier practice (e.g., Herrnstein, 1961, 1970) was to present data as proportions. However the methods of data presentation have been changing and it is now more common to present the data as ratios (e.g., Davison & Hunter, 1979; Logue, 1978; Matthews & Temple, 1979) although not all authors do so (e.g., Myers & Myers, 1977; van Haaren, 1981) in spite of Baum's (1974b, 1979) suggestions. A ratio measure gives equal weight to equal changes in the ratio whereas proportions are bounded functions in which large (ratio) changes at extreme preference values become very small and not visible on graphic plots.

Undermatching

Data which appear to show undermatching present at least two separate problems. The first is that of judging whether the lines fitted to the data describe the data well enough to justify the added complication of a power function in the apparently simple matching law. The second problem occurs because different authors report different degrees of undermatching with (possibly) slight differences in procedure(s). If these are not judged to be errors (i.e. undermatching is accepted as a real finding) then there appears to be no simple or clear set of explanations for undermatching at present.

Fits of the Lines. In addressing the first of these problems de Villiers (1977) re-analysed the data from seven published studies. He found (for the group data) that the regression lines accounted for only 8% more of the y-variance than did lines with a slope of 1.00. He concluded that the simple matching model adequately described the data published. However for some subjects the fit of the regression line was considerably better than that of the line fitted assuming a slope of 1.00, while assuming a slope of 1.00 never provided a better fit.

Baum (1979) pointed out that there is no accepted criterion of acceptable loss in predictability (or goodness of fit) against which to judge the various models. He suggested that a loss of 1% might be generally acceptable. Using this criterion Baum (1979) concluded, on the basis of the results from 23 studies, that slopes between 0.90 and 1.11 approximated 1.00. He therefore appears to have been suggesting that although the best-fitting values of a frequently deviate from 1.00 such deviations are "errors" from "true" matching. Mullins, Agunwamba, and Donohoe (1982) have pointed out that the danger with specifying a range of values as equivalent to 1.00 is that this "rule" may be applied to the data from other studies without regard to the variability in those data. They suggested that providing confidence intervals for the slopes of the fitted lines would provide more information and would not require the assumption that the "true" slope was 1.00. If Staddon (1968) was correct in suggesting that matching is a special case of a more general power-law relationship between the ratios of behaviour and of reinforcement, and that matching occurs with only a narrow range of procedures, then testing the slopes of the fitted lines for significant differences from 1.00 may be no more meaningful than would testing for differences from any other arbitrarily selected value.

Procedural Variations. Baum (1979) has suggested that procedural variables such as the level of deprivation, the type of reinforcer, the way in which the variable intervals are generated, and the duration of the COD programmed may affect the degree of undermatching. His suggestion was based, in large part, on the observation that the findings from his own (Baum 1973, 1974a, 1975, 1976; Baum & Rachlin, 1969) and Davison's studies (Beautrais & Davison, 1977; Davison & Hunter, 1976; Hollard & Davison, 1971; Lobb & Davison, 1975; Trevett, Davison, & Williams, 1972) appeared to differ systematically (he reported matching of both time and response data while Davison reported

undermatching). However, in a later review of studies which have investigated conc VI VI schedule performance Wearden and Burgess (1982) concluded that procedural differences between studies appeared to have little affect on the degree of undermatching found: They pointed out that in spite of considerable procedural variations among the studies undermatching is the common finding for both response and time measures.

Wearden and Burgess' (1982) conclusion does not appear, to the present author, to be supported fully. First, Wearden and Burgess were talking about effects that could be observed across studies (which usually differed in more ways than one). They recognised that there were data showing within-study changes in the degree of undermatching with changes in some variable such as COD (e.g., Scown, Foster, & Temple, 1982; Shull & Pliskoff, 1967) but disregarded them. The data their conclusion are based upon therefore did not come from any systematic manipulation of the procedural variables. Second, their conclusion was not based on all the available data. Some studies have reported levels of undermatching or overmatching well outside the range generally observed. For example, Matthews and Temple (1979) reported a large degree of undermatching for both response and time measures (mean a values of 0.44 and 0.67, respectively) using dairy cows as subjects while Pliskoff, Cicerone and Nelson (1978) reported overmatching using a fixed-ratio requirement on the changeover key rather than a COD (the responses made on the changeover key to complete the fixed-ratio requirement were not counted as responses on the schedules). In both cases there were major procedural differences between the study and the majority of conc VI VI studies.

It would be premature to conclude that procedural variables do not affect conc VI VI schedule performance. It is possible that, with more systematic investigation, particular procedural variables will be found to have consistent effects. A recent review of some 18 experiments

involving conc VI VI schedule performance (Taylor & Davison, 1983) offers some suggestions. Taylor and Davison (1983) noted that the sensitivities to reinforcement (a in Equation 0.4) calculated from the response data were significantly smaller when arithmetic rather than exponential progressions were used to provide the intervals of the variable-interval schedules. There were no such differences apparent in the time-allocation data. Unfortunately Taylor and Davison (1983) do not offer a specific explanation for their findings except in terms of possible local differences in the distributions of reinforcements. Descriptive studies of this nature are valuable as a first step in suggesting those variables which might affect concurrent-schedule behaviour and need further experimental investigation.

A further complication in the interpretation of results arises from the apparently common practice of selecting those procedures (and those parameter values) which are expected to produce the closest approximations to matching. Often there appears to be little theoretical justification for the procedures selected. For example, both Baum (1979) and de Villiers (1977) have claimed that larger COD values (larger than some minimum value) produce better approximations to matching. The lack of a COD or the inadequate duration of the COD has often been suggested as a possible reason for undermatching (Baum, 1979; de Villiers, 1977; Herrnstein, 1961). That few authors have investigated performance on conc VI VI schedules without programming a COD suggests that this view is widely accepted.

Many authors appear to have chosen to use a particular COD duration because it was used in previous studies (with the same species) which reported finding good approximations to matching (de Villiers, 1977). In a similar vein Brownstein and Pliskoff (1968) selected the COD programmed, for individual birds, throughout the remainder of their study by, first, increasing the COD until the proportion of responses made on

one of two unequal schedules closely approximated the proportion of reinforcements obtained on that schedule (i.e., matched). Matching has also been used to justify the inclusion (or otherwise) of the responses made during the COD in the measure of preference between schedules (e.g., Baum & Rachlin, 1979; Silberberg & Fantino, 1970).

Navarick (1979) has pointed out that, using this reasoning, the assumption that the procedural variations used were justified if matching was found (or the converse) is logically circular. Even when a model adequately describes the data a problem arises because of the decision to use (or not) a COD or some other procedural variation. For example, de Villiers (1977) concluded that simple matching was an adequate model for most conc VI VI data as long as the COD was adequate. This approach presupposes its results in that it is assumed that if matching is not found then the COD was not sufficiently long.

It is the present author's view that the undermatching found when a COD is used to separate the two schedules in time should be accepted as real and that the effects of the COD on conc VI VI schedule performance be systematically investigated.

Changeover Delay

The variable most often implicated in undermatching is the COD (Baum, 1974b, 1979; de Villiers, 1977; Navarick, 1979). However, since Herrnstein's (1961) assertion that a COD was required to produce matching there have been few studies which have looked specifically at the effects of the COD on matching. Shull and Pliskoff (1967) varied the length of the COD (from 0 seconds to 20 seconds) with each of two pairs of conc VI VI schedules. They reported that increasing COD duration had differential effects depending on whether the schedules were equal or not. When the schedules were equal (conc VI 90-sec VI 90-sec) the proportion of responses made on one schedule approximated 0.50 at all values of the COD. When the schedules were unequal (conc VI 60-sec VI

180-sec) the response proportion (taken to the VI 60-sec schedule) increased as the COD increased. However, the proportion of the reinforcements obtained on this schedule also increased and the "match" between the response and reinforcement proportions improved as the COD increased. Close examination of their data, however, suggests that the closeness of this match did not deteriorate to previous levels when the COD was then reduced. Brownstein and Pliskoff (1968), using concurrent variable-time (60-sec) variable-time (180-sec) schedules (on which reinforcement was delivered after a variable period of time independent of the animal's behaviour) reported a similar improvement in the match of the time proportions to the proportions of obtained reinforcements as the COD increased. However, they did not increase the COD beyond the value at which they first obtained a "good" match. This value was different for all three pigeons (7.5, 5, and 2 seconds, respectively). In contrast to these two studies Allison and Lloyd (1971) and Silberberg and Fantino (1970) reported no change in the degree of matching over the range of COD values they studied (2, 5, 7.5 and 12.5 seconds and 0.875, 1.75 and 3.50 seconds, respectively).

In all these studies the proportion of the reinforcements obtained on a schedule was free to vary. For example, in Shull and Pliskoff's (1967) study this varied from around 0.73 with a 0-sec COD to around 0.90 with a 20-sec COD. In contrast Stubbs and Pliskoff's (1969) procedure (using dependent schedules) ensured that the proportion of reinforcements did not change as a function of the animal's behaviour. The proportion of reinforcements to be produced on one schedule was set at 0.75 and the COD was varied (0, 8, 16, and 32 seconds). They reported that the proportions of responses made and times spent (on the schedule producing 75% of the reinforcements) were close to 0.75 at all values of the COD and that, therefore, the degree of matching did not change as the COD was increased. However, Silberberg and Schrot (1974), also using

unequal and dependent conc VI VI schedules, reported an increase in both the time and response proportions with increased COD. The degree of matching between these two proportions and the proportion of reinforcements (which was constant) did, therefore, vary with changes in the length of the COD.

It is not clear what the differences in these results imply. Both Baum (1974b, 1979) and de Villiers (1977) have stated that some minimum COD value is necessary for matching, but that beyond this minimum matching is found at all values of the COD. It appears, to the present author, that the available data do not support this conclusion fully. First, the findings described above are contradictory (cf. Shull & Pliskoff, 1967; Allison & Lloyd, 1971). Second, some authors (e.g., Baum, 1974a; Bradshaw, Szabadi, & Bevan, 1976; Heyman, 1979) have reported matching with no COD so that Baum (1982) concluded that there is every chance of obtaining matching with no COD programmed so long as sufficient care is taken with the procedure. However it is not exactly clear what parameters of the procedure need to be chosen with care. Nor is it clear how "sufficient care" might be defined independent of the experimental results. For example, Herrnstein's (1961) results, on the basis of which he suggested that a COD was necessary for matching, may have been influenced by the training which immediately preceded the experimental conditions. This training produced nearly perfect alternation between the schedules. If the conditions in which no COD was programmed had not followed this training so closely or if a greater range of relative reinforcement rates had been programmed with no COD then his results may have been different. Third, no study investigating the effect of the COD duration on conc VI VI schedule performance (known to this author) has parametrically varied both the COD and the reinforcement rates. Yet assessment of matching requires that the reinforcement rates on the two schedules be manipulated over an adequate

range (Baum, 1974b; Charman & Davison, 1982). There is some evidence from studies of performance on multiple schedules (sequentially arranged schedules on a single key) that effects observed when the relative reinforcement rates are kept constant and a procedural variable manipulated may not be apparent once the relative reinforcement rates are varied (Charman & Davison, 1982).

Those studies which have manipulated the COD length have generally been investigating changes in concurrent schedule performance other than (specifically) changes in matching. One reported finding concerns the effect of COD length on the rate of changing over between the schedules. Stubbs, Pliskoff, and Reid (1977), in summarising the data from six published studies, concluded that as the duration of the COD increases the rate of changing over between schedules decreases and the average time spent on a schedule between changeovers (the interchangeover time) increases. Baum (1979) has suggested that reduced rates of changeover (no matter how they are produced) will tend to increase matching. He argued that responding to an alternative (in the unrestricted situation) consists of a constant-length period of uninterrupted responding (a bout) followed by a variable period of pausing and responding. Short interchangeover intervals limit the period of responding possible on a schedule and, therefore, may prevent (or lessen) any differentiation in the number of responses that might occur after this first bout of responding, if the interchangeover interval is shorter than this bout.

The pattern of responding on <u>conc</u> VI VI schedules typically involves a relatively long but variable time spent on the richer schedule and a shorter, more constant, time on the leaner schedule (Menlove, 1975) when a COD is programmed. A second finding is that the local rates of responding are higher immediately following a changeover than they are at any other time and that these response "bursts" extend for (approximately) the duration of the COD (Catania, 1963; Menlove,

1975; Pliskoff, 1971; Silberberg & Fantino, 1970). This effect has been reported for CODs up to four seconds. The information has not been presented in those studies which used CODs outside this range.

Catania (1963) and Silberberg and Fantino (1970) have suggested that the increased rate of responding during the COD may be due to a momentarily higher rate of reinforcement following a changeover (and the COD) than at any other time. Because the variable-interval generators continue timing irrespective of which schedule the animal is responding on, the longer an animal spends responding on one schedule the greater the probability that a reinforcement will be set up on the other schedule (Dreyfus, Dorman, Fetterman, & Stubbs, 1982; Menlove, 1975). Bourland and Miller (1978) suggested that the colour change on the main key associated with a change of schedule in the CO-key procedure (and presumably the position change associated with changing over in the two-key procedure) might signal this increased probability of reinforcement. They reported that when a changeover produced a schedule change without the accompanying stimulus change the response rates were still higher during the COD than after, although the difference was not as great as that produced with the usual stimulus change.

Silberberg and Fantino (1970) reported that relative responding during the COD was essentially insensitive to changes in the relative reinforcement rates on the schedules although there was a slight tendency for proportionately more responses to be made on the leaner schedule. They concluded that this period of altered responding (during the COD) was necessary if matching was to be found. This conclusion was based on their findings that the proportion of responses made after the COD on one schedule overmatched the proportion of reinforcements obtained on that schedule, and that programming blackout (darkness) during the COD, which effectively eliminated responding during this period, did not result in matching.

Stubbs and Pliskoff (1969) and Pliskoff (1971) have pointed out that complex contingencies are operating once a COD is programmed. The schedules are no longer simple variable-interval schedules. There are means other than the COD of separating (in time) responding on one schedule and reinforcement on the other. These have included the use of a fixed-ratio changeover response requirement (Guilkey, Shull, & Brownstein, 1975; Pliskoff, Cicerone, & Nelson, 1978; Pliskoff & Fetterman, 1981; Stubbs & Pliskoff, 1969; White, 1979), a period of timeout (Todorov, 1971), and a larger than usual spatial separation of the keys (Baum, 1981a, 1982). Undermatching, matching, and even overmatching (values of a in Equation 0.4 greater than 1.00) have been reported with these procedures (e.g., Baum, 1981a, 1982; Pliskoff & Fetterman, 1981). These results contrast with the predominant finding of undermatching when a COD is programmed (Baum, 1979; Myers & Myers, 1977; Wearden & Burgess, 1982).

One major difference between these procedures and those employing a COD is that the variable-interval timers are usually stopped while the changeover requirement is being completed but they continue timing during the COD. White (1979) has suggested that this difference results in higher momentary probabilities of reinforcement following a COD than occurs following completion of a changeover ratio (COR) and may explain why no response burst following a changeover is reported with the COR procedure. However the difference between the two procedures in the momentary probability of reinforcement following a changeover (or a COD) is likely to be small. On any interval schedule there will be an increased probability of reinforcement as time away from the schedule accumulates. Only if the COD is very long relative to the interchangeover times will the COD time cause a marked extra increase in the probability of reinforcement. It seems more likely that the response burst (or lack of it) is reflecting the different contingencies

operating following completion of the different changeover requirements. The COD may act as a fixed-interval schedule with a partial probability of reinforcement followed by the variable-interval schedule whereas with the COR procedure the variable-interval schedule is in effect once the changeover is completed.

A second difference between the COD and other procedures lies in how the responses made (or times taken) to change over are treated. When a COD is programmed in a two-key procedure the changeover responses themselves as well as the responses made during the COD are usually counted as responses made on the schedules. In these other procedures the responses made during the changeover are, generally, not counted as responses on the schedules. Including the changeover responses as schedule responses would necessarily result in less overmatching since equal numbers of responses would be added to the responding on each schedule. Some variation is possible in the times taken to changeover so that the effect of adding this to the times spent on the schedules is less clear. It seems that these different ways of separating behaviour on the two schedules may affect the degree of matching found.

Navarick (1979) has suggested that one (or more) of these alternative procedures may be more appropriate than the COD. He points out that the decision about which procedures are most appropriate should not be justified on the basis of whether matching results but according to whether they satisfy the assumptions underlying their use (i.e., that they maintain the independence of the schedules).

These findings of undermatching, matching, and overmatching add support to Staddon's (1968) suggestion that matching is only one of a family of possible power functions which might describe performance on conc VI VI schedules. The generalised matching law is one such function, which appears able to describe the available data. It is possible to accept that the generalised matching law provides a better description

of the data than does the simple matching law and still hold that the underlying process controlling the data is one of matching, but this is not necessary. The generalised matching law is probably best regarded as a descriptive model. It does not address itself to the possible processes which may be responsible for the behaviour observed. In that sense it does not rule out other models which attempt such explanations. These other models have included momentary maximising (Shimp 1966, 1969; Staddon, Hinson, & Kram, 1981), optimal behaviour (Baum, 1981b; Staddon & Motheral, 1978), and melioration (Vaughan, 1981). In general these models appear to assume that behaviour under concurrent schedules will be best described by strict matching. There appears also to be an implicit assumption that there are sufficient data available to support this. As discussed above strict matching is by no means the common finding.

The variables affecting behaviour on conc VI VI schedules are complex and their effects on performance are not fully understood. The purpose of this thesis was to collect more data on the effects of the COD on conc VI VI performance.

EXPERIMENT 1

The initial aim of this first study was to explore the effects of the length of the COD on conc VI VI schedule performance by varying parametrically both the length of the COD programmed and, at each COD value, the ratio of the reinforcement rates.

Method

Subjects

Six domestic hens (White Shaver 288's), numbered 11 through 16, served. They were eight months old and experimentally naive at the start of the study. They were maintained at about 80% of their free-feeding weights (± 15 g) by supplementary feed given after the daily experimental sessions. At these weights the hens laid eggs infrequently but had fleshy combs. All hens were housed in individual cages with water and grit freely available.

Apparatus

The experimental chamber consisted of a wooden (particle board) chamber 414 mm wide (response panel) x 535 mm high x 570 mm long. Two perspex response keys (in a metal surround) were mounted an equal distance either side of the response panel's vertical mid-line. The keys were 30 mm in diameter, 200 mm apart (centre to centre) and 385 mm above the grid floor. They were translucent and were operative when lit from behind by a 1 W white light. Effective pecks on the response keys (requiring a force of at least 0.20 N) closed a microswitch which extinguished the key lights and produced a tone from a 60 mm-diameter speaker, both for 35 msec. The speaker was mounted on the outside of the chamber midway between the keys and sounded in the chamber through a series of drilled holes.

Access to the food magazine was midway between the keys and 145 mm from the floor. During reinforcement both key lights were extinguished and the food magazine was illuminated with a 1 W white light and raised to allow 2.5-sec access to kibbled wheat. Apart from the key and magazine lights no other illumination was provided. An exhaust fan on the wall opposite the response panel provided ventilation and some masking noise.

Experimental events were controlled by remotely situated solid-state logic equipment. All data were collected on solid-state counters. A six-pen chart recorder (CR552 Recorder, J. J. Lloyd Instruments, Southhampton), with the paper moving 2 mm/sec, was used from time to time.

Procedure

Pre-Training. The hens were magazine trained and then trained, by the method of successive approximations, to peck an illuminated response key. Once responding on a VI 60-sec schedule was established an equal but independent VI schedule was introduced on the second key and a 2-sec COD was programmed.

Experimental Conditions. Standard two-key independent concurrent variable-interval scheduling was in effect throughout. The variable-interval generators utilised 12 intervals (in pseudo-random order) based on an arithmetic progression of the form $a + bx$ where a was the smallest interval, $b = 2a$, and $x = 0, 1, \ldots, 11$. For a VI 15-sec schedule the smallest interval (a) was 1.25 seconds and the largest interval was 28.75 seconds. The average was 15 seconds. For all other schedule values a was increased by the appropriate factor to give the required average. The variable-interval generators operated during reinforcement delivery although these periods were excluded from measures of response time.

A COD of 2 seconds was programmed during the first six conditions for all hens. During Conditions 7 to 12 no COD was programmed for Hens 11, 13, and 15 and a COD of 7.5 seconds was programmed for Hens 12, 14, and 16. This was reversed during Conditions 13 to 17. With no COD programmed the first response on a key, after responding on the other, could produce reinforcement. This was not equivalent to a 0-sec COD which requires at least two responses on a key, after responding on the other, to produce reinforcement. During Condition 18 the COD programmed was increased, over 14 days, from 1 second to 15 seconds. This 15-sec COD was in effect during Conditions 18 to 22 for all hens. During Conditions 23 to 27 a 4-sec COD was programmed for all hens. The COD timers were started by the first response on a key after responding on the other.

At each COD value behaviour on five (six when the COD was two seconds) pairs of concurrent variable-interval schedules was studied. The key on which the richer schedule was presented alternated each condition. The condition in which the COD was first altered (Condition 7) was repeated in Condition 11. Table 1.1 gives details of the experimental conditions and of the number of days they were in effect.

Responses on both keys (total responses and responses within the COD), time on both keys (time was accumulated on a schedule until a response on the other schedule key), changeovers (the first response on a schedule after responding on the other) and reinforcements obtained on both schedules were recorded each session. The number of reinforcements obtained on each schedule within two seconds of the end of the COD (and from the changeover response when no COD was programmed) were also recorded during the sixth and later conditions. On at least one of the last five days of each condition an event record was taken, for all hens, of responses made, times spent, the availability of reinforcement,

Table 1.1

The order of the conditions, the COD values, the reinforcement schedules, and the number of days each condition was in effect.

Cond	COD (sec)	VI Schedule (sec) Left	VI Schedule (sec) Right	Days in Effect
	2 (all hens)			
1		60	60	43
2		30	120	27
3		120	60	22
4		60	180	31
5		180	30	30
6		30	60	72
	No COD (Hens 11,13,15) 7.5 (Hens 12,14,16)			
7		60	60	41
8		180	30	24
9		30	120	29
10		120	60	29
11		60	60	35
12		30	60	31
	7.5 (Hens 11,13,15) No COD (Hens 12,14,16)			
13		60	60	34
14		180	30	32
15		30	120	41
16		120	60	26
17		30	60	66
	15 (all hens)			
18		60	60	67
19		180	30	22
20		30	120	28
21		120	60	62
22		30	60	46
	4 (all hens)			
23		60	60	37
24		180	30	24
25		30	120	42
26		120	60	25
27		30	60	37

and reinforcements obtained on the two schedules.

Sessions, which began and ended (after 40 reinforcements) in blackout, were conducted seven days a week. The hens were run in the same order each day. Each condition was in effect until all six hens had met the stability criterion five times (not necessarily in consecutive sessions). The criterion required that the median relative number of responses over five sessions was within 0.05 of the median of the previous five sessions (Davison, 1972).

Results

The last five days data from all conditions and all hens are presented in Appendix 1.1. The sums of the daily data over the last five days of each condition (except Condition 7) were used in all analyses. Group data, unless mentioned otherwise, were analysed by summing the daily data from each hen over the last five days of each condition. Figures 1.1 to 1.7 were drawn from these summed data (individual and group). All ratios were taken to the left key, and the logarithms of the ratios to the base 10.

When the COD was first varied (in Condition 7) behaviour on the VI 60-sec VI 60-sec schedules did not replicate the data from the previous equal schedule condition (Condition 1). This condition was repeated (in Condition 11) and the ratios of the (total) responses made and the times spent on the two schedules from all hens more closely approximated their original responding on equal schedules and were taken as a better estimate of their "true" behaviour. Therefore, the data from Condition 7 have been excluded from the analysis. All subsequent changes of COD value took place with equal schedules in effect and, when the change was large, in gradual steps. Under these conditions responding was essentially equal on the two schedules.

Inspection of the data from Conditions 8-12 and 13-17 revealed no systematic differences in any measures between the data from hens whose experience of COD values had been 2 sec-no COD-7.5 sec and those whose experience had been 2 sec-7.5 sec-no COD. Accordingly the group data, at each COD value, were based on the data from all six hens irrespective of the order in which they experienced the COD values.

Sensitivity to Reinforcement

Total Responses and Times Spent. Figures 1.1 (a) to 1.1 (e) present the logarithms (to the base 10) of the ratios of the total responses made and of the ratios of the times spent on the two schedules, for each hen and each COD value, as a function of the logarithms of the ratios of the obtained reinforcement rates. For ease of presentation these and subsequent similar data will be referred to as the log ratios of the responses made (or the log response ratios), the log ratios of the times spent (or the log time ratios), and the log ratios of the obtained reinforcements (or the log reinforcement ratios), respectively.

Figures 1.1 (a) to 1.1 (e) show that, at all COD values (including no COD), the log response and log time ratios changed with the log reinforcement ratios. The relation appeared to be approximately linear. Therefore, least-squares lines were fitted to all sets of data. Visual inspection of the residual variation in the predicted data revealed no systematic deviations from linearity. The lines and their equations are shown in the figures. The slopes (a) of these lines (responses and times) are plotted against COD value, for each hen, in Figure 1.2.

Table 1.2 gives the slopes and intercepts of the fitted lines, the amounts of the y-variance accounted for by the lines (r^2), and the standard errors of the estimates of y (Sy.x). The slopes and intercepts of the fitted lines together with their standard deviations (SD) and the results of t-tests (Student's t distribution) for the significance of differences of the slopes from 1.00 and 0.00 and the intercepts from 0.00 are presented in Appendix 1.2.

From Figure 1.2 it can be seen that, overall, there were no consistent differences between the slopes of the lines fitted to the response data and the slopes of the lines fitted to the time data. The only consistencies were in the 7.5-sec COD data and in the data from Hen 15. When a 7.5-sec COD was programmed the slopes of the lines fitted to

Figures 1.1 (a) to 1.1 (e)

The logarithms of the ratios of the total responses (squares) and of the ratios of the times spent (triangles) plotted against the logarithms of the ratios of the obtained reinforcements, for each hen at each of the COD values programmed. The least-squares lines fitted to the log response ratios are shown as solid lines and are described by the upper of the two equations given for each hen's data. The least-squares lines fitted to the log time ratios are shown as dashed lines and are described by the lower of the two equations given.

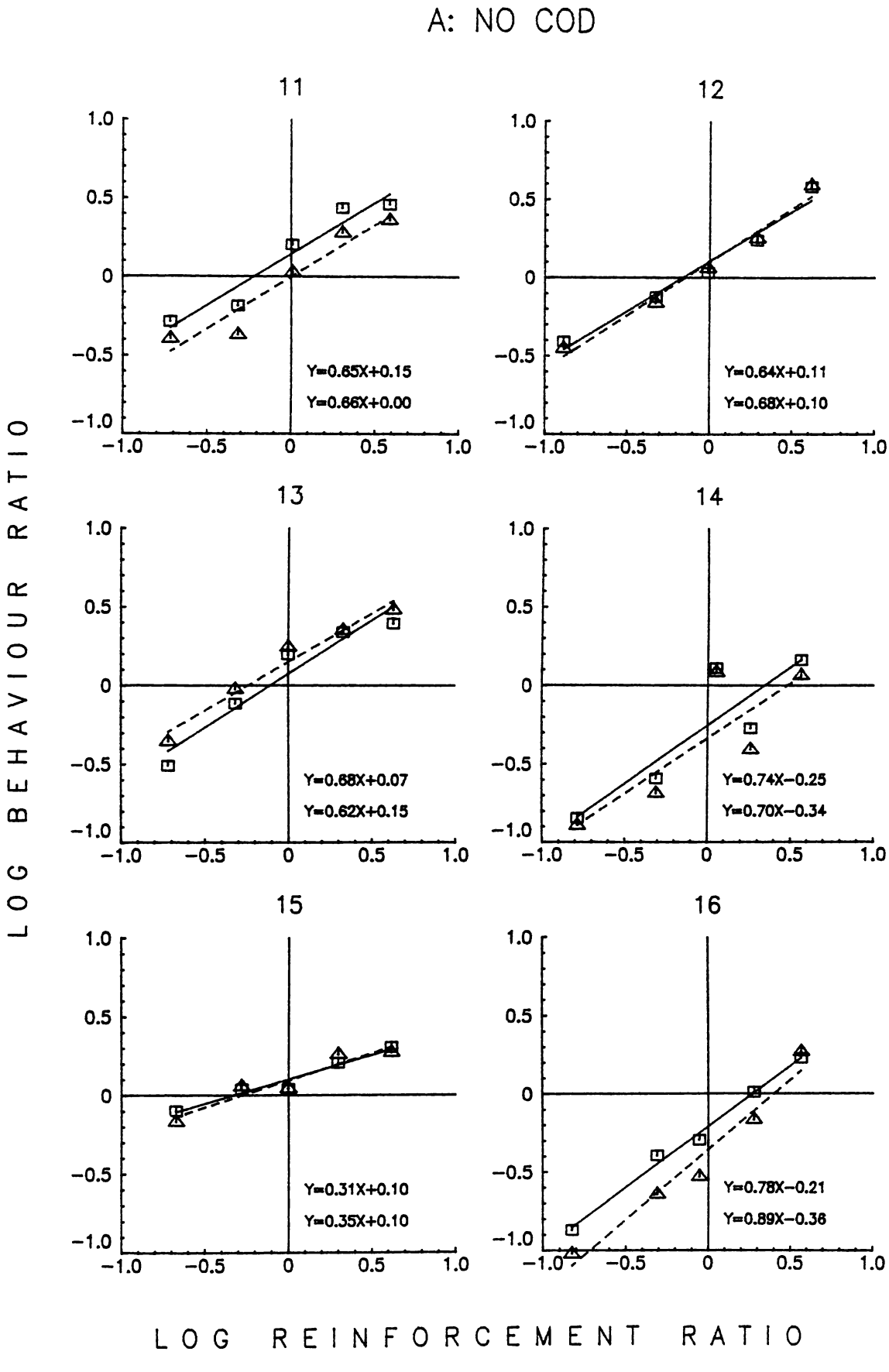
a) no COD

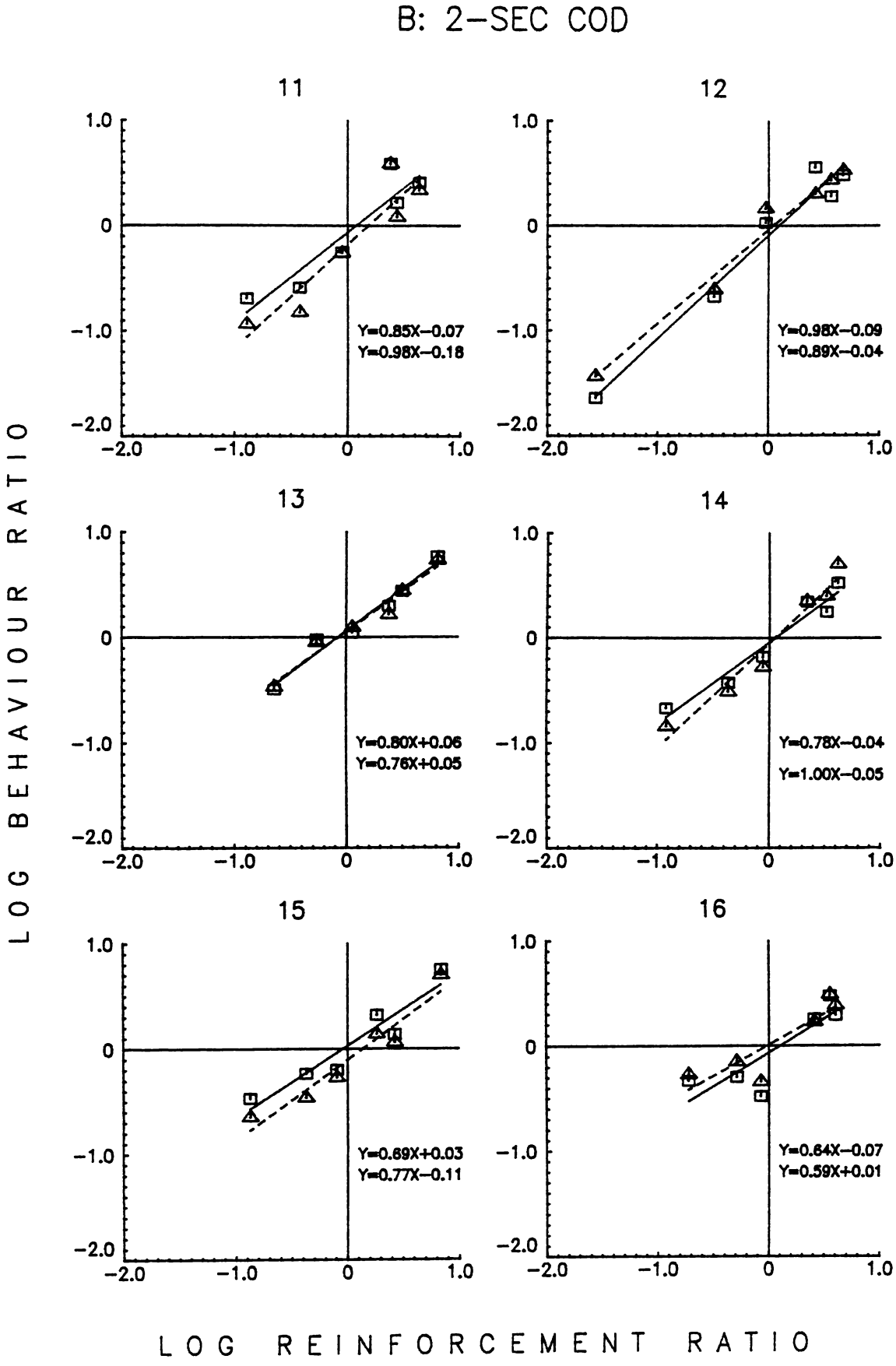
b) 2-sec COD

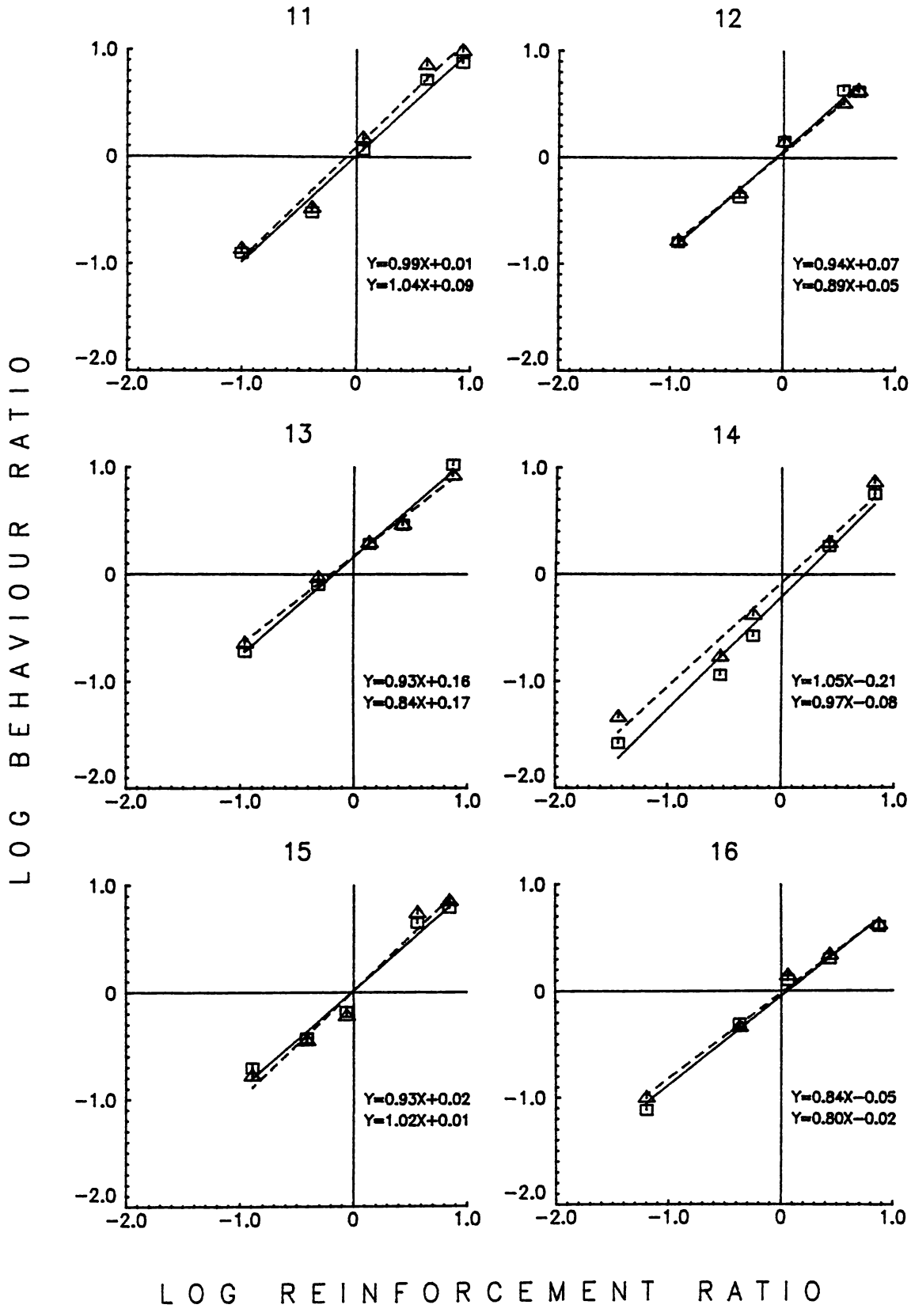
c) 4-sec COD

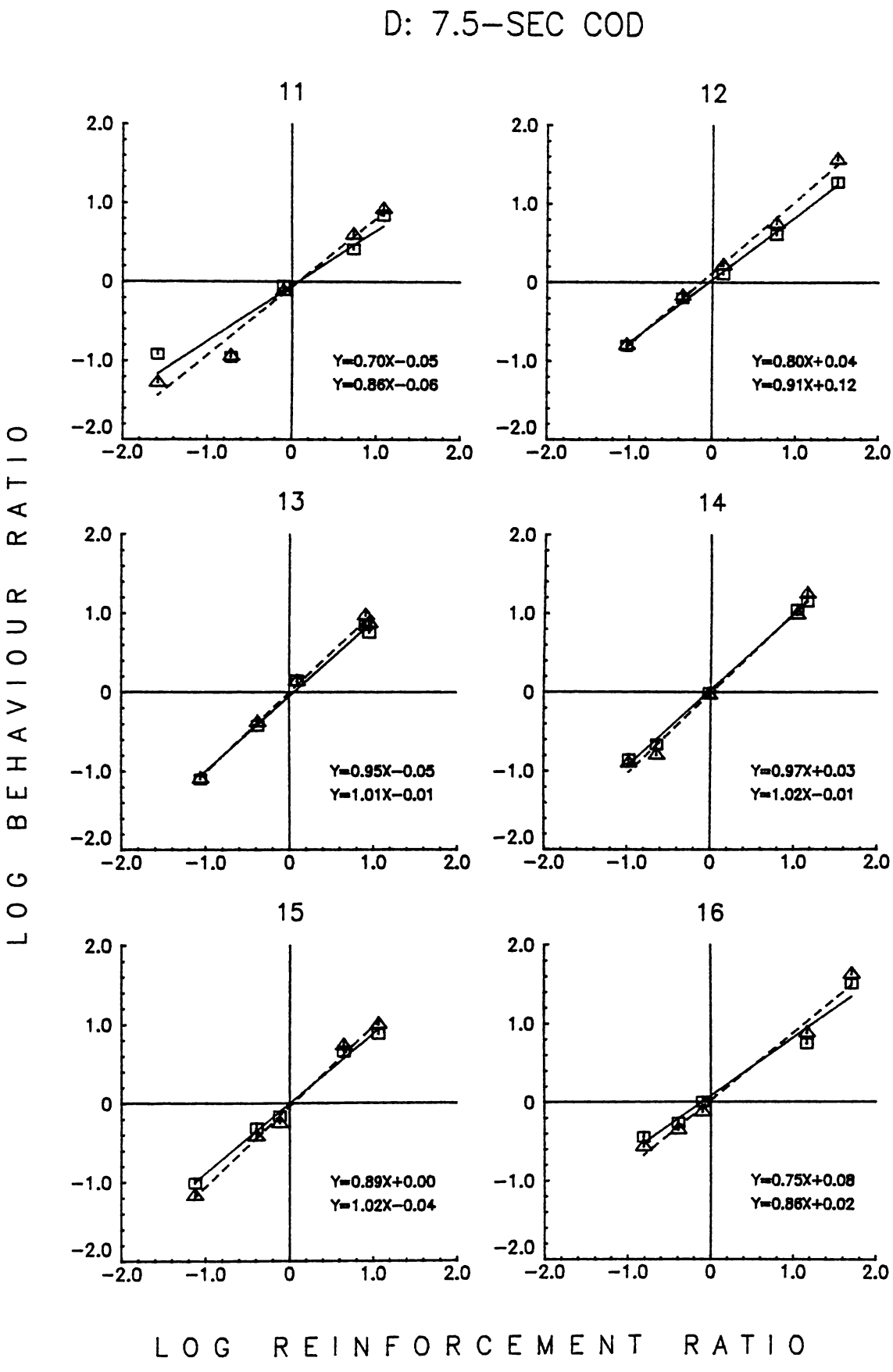
d) 7.5-sec COD

e) 15-sec COD


A: NO COD
11
12
13
14
15
16
Y=0.65X+0.15
Y=0.66X+0.00
Y=0.64X+0.11
Y=0.68X+0.10
Y=0.68X+0.07
Y=0.62X+0.15
Y=0.74X−0.25
Y=0.70X−0.34
Y=0.31X+0.10
Y=0.35X+0.10
Y=0.78X−0.21
Y=0.89X−0.36
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO


B: 2-SEC COD
11
12
13
14
15
16
Y=0.85X-0.07
Y=0.98X-0.18
Y=0.98X-0.09
Y=0.89X-0.04
Y=0.80X+0.06
Y=0.76X+0.05
Y=0.78X-0.04
Y=1.00X-0.05
Y=0.69X+0.03
Y=0.77X-0.11
Y=0.64X-0.07
Y=0.59X+0.01
1.0
0
-1.0
-2.0
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO


C: 4–SEC COD
11
12
13
14
15
16
Y=0.99X+0.01
Y=1.04X+0.09
Y=0.94X+0.07
Y=0.89X+0.05
Y=0.93X+0.16
Y=0.84X+0.17
Y=1.05X–0.21
Y=0.97X–0.08
Y=0.93X+0.02
Y=1.02X+0.01
Y=0.84X–0.05
Y=0.80X–0.02
1.0
0
–1.0
–2.0
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO


D: 7.5–SEC COD
11
12
13
14
15
16
Y=0.70X–0.05
Y=0.86X–0.06
Y=0.80X+0.04
Y=0.91X+0.12
Y=0.95X–0.05
Y=1.01X–0.01
Y=0.97X+0.03
Y=1.02X–0.01
Y=0.89X+0.00
Y=1.02X–0.04
Y=0.75X+0.08
Y=0.86X+0.02
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO

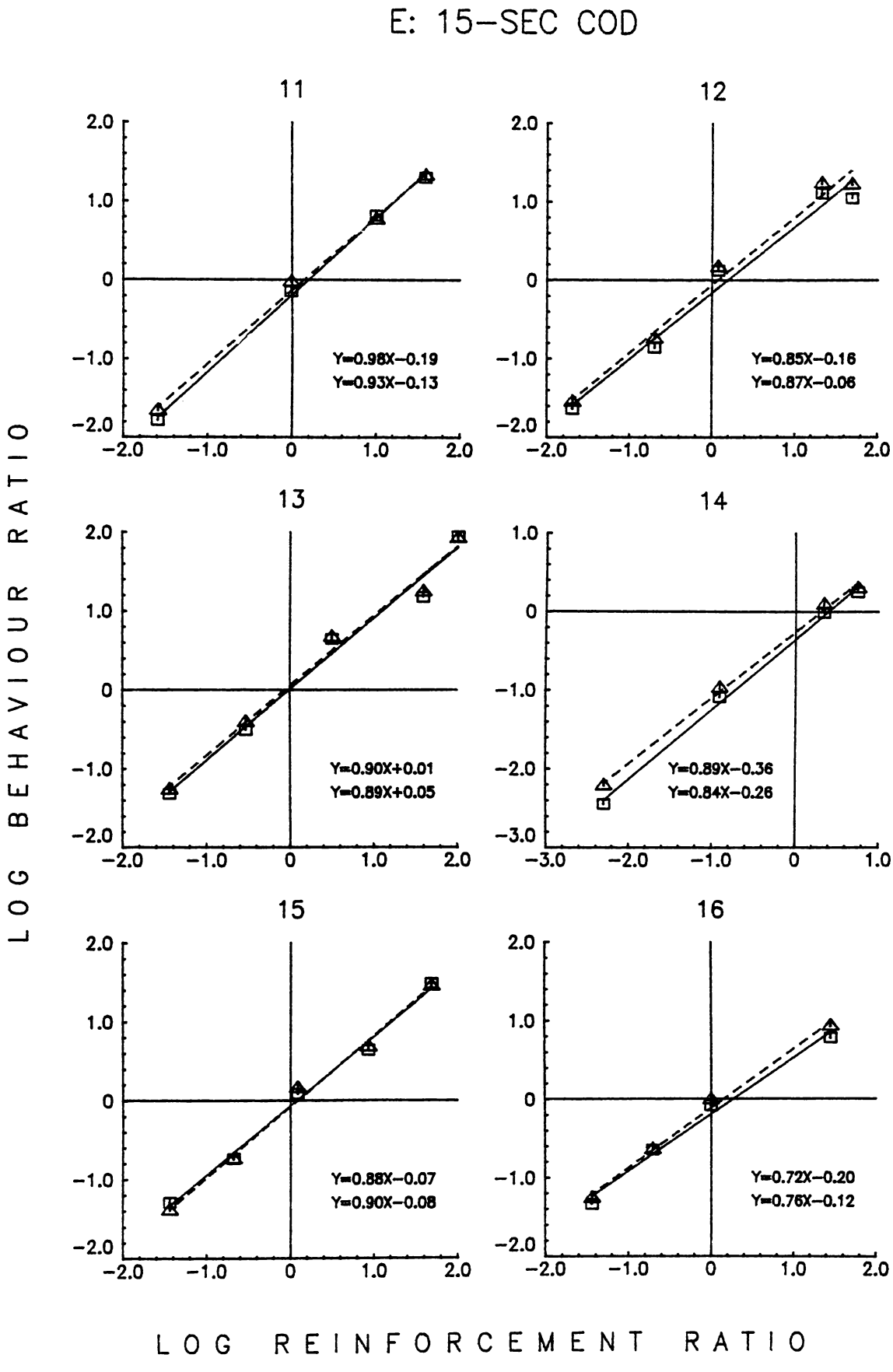

E: 15-SEC COD
11
Y=0.98X-0.19
Y=0.93X-0.13
12
Y=0.85X-0.16
Y=0.87X-0.06
13
Y=0.90X+0.01
Y=0.89X+0.05
14
Y=0.89X-0.36
Y=0.84X-0.26
15
Y=0.88X-0.07
Y=0.90X-0.08
16
Y=0.72X-0.20
Y=0.76X-0.12
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO

Figure 1.2

The slopes of the lines (a in Equation 0.4) fitted to the total response data (squares) and to the time data (circles) plotted against COD value, for each hen. The lines were fitted to the logarithms of the ratios of each measure of behaviour as a function of the logarithms of the ratios of the obtained reinforcements.

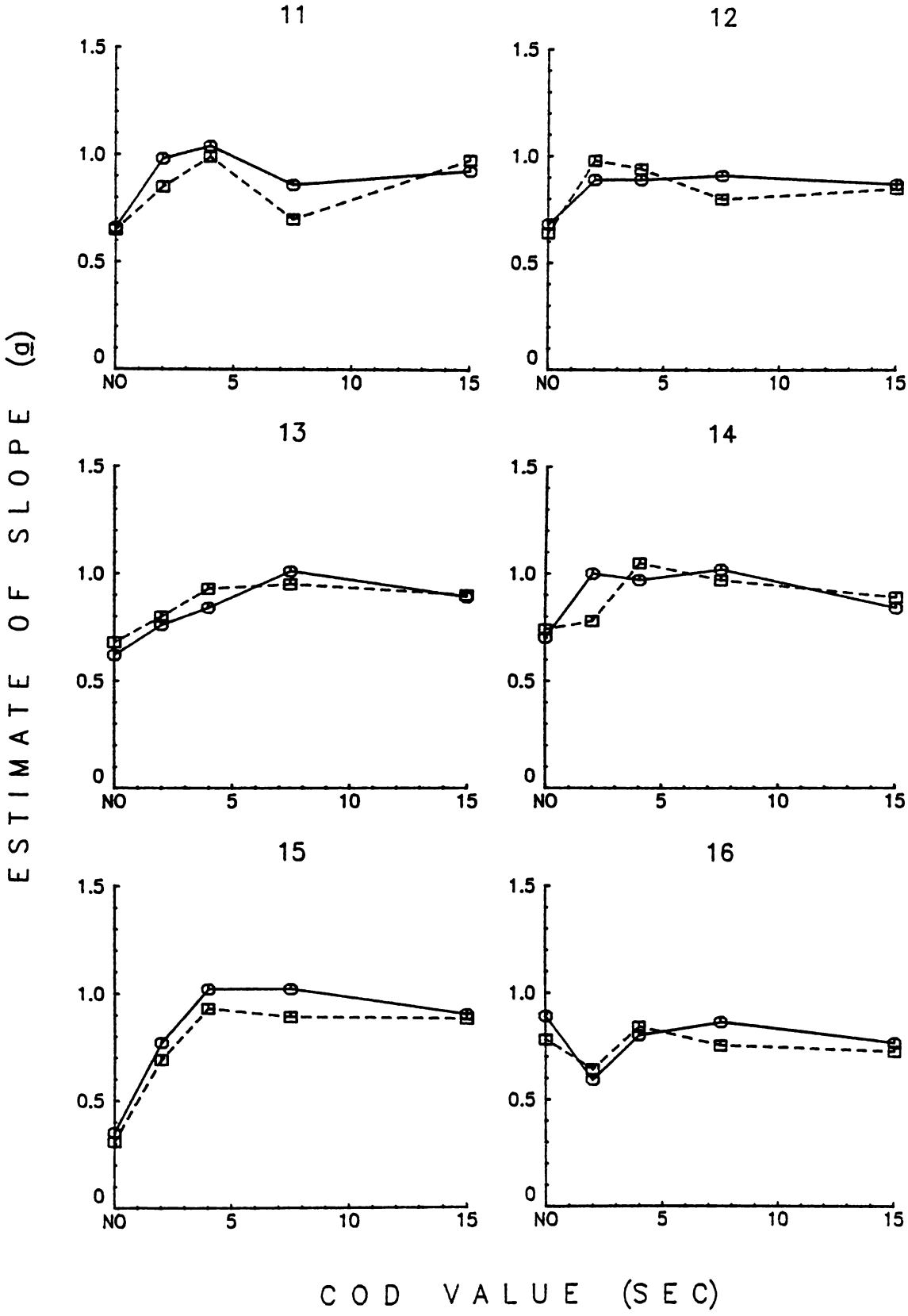

11
12
13
14
15
16
1.5
1.0
0.5
0
NO
5
10
15
ESTIMATE OF SLOPE (g)
COD VALUE (SEC)

Table 1.2

The slopes and intercepts of the least-squares regression lines fitted to the log ratios of the total responses and times as a function of the log ratios of the obtained reinforcement rates, for each hen and the group (GP) at each COD value. The amounts of the y-variance accounted for by the lines (r^2) and the standard errors of the estimates (Sy.x) are given.

	No COD				2-sec COD				4-sec COD				7.5-sec COD				15-sec COD			
Hen	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x
TOTAL RESPONSES																				
11	0.65	0.15	0.93	0.10	0.85	-0.07	0.87	0.22	0.99	0.01	0.98	0.12	0.70	-0.05	0.90	0.29	0.98	-0.19	1.00	0.07
12	0.64	0.11	0.97	0.08	0.98	-0.09	0.96	0.18	0.94	0.07	0.99	0.09	0.80	0.04	1.00	0.05	0.85	-0.16	0.98	0.21
13	0.68	0.07	0.93	0.11	0.80	0.06	0.97	0.09	0.93	0.16	0.99	0.07	0.95	-0.05	0.99	0.09	0.90	0.01	0.98	0.21
14	0.74	-0.25	0.79	0.23	0.78	-0.04	0.95	0.12	1.05	-0.21	0.98	0.15	0.97	0.03	1.00	0.06	0.89	-0.36	1.00	0.08
15	0.31	0.10	0.95	0.04	0.69	0.03	0.89	0.16	0.93	0.02	0.97	0.12	0.89	0.00	0.99	0.07	0.88	-0.07	0.99	0.10
16	0.78	-0.21	0.99	0.04	0.64	-0.07	0.73	0.23	0.84	-0.05	0.99	0.08	0.75	0.08	0.97	0.16	0.72	-0.20	0.99	0.12
GP	0.63	-0.01	0.99	0.04	0.79	-0.03	0.96	0.11	0.94	0.00	1.00	0.05	0.83	0.01	1.00	0.06	0.94	-0.20	0.98	0.18
TIMES																				
11	0.66	0.00	0.92	0.11	0.98	-0.18	0.86	0.26	1.04	0.09	0.98	0.14	0.86	-0.06	0.97	0.18	0.93	-0.13	1.00	0.09
12	0.68	0.10	0.98	0.07	0.89	-0.04	0.98	0.13	0.89	0.05	0.99	0.06	0.91	0.12	1.00	0.06	0.87	-0.06	0.99	0.17
13	0.62	0.15	0.96	0.07	0.76	0.05	0.96	0.09	0.84	0.17	0.99	0.05	1.01	-0.01	1.00	0.07	0.89	0.05	0.99	0.17
14	0.70	-0.34	0.70	0.28	1.00	-0.05	0.96	0.14	0.97	-0.08	0.98	0.16	1.02	-0.01	0.99	0.11	0.84	-0.26	1.00	0.08
15	0.35	0.10	0.91	0.06	0.77	-0.11	0.93	0.14	1.02	0.01	0.97	0.15	1.02	-0.04	0.99	0.09	0.90	-0.08	0.99	0.11
16	0.89	-0.36	0.96	0.12	0.59	0.01	0.78	0.19	0.80	-0.02	0.99	0.08	0.86	0.02	0.98	0.14	0.76	-0.12	0.99	0.09
GP	0.65	-0.06	0.99	0.04	0.82	-0.06	0.98	0.07	0.92	0.04	1.00	0.05	0.94	0.00	1.00	0.06	0.99	-0.05	0.96	0.28

the time data were greater,for all birds, than the slopes for the response data (by 0.05 to 0.16; Table 1.2). At all other COD values the steeper line was as likely to be that fitted to the log response ratios. For Hen 15 the lines fitted to the time data were steeper (by 0.02 to 0.13; Table 1.2) than those fitted to the response data, at all COD values. For all other hens there was no consistent pattern.

It can also be seen, from Figure 1.2 (also Figures 1.1 (a) to 1.1 (e) and Table 1.2), that the slopes of the lines fitted to the log ratios of total responses made and the log ratios of times spent, for the individual hens at each of the COD values, were generally less than 1.00 (53 of 60 cases). The slopes of the lines fitted to the group data obtained at each COD value were all less than 1.00 (Table 1.2).

Excluding the data from Hen 16 (for whom the slopes of the fitted lines did not change significantly with COD value), the slopes of the fitted lines, for both responses and times, initially increased as the COD increased but then stayed at this value or decreased slightly. Again this is seen most clearly in Figure 1.2. The COD value giving the greatest slope was not the same for all hens (ranging from no COD to a COD of 7.5 seconds; Table 1.2). For any individual hen the COD value giving the greatest slopes was different for response and time measures. However, the general trend was similar for the two measures for any individual hen. The only consistent difference in the slopes of the fitted lines was between those conditions where no COD was programmed and those where any COD was programmed. For five of the six hens (the exception was Hen 16) the slopes of the lines fitted to the log ratios of both the total responses made and the times spent were lower when no COD was programmed than when any COD was programmed (Table 1.2).

Figure 1.1 (a) and Table 1.2 show that when no COD was programmed the slopes of the lines fitted to both the log response ratios and the log time ratios, for individual hens, ranged from 0.31 to 0.89.

Excluding Hen 15's data (0.31 and 0.35 for responses and times respectively) the range was 0.63 to 0.78 for responses and 0.62 to 0.89 for times. The slopes of the lines fitted to the group data were 0.63 (responses) and 0.65 (times). In 11 of 12 cases the slopes of the fitted lines, for individual hens, were significantly different from 0.00 (Appendix 1.2). Four of the lines fitted to the log response ratios (of six) and three of the lines fitted to the log time ratios (of six) were significantly less than 1.00 (Appendix 1.2). Both measures gave slopes, for the group, which were significantly greater than 0.00 and less than 1.00 (Appendix 1.2).

When a COD was programmed the slopes of the lines fitted to the log response ratios, for the individual hens' data, were 0.64-0.98, 0.84-1.05, 0.70-0.97, and 0.72-0.98 with COD values of 2, 4, 7.5, and 15 seconds respectively (Table 1.2). The equivalent ranges for the time data were 0.59-1.00, 0.80-1.04, 0.86-1.02, and 0.76-0.93 (Table 1.2). All the slopes of the fitted lines (individual birds' data) were significantly different from 0.00 (Appendix 1.2) and were generally not significantly different from 1.00 (21 of 24 fitted to log response ratios and 19 of 24 fitted to log time ratios).

All lines fitted to the log ratios of total responses and to the log time ratios, regardless of COD value, described the data well in terms of r^2 (the range was 0.70 to 1.00 with only 7 out of 70 cases below 0.90; Table 1.2). There was some variability about the line, which is evident in the values of Sy.x (0.04 to 0.29; Table 1.2). The standard deviations of the slopes of the fitted lines were generally small (the range was 0.02 to 0.27, with 54 of 70 cases below 0.10; Appendix 1.2). No consistent biases for responding on one or other key were apparent, across hens and COD values. Some hens did have slight (but significant) biases as shown by intercepts of the fitted lines which were different from zero (Appendix 1.2). When a bias showed in the response data it was

also there in the time data.

COD and Post-COD Responses. Figures 1.3 (a) to 1.3 (d) present, for each hen and each COD value, the log ratios of the responses made during the COD periods and the log ratios of the responses made after the COD periods on the two schedules, plotted against the log ratios of the reinforcements obtained. Lines were fitted by the method of least squares and are summarised, as above, in Table 1.3 and Appendix 1.2. The lines and their equations are given in the figures.

Figures 1.3 (a) to 1.3 (d) and Table 1.3 show that the slopes of the lines fitted to the log ratios of the responses made during the COD periods were close to 0.00, for all hens and all COD values. The slopes ranged between -0.12 and 0.03, -0.09 and 0.06, -0.21 and -0.06, and -0.03 and 0.16 with 2-, 4-, 7.5-, and 15-sec CODs respectively (Table 1.3). The slopes of the lines did not differ consistently from 0.00 except when the COD programmed was 7.5 seconds, when the slopes were all negative and generally further from 0.00 than they were at other COD values. The slopes of four of the six lines fitted to the COD responses when the COD was 7.5 seconds were significantly different from 0.00 (Appendix 1.2). At other COD values only the slopes of two lines (when the COD was 15 seconds) were significantly different from 0.00 (Appendix 1.2).

In terms of r^2, the lines fitted to the log ratios of the responses made during the COD periods generally did not fit the data well (r^2 ranged between 0.01 and 0.96; Table 1.3). However, when the slopes of the fitted lines approximate 0.00 r^2 is, probably, not an appropriate measure of the goodness of fit of the lines to the data. This will be discussed further in a later section. The standard errors of the estimates ranged between 0.01 and 0.16 (Table 1.3) and were no larger than those from the lines fitted to the log ratios of total responses or times (Table 1.2). Therefore, it may be concluded that the lines

Figures 1.3 (a) to 1.3 (d)

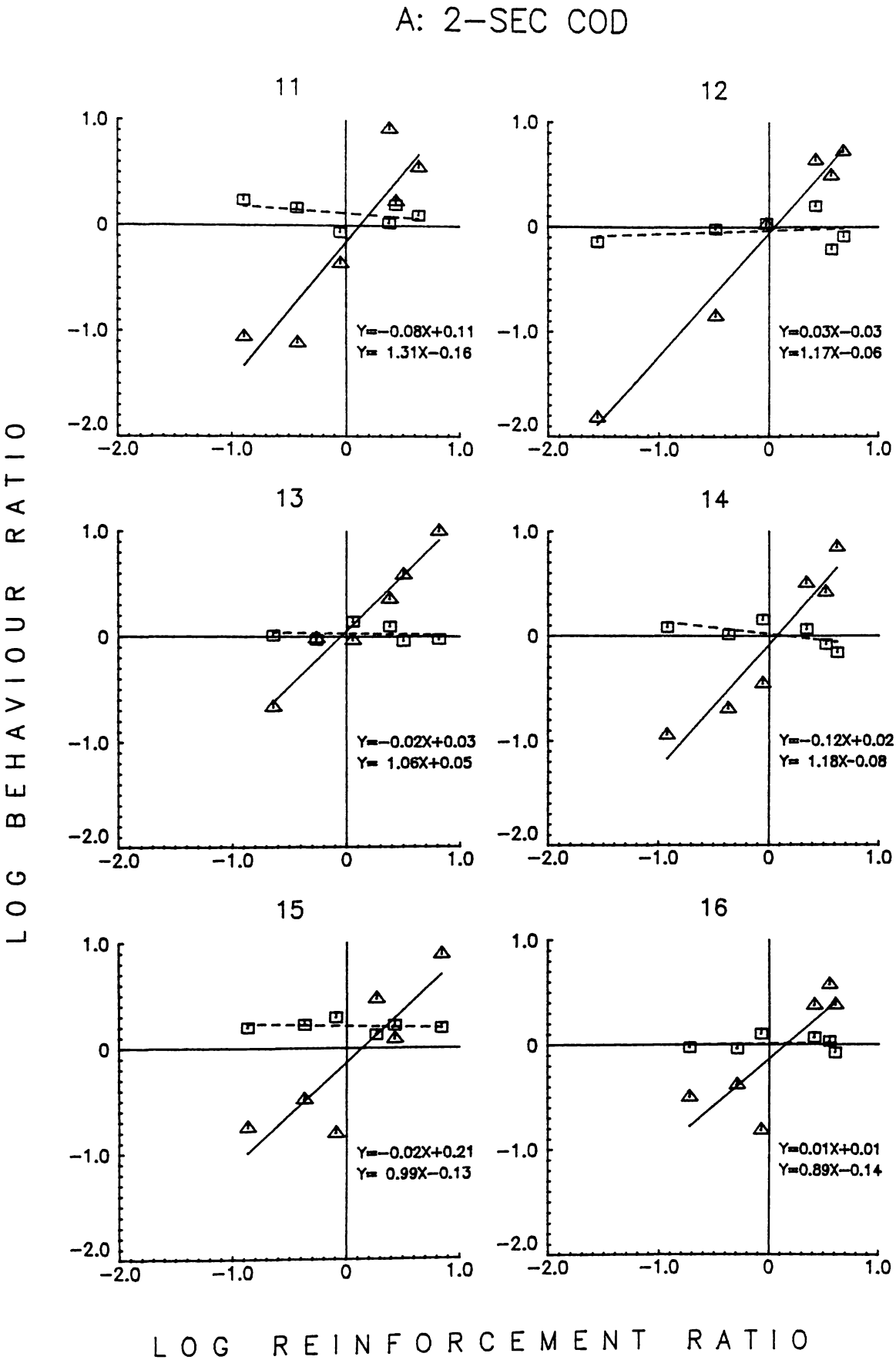
The logarithms of the ratios of the responses made during the COD (squares) and of the ratios of the responses made after the COD (triangles) plotted against the logarithms of the ratios of the obtained reinforcements, for each hen at each of the COD values programmed. The least-squares lines fitted to the log ratios of the COD responses are shown as dashed lines and are described by the upper of the two equations given for each hen's data. The least-squares lines fitted to the log ratios of the post-COD data are shown as solid lines and are described by the lower of the two equations.

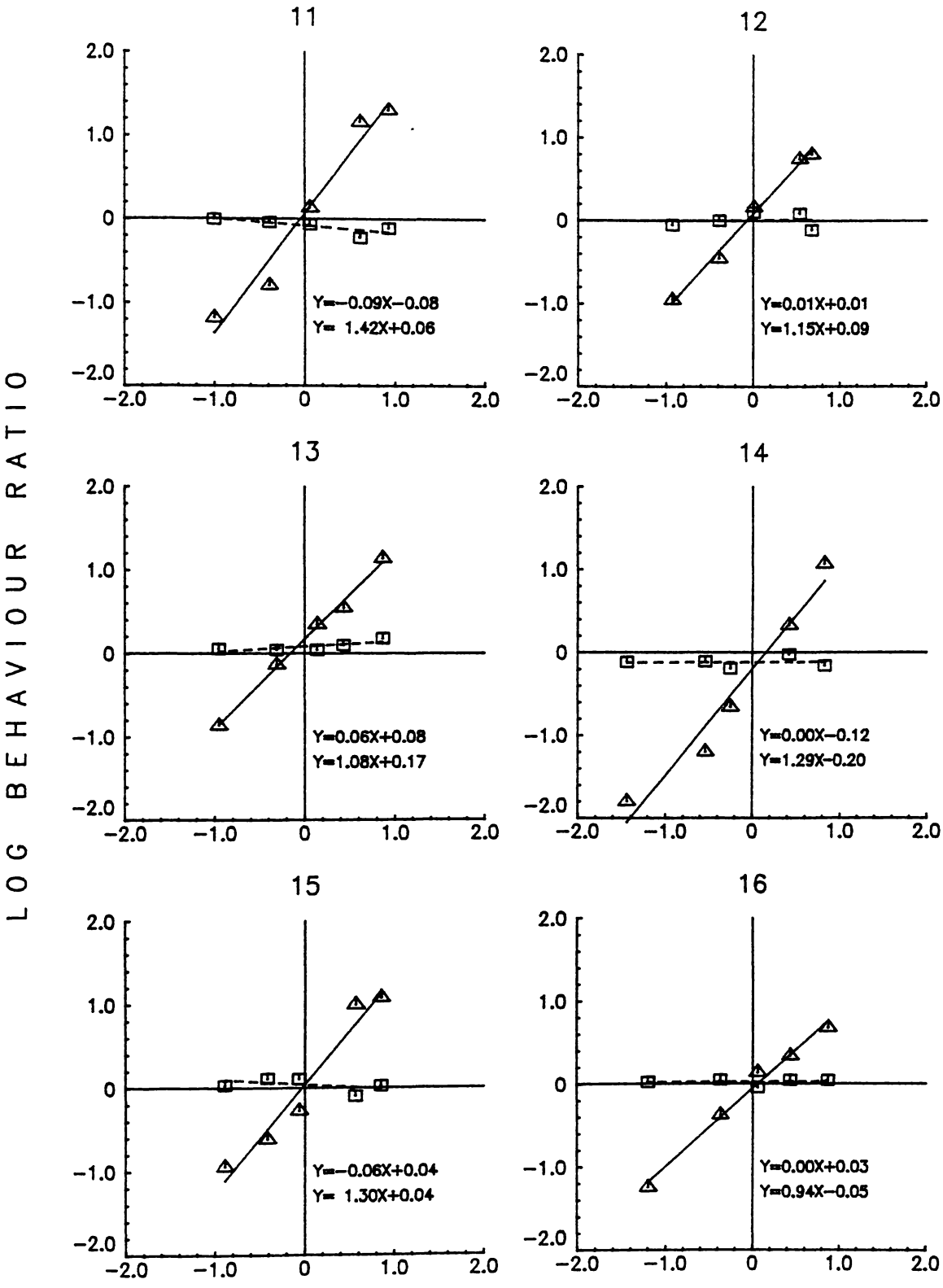
a) 2-sec COD

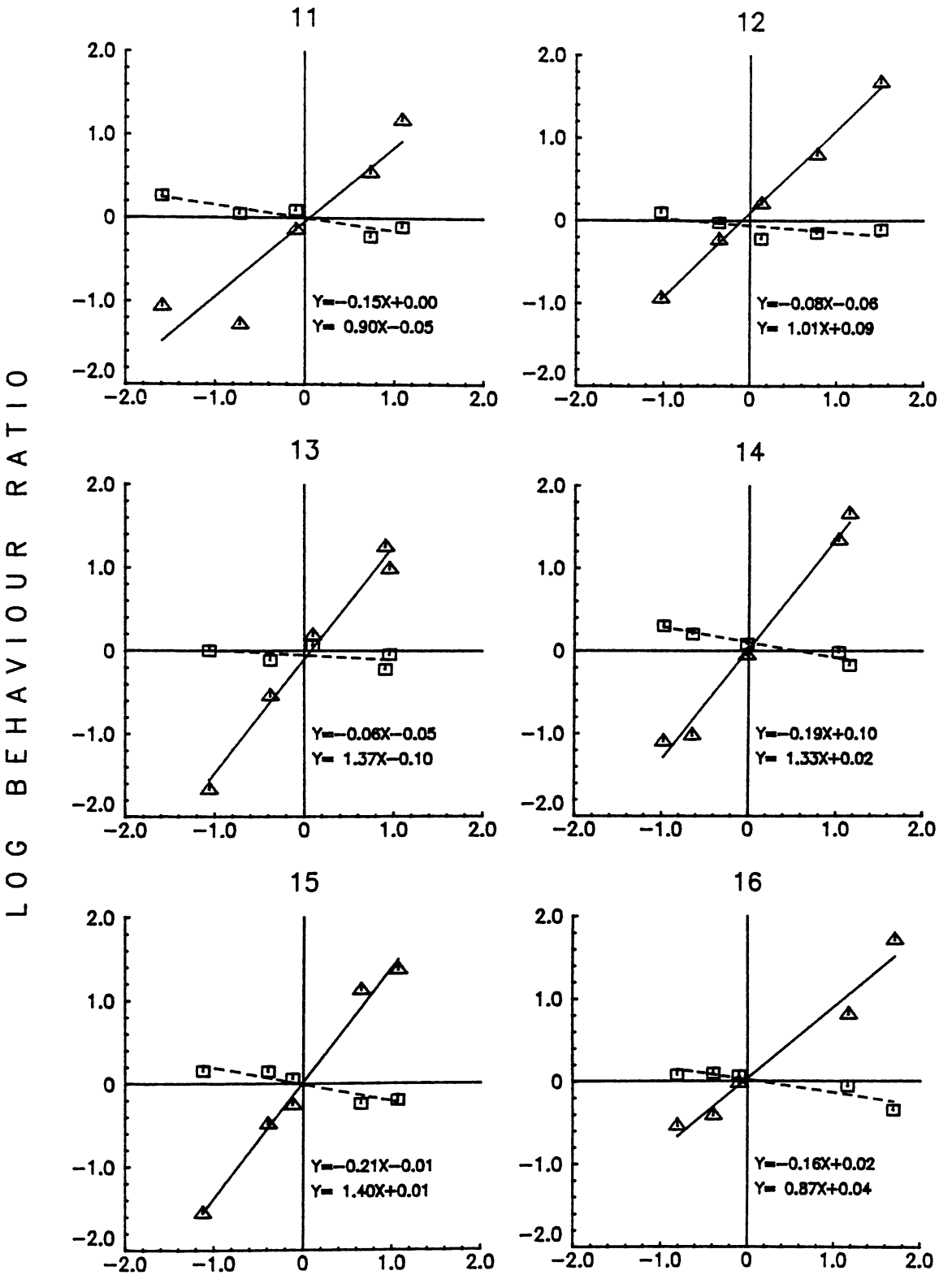
b) 4-sec COD

c) 7.5-sec COD

d) 15-sec COD


A: 2–SEC COD
11
12
13
14
15
16
Y=–0.08X+0.11
Y= 1.31X–0.16
Y=0.03X–0.03
Y=1.17X–0.06
Y=–0.02X+0.03
Y= 1.06X+0.05
Y=–0.12X+0.02
Y= 1.18X–0.08
Y=–0.02X+0.21
Y= 0.99X–0.13
Y=0.01X+0.01
Y=0.89X–0.14
1.0
0
–1.0
–2.0
–2.0
–1.0
0
1.0
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO


B: 4–SEC COD
11
12
13
14
15
16
Y=–0.09X–0.08
Y= 1.42X+0.06
Y=0.01X+0.01
Y=1.15X+0.09
Y=0.06X+0.08
Y=1.08X+0.17
Y=0.00X–0.12
Y=1.29X–0.20
Y=–0.06X+0.04
Y= 1.30X+0.04
Y=0.00X+0.03
Y=0.94X–0.05
2.0
1.0
0
–1.0
–2.0
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO


C: 7.5–SEC COD
11
12
13
14
15
16
Y=–0.15X+0.00
Y= 0.90X–0.05
Y=–0.08X–0.06
Y= 1.01X+0.09
Y=–0.06X–0.05
Y= 1.37X–0.10
Y=–0.19X+0.10
Y= 1.33X+0.02
Y=–0.21X–0.01
Y= 1.40X+0.01
Y=–0.16X+0.02
Y= 0.87X+0.04
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO

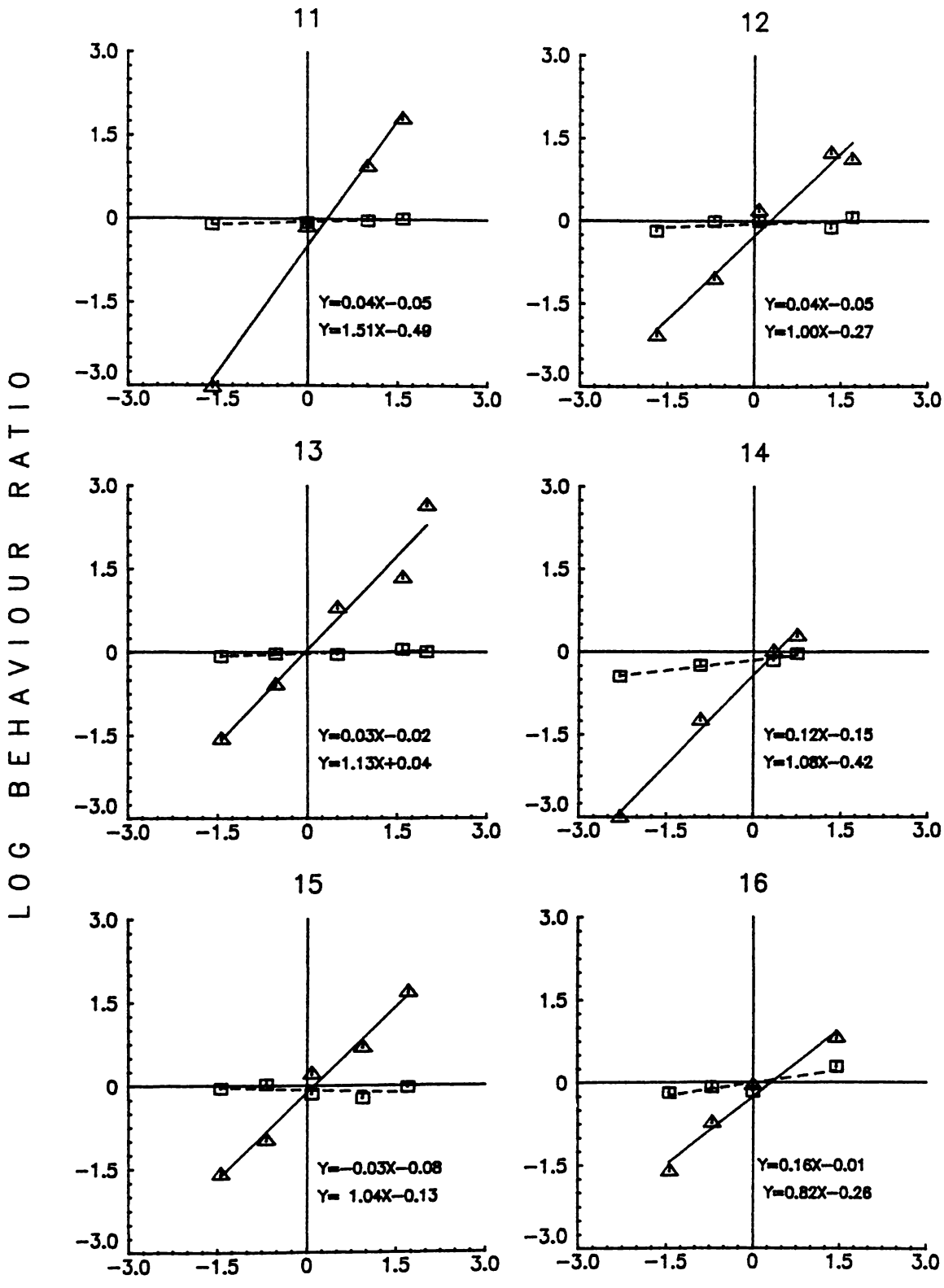

D: 15–SEC COD
11
12
13
14
15
16
Y=0.04X–0.05
Y=1.51X–0.49
Y=0.04X–0.05
Y=1.00X–0.27
Y=0.03X–0.02
Y=1.13X+0.04
Y=0.12X–0.15
Y=1.06X–0.42
Y=–0.03X–0.08
Y= 1.04X–0.13
Y=0.16X–0.01
Y=0.82X–0.26
3.0
1.5
0
–1.5
–3.0
LOG BEHAVIOUR RATIO
LOG REINFORCEMENT RATIO

Table 1.3

The slopes and the intercepts of the least-squares regression lines fitted to the log ratios of the responses made during the COD and of the responses made after the COD as a function of the log ratios of the obtained reinforcement rates, for each hen and the group (GP) at each COD value. The amounts of the y-variance accounted for by the lines (r^2) and the standard errors of the estimates (Sy.x) are given.

	2-sec COD				4-sec COD				7.5-sec COD				15-sec COD			
Hen	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x
RESPONSES DURING COD																
11	-0.08	0.11	0.15	0.12	-0.09	-0.08	0.61	0.06	-0.15	0.00	0.81	0.09	0.04	-0.05	0.95	0.01
12	0.03	-0.03	0.04	0.16	0.01	0.01	0.01	0.10	-0.08	-0.06	0.43	0.11	0.04	-0.05	0.28	0.10
13	-0.02	0.03	0.01	0.09	0.06	0.08	0.56	0.05	-0.06	-0.05	0.20	0.11	0.03	-0.02	0.75	0.03
14	-0.12	0.02	0.39	0.10	0.00	-0.12	0.00	0.07	-0.19	0.10	0.92	0.06	0.12	-0.15	0.96	0.04
15	-0.02	0.21	0.06	0.06	-0.06	0.04	0.25	0.09	-0.21	-0.01	0.84	0.09	-0.03	-0.08	0.12	0.11
16	0.01	0.01	0.01	0.08	0.00	0.03	0.01	0.04	-0.16	0.02	0.81	0.09	0.16	-0.01	0.78	0.13
GP	-0.03	0.06	0.15	0.04	-0.01	-0.01	0.40	0.01	-0.14	0.00	0.91	0.05	0.10	-0.11	0.60	0.11
RESPONSES AFTER COD																
11	1.31	-0.16	0.82	0.40	1.42	0.06	0.96	0.25	0.90	-0.05	0.87	0.44	1.51	-0.49	0.99	0.28
12	1.17	-0.06	0.98	0.17	1.15	0.09	0.99	0.08	1.01	0.09	1.00	0.06	1.00	-0.27	0.97	0.31
13	1.06	0.05	0.95	0.15	1.08	0.17	1.00	0.06	1.37	-0.10	0.98	0.19	1.13	0.04	0.96	0.37
14	1.18	-0.08	0.91	0.25	1.29	-0.20	0.96	0.27	1.33	0.02	0.99	0.17	1.08	-0.42	0.99	0.16
15	0.99	-0.13	0.76	0.38	1.30	0.04	0.96	0.22	1.40	0.01	0.99	0.16	1.04	-0.13	0.98	0.19
16	0.89	-0.14	0.68	0.36	0.94	-0.05	0.99	0.10	0.87	0.04	0.97	0.20	0.82	-0.26	0.97	0.22
GP	1.09	-0.09	0.93	0.20	1.19	0.02	0.99	0.11	1.12	0.00	0.99	0.09	1.14	-0.27	0.98	0.23

provided an adequate description of the data.

Responding during the COD was analysed separately for the first two seconds and the remainder (if appropriate) of the COD period. When no COD was programmed the first two seconds following a changeover were analysed. Table 1.4 presents the slopes and intercepts of the lines fitted to the log ratios of the responses made in the two seconds immediately following a changeover and those made in the remainder of the COD period, for all hens and the group at each COD value. The amount of the y-variance accounted for by the lines (r^2) and the standard errors of the estimates (Sy.x) are given also. The data from the 2-sec COD conditions have been presented already (responses during the COD; Table 1.3).

From Table 1.4 it can be seen that at all COD values the slopes of the lines fitted to the log ratios of the responses made in the first two seconds following a changeover were, essentially, equal to 0.00. The ranges of the slopes, from the individual hens' data, were -0.03 to 0.16, -0.12 to 0.03, -0.10 to 0.08, -0.17 to- 0.03, and -0.03 to 0.14 with no COD, 2-, 4-, 7.5-, and 15-sec CODs programmed respectively. There were no consistent biases for either key, across hens or COD values. The intercepts of the fitted lines were in the range -0.16 to 0.21.

Table 1.4 also shows that at all values of the COD the slopes of the lines fitted to the log ratios of the responses made in the remainder of the COD periods (after the first two seconds) were essentially equal to 0.00, as they were in the first two seconds. The slopes of the fitted lines ranged between -0.08 to 0.07, -0.23 to -0.04, and -0.03 to 0.16 with CODs of 4, 7.5, and 15 seconds, respectively. There were no consistent key biases, across hens or COD values. The intercepts of the lines ranged between -0.24 and 0.14.

Table 1.4

The slopes and the intercepts of the least-squares lines fitted to the log ratios of the responses made in the two seconds following a changeover and to the log ratios of the responses made in the remainder of the COD period as a function of the log ratios of the reinforcement rates, for each hen and the group (GP) at each COD value. The amounts of the y-variance accounted for by the lines (r^2) and the standard errors of the estimates (Sy.x) are given.

	No COD				4-sec COD				7.5-sec COD				15-sec COD			
Hen	slp	intcpt	r^2	Sy.x	slp	intcpt	r^2	Sy.x	slp	intcpt	r^2	Sy.x	slp	intcpt	r^2	Sy.x
2 SEC FOLLOWING A CHANGEOVER																
11	0.12	0.06	0.72	0.04	-0.09	-0.11	0.78	0.04	-0.11	0.04	0.70	0.09	0.05	-0.15	0.39	0.11
12	-0.03	0.06	0.10	0.06	-0.01	-0.03	0.01	0.09	-0.03	-0.07	0.08	0.12	-0.03	-0.09	0.28	0.07
13	0.11	-0.10	0.65	0.05	0.08	0.05	0.50	0.06	-0.09	-0.05	0.50	0.09	-0.03	-0.05	0.57	0.05
14	0.16	-0.11	0.54	0.09	-0.03	-0.05	0.21	0.06	-0.17	0.11	0.87	0.08	0.11	-0.16	0.82	0.09
15	0.08	0.11	0.73	0.03	-0.10	0.03	0.33	0.12	-0.15	0.01	0.86	0.06	-0.02	0.00	0.04	0.17
16	0.10	-0.06	0.52	0.06	0.04	0.01	0.44	0.04	-0.07	-0.01	0.78	0.05	0.14	0.02	0.71	0.14
GP	0.08	0.02	0.98	0.01	-0.04	-0.02	0.65	0.02	-0.12	0.01	0.85	0.05	-0.01	-0.08	0.15	0.05
REMAINDER OF THE COD PERIOD																
11					-0.08	-0.05	0.36	0.09	-0.17	-0.02	0.85	0.09	0.04	-0.04	0.79	0.03
12					0.06	0.08	0.10	0.14	-0.11	-0.05	0.49	0.13	0.06	-0.04	0.39	0.12
13					0.04	0.14	0.19	0.07	-0.04	-0.06	0.10	0.13	0.04	-0.02	0.79	0.04
14					0.07	-0.24	0.21	0.14	-0.19	0.10	0.94	0.06	0.13	-0.15	0.93	0.06
15					-0.01	0.05	0.04	0.05	-0.23	-0.03	0.83	0.10	-0.03	-0.10	0.10	0.12
16					-0.05	0.05	0.16	0.10	-0.22	0.03	0.75	0.16	0.16	-0.01	0.79	0.13
GP					-0.03	0.01	0.48	0.02	-0.16	0.00	0.91	0.05	0.06	-0.07	0.48	0.09

The responses made during the COD periods were subtracted from the total responses made on each schedule to give post-COD responses. Figures 1.3 (a) to 1.3 (d) and Table 1.3 show that the slopes of the lines fitted to the log ratios of the post-COD responses did not change consistently, across hens, with increasing COD. The slopes ranged between 0.89-1.31, 0.94-1.42, 0.87-1.40, and 0.82-1.51 with CODs of 2, 4, 7.5, and 15 seconds, respectively. The slopes of 18 of the 24 lines fitted to the individual hens' data were greater than 1.00. All slopes were (obviously) significantly different from 0.00 but only four (all greater than 1.00) were significantly different from 1.00 (Appendix 1.2). The slopes of the lines fitted to the group data, at all COD values, were not significantly greater than 1.00. In all cases the slopes of the lines fitted to the log ratios of the post-COD responses were greater than the slopes of the lines fitted to the log ratios of the total responses. This increase averaged 0.27 (range 0.10 to 0.53, median 0.25).

All lines fitted to the post-COD data described the data well in terms of r^2 (range 0.68 to 1.00 with only 4 of 24 cases less than 0.90; Table 1.3). However, the standard errors of the estimates (which ranged between 0.06 and 0.44; Table 1.3) were larger than those for the lines fitted to the total response data (Table 1.2). That is, there was more variability about the fitted lines in the post-COD data than in the total response data.

Changeover Responding

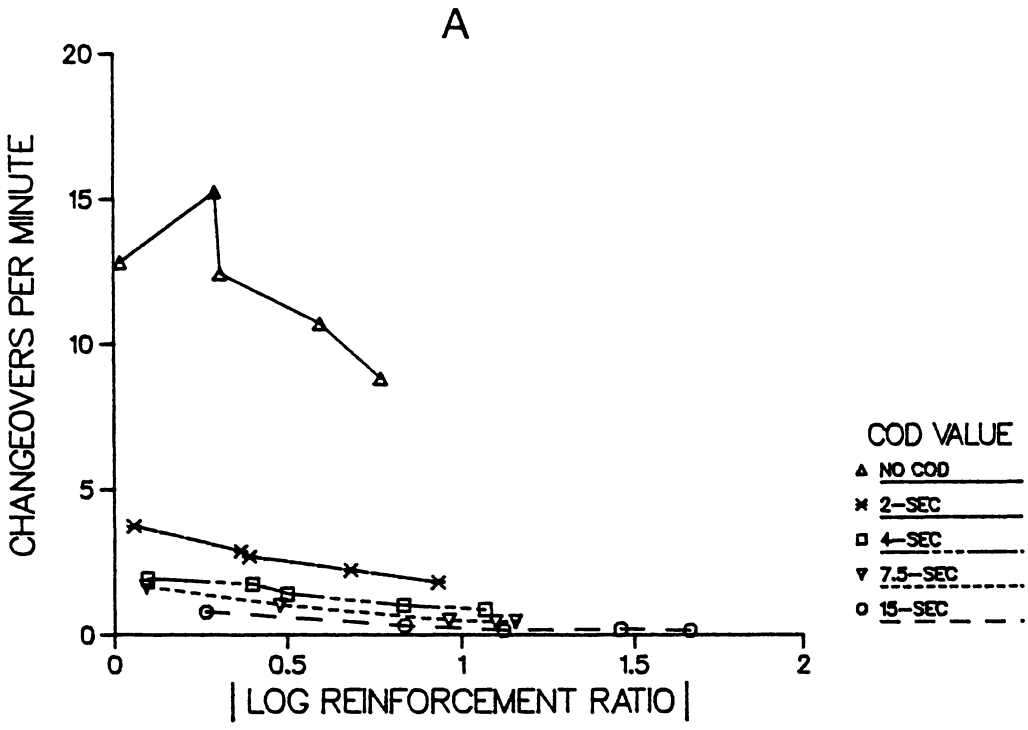
Rate of Changeover. Figure 1.4 presents, for the group, the number of changeovers made per minute plotted as a function of a) the absolute values of the log ratios of the obtained reinforcement rates and b) the COD value. In this case, and all future instances where group data and not the individual hens' data are shown, three people familiar with the experiment had inspected the data and judged the group data to be

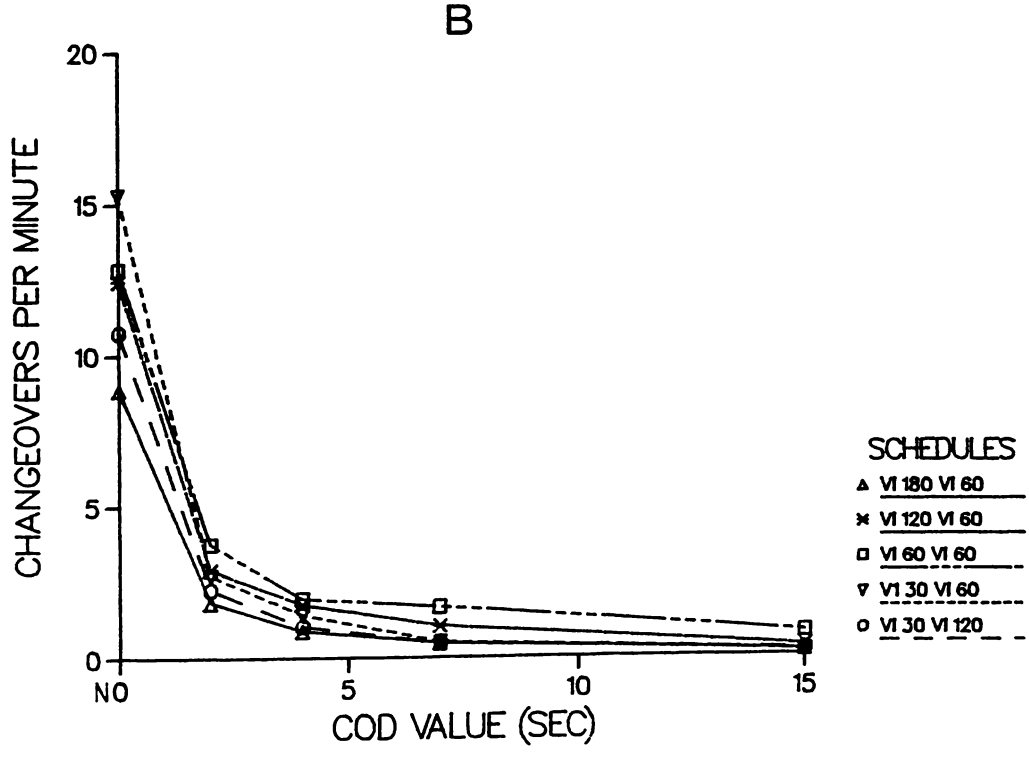
Figures 1.4 (a) and 1.4 (b)

The number of changeovers per minute plotted, for the group, against

a) the absolute value of the logarithms of the ratios of the obtained reinforcements, for each COD value and

b) the COD value, for each of the schedule pairs.


A
CHANGEOVERS PER MINUTE
20
15
10
5
0
0
0.5
1
1.5
2
| LOG REINFORCEMENT RATIO |
COD VALUE
NO COD
2-SEC
4-SEC
7.5-SEC
15-SEC


B
CHANGEOVERS PER MINUTE
20
15
10
5
0
NO
5
10
15
COD VALUE (SEC)
SCHEDULES
VI 180 VI 60
VI 120 VI 60
VI 60 VI 60
VI 30 VI 60
VI 30 VI 120

similar to, and representative of, the individual data.

Figure 1.4 shows that the rate of changeovers decreased as a) the COD value increased, and b) the absolute value of the log ratio of the reinforcement rates increased. The largest decrease in the changeover rates was between conditions where no COD was programmed and conditions where a COD was programmed (Figure 1.4 (a)). For example, on VI 60-sec VI 60-sec schedules the number of changeovers per minute decreased, for the group, from 13/min when no COD was programmed to 4/min when a 2-sec COD was programmed and 1/min when a 15-sec COD was programmed.

Responding during the COD. Local rates of responding during and after the COD were examined but, because the time spent in the COD periods was not recorded, it was not possible to calculate them accurately. The estimates of the times spent in COD and post COD were based on the number of changeovers made to a schedule (multiplied by the COD length). However at the larger COD values (7.5 and 15 seconds) this was quite inaccurate because very few changeovers were made and the proportion of CODs which were not completed before the animal changed to the other schedule was often large (observation based on the event records). Therefore the estimated response rates are not presented, other than to note that the more reliable data from the shorter COD conditions suggested that responding during the COD occurred at a higher rate than did responding after the COD and that this difference was most marked at the shortest COD durations. Instead, the proportion of total responses on a schedule made during the COD are presented.

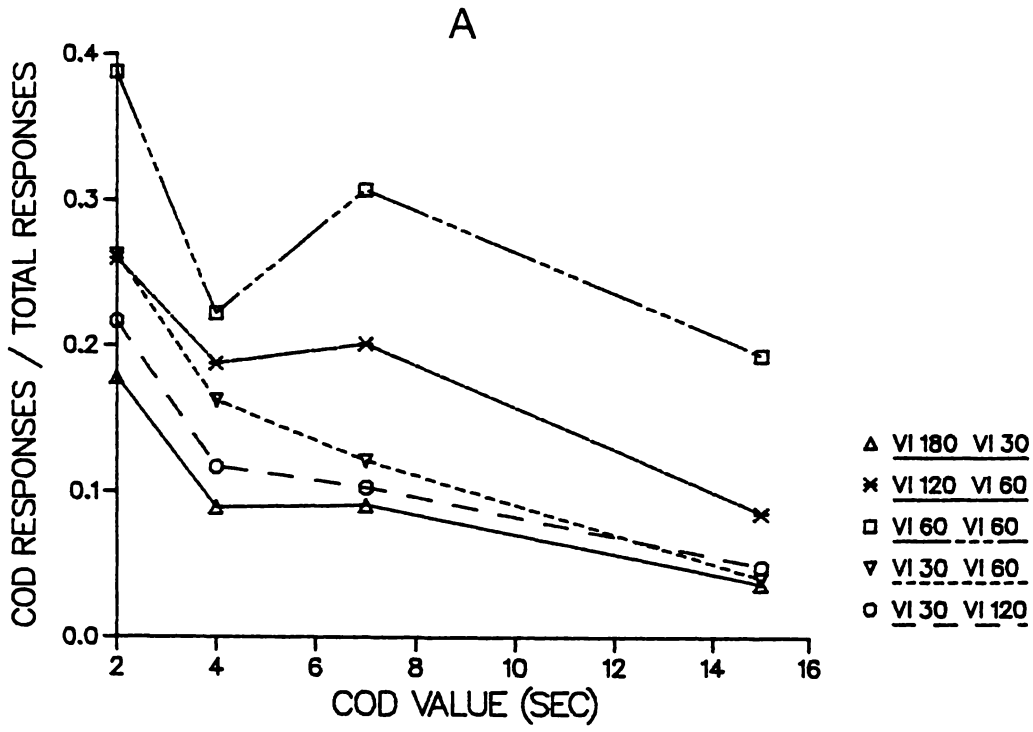
Figure 1.5 presents the proportion of total responses which were made during the COD (regardless of schedule), for the group. This proportion is shown plotted against a) the COD value, and b) the absolute value of the log reinforcement ratio. On each schedule pair there was a tendency for the proportion of responses made in the COD to be highest when the COD was 2 seconds (0.18 to 0.39) and lowest when the

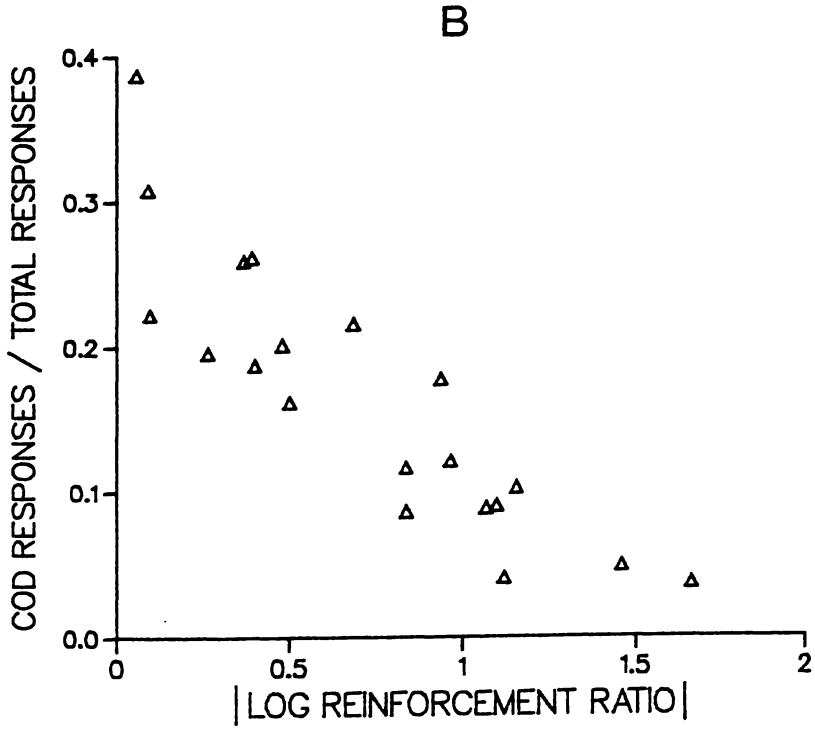
Figures 1.5 (a) and 1.5 (b)

The proportion of the total responses made on either schedule which were made during the COD plotted, for the group, against

a) COD value, for each pair of schedules, and

b) the absolute values of the logarithms of the ratios of the obtained reinforcements.


A
COD RESPONSES / TOTAL RESPONSES
0.4
0.3
0.2
0.1
0.0
2
4
6
8
10
12
14
16
COD VALUE (SEC)
VI 180 VI 30
VI 120 VI 60
VI 60 VI 60
VI 30 VI 60
VI 30 VI 120


B
COD RESPONSES / TOTAL RESPONSES
0.4
0.3
0.2
0.1
0.0
0
0.5
1
1.5
2
|LOG REINFORCEMENT RATIO|

COD was 15 seconds (0.04 to 0.20). There was also a tendency for this proportion to be less when the schedules were more disparate (i.e., at higher absolute values of the log reinforcement ratio).

Reinforcement following a Changeover. Figure 1.6 presents, for the group, the proportion of changeovers to each schedule which were followed by reinforcement within either two seconds of the end of the COD period or, when no COD was programmed, within two seconds of a changeover plotted against COD value. These data were not collected for four of the schedule pairs when a two second COD was programmed. Therefore only one of the plots (VI 30-sec VI 60-sec) has five pairs of data points shown.

Figure 1.6 shows that for all pairs of schedules (and both schedules of the pair) the proportion of changeovers (to either schedule) followed by reinforcement within this two second period was greater when any COD was programmed than when no COD was in effect. With no COD programmed the proportions ranged between 0.03 and 0.09 (for the group). When any COD was programmed the proportions ranged between 0.14 and 0.35, there being a slight tendency for these to increase with COD value (Figure 1.6). There was no (apparent) systematic difference between the leaner and richer schedules of any pair, in terms of the proportions of changeovers (to the schedule) which were followed closely by reinforcement.

Figure 1.7 presents the proportion of the reinforcements obtained on each schedule which were delivered within two seconds of either the end of the COD or, when no COD was programmed, of a changeover. These data were not collected when the COD was two seconds. The group data are shown, plotted against the log ratios of the reinforcements obtained, for each COD value. On equal schedules the proportions of reinforcements which followed a changeover closely were approximately equal on the two schedules. There was a tendency for these proportions to decrease as the

Figure 1.6

The proportions of changeovers to each key followed closely (within two seconds of the end of the COD or, when no COD was programmed, within two seconds of a changeover) by reinforcement plotted, for the group, against COD value. The proportions of such changeovers to the left key are shown by triangles and a solid line joining the data points. Those to the right key are shown by squares and a dashed line. The data from each pair of schedules are given.

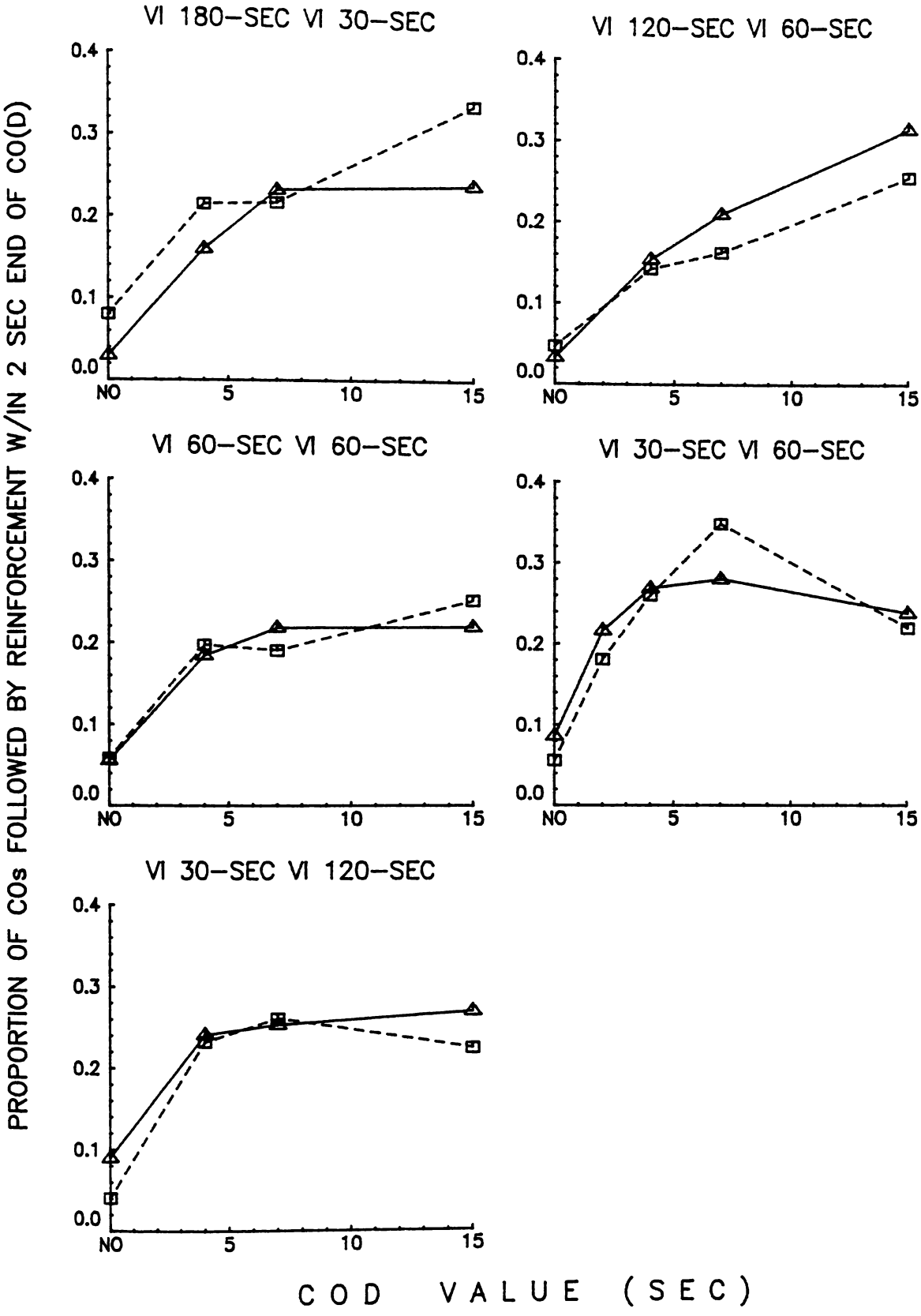
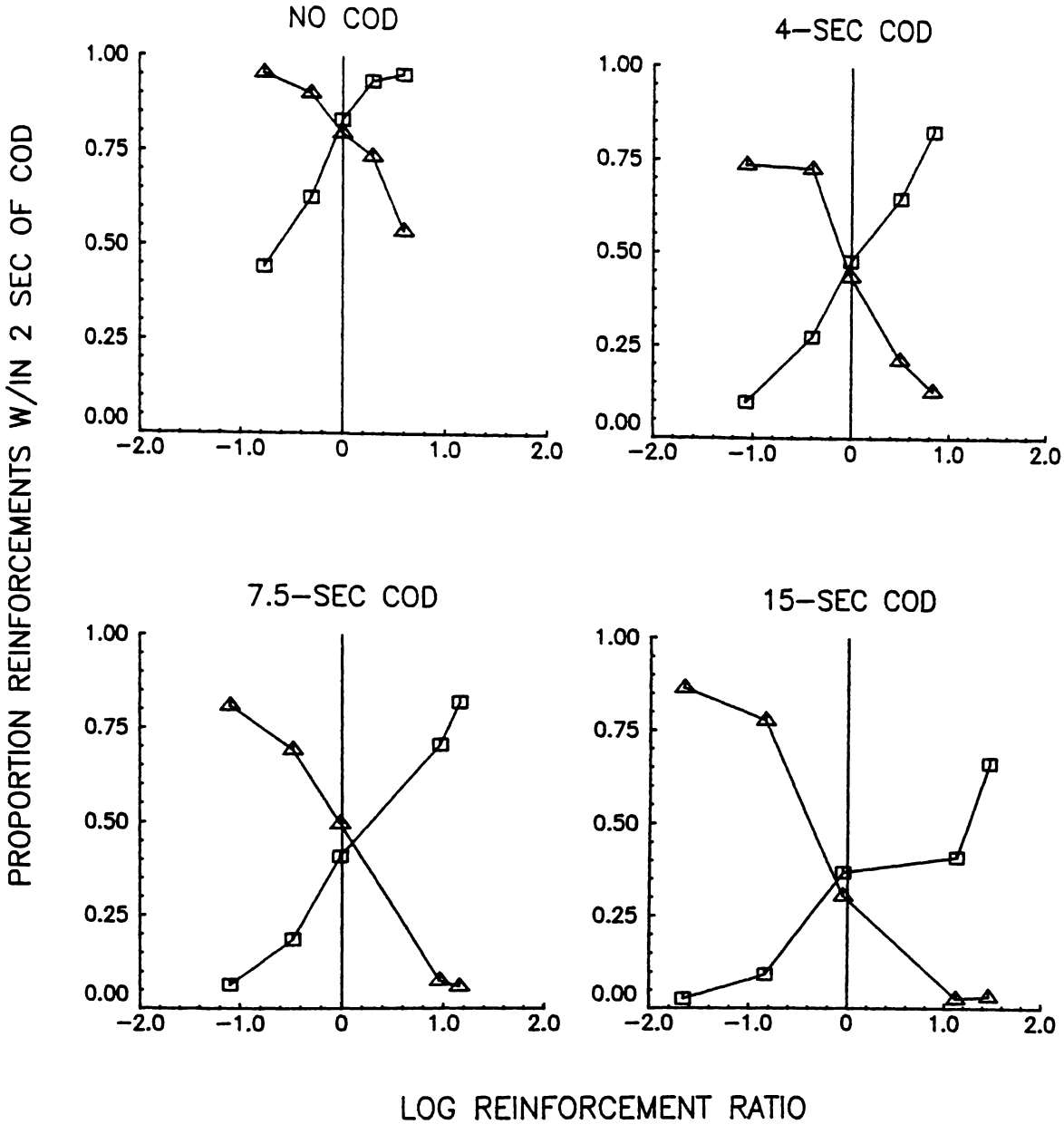

VI 180–SEC VI 30–SEC
VI 120–SEC VI 60–SEC
VI 60–SEC VI 60–SEC
VI 30–SEC VI 60–SEC
VI 30–SEC VI 120–SEC
0.4
0.3
0.2
0.1
0.0
NO
5
10
15
PROPORTION OF COs FOLLOWED BY REINFORCEMENT W/IN 2 SEC END OF CO(D)
COD VALUE (SEC)

Figure 1.7

The proportions of reinforcements obtained on each key within two seconds of either the end of the COD or, when no COD was programmed, of a changeover plotted, for the group at four of the COD values, against the logarithms of the ratios of obtained reinforcements. The proportions obtained on the left key are given as triangles and those obtained on the right key are given as squares. These data were not collected when the COD was 2-sec.


NO COD
4–SEC COD
7.5–SEC COD
15–SEC COD
PROPORTION REINFORCEMENTS W/IN 2 SEC OF COD
LOG REINFORCEMENT RATIO
1.00
0.75
0.50
0.25
0.00
−2.0
−1.0
0
1.0
2.0

COD was increased. The proportions, for the group, were 0.80 and 0.83, 0.44 and 0.48, 0.41 and 0.50, and 0.30 and 0.37 with no COD, 4-, 7.5-, and 15-sec CODs, respectively. On unequal schedules the proportions of reinforcements delivered within two seconds of the end of the COD (or a changeover) were greater on the leaner of the two schedules. The proportions from the two schedules were further apart the further the log ratios of the reinforcement rates were from 0.00.

Discussion

In the present experiment responding (and reinforcement) during a session was sometimes exclusive to one schedule, particularly at the longer COD values. Such data cannot be expressed as log ratios. Unless behaviour was exclusive on all five days at the end of a condition this problem is circumvented by summing the data over the five days. However this means that no measure of the variability in the data (recommended by Zeiler, 1977) is possible as would be the case were the mean (and the standard deviation) of the daily log ratios calculated. This latter is equivalent to taking the geometric mean of the daily ratios and expressing this in logarithmic terms. However, Baum (1979) reported that averaging his data in various ways has never produced substantially different results. Unless variation across sessions is highly asymmetrical all measures of central tendency will be about the same. Therefore, the lines fitted by the method of least squares (which implicitly averages) to the data from individual sessions are unlikely to differ (by much) from those fitted to data summed over several sessions. The question is really one of what to do with exclusive data. They can be either eliminated from the analysis or allowed to weight the response measure. It is the present author's view that such data should be included in the present study where manipulations of the COD value might be expected to produce near exclusive responding. Hence the data from this experiment (and those from Experiments 2 and 3) were summed over the last five days of a condition.

Sensitivity to Reinforcement

Total Responses and Times. The first major finding from the present experiment was that the only consistent changes in the slopes of the lines fitted to the log (total) response ratios and log time ratios, as functions of the log reinforcement ratios, were between conditions where

no COD was programmed and conditions where any COD was programmed (Table 1.2; Figures 1.1 (a-e) and 1.2). The slopes of the lines fitted to the data obtained with no COD were generally lower than those fitted to data obtained when any COD was programmed. Thus it would seem that the presence of a COD rather than COD length (within the range investigated) had an effect on the degree of matching observed.

Regardless of whether a COD was programmed the slopes of the lines fitted to both the log response ratios and to the log time ratios were, generally, below 1.00 (those based on the group data were all below 1.00). This finding is in line with the results from the majority of studies employing conc VI VI schedules (Wearden & Burgess, 1982). There was no tendency overall for the slopes of the lines fitted to the log response ratios to differ consistently from the slopes of the lines fitted to the log time ratios (Figure 1.2). In contrast, Taylor and Davison's (1983) analysis suggested that with conc VI VI schedules arranged using an arithmetic progression, as was the case here, the slopes of the lines fitted to the time data might have been expected generally to exceed the slopes of those fitted to the response data. However they also report finding large variation in the sensitivities of times and responses so the present data cannot be considered exceptional. For example, Hunter and Davison (1978) and Pliskoff and Brown (1976), both cited in Taylor and Davison (1983), found that the slopes of the lines fitted to the log response ratios exceeded the slopes of the lines fitted to the log time ratios, for approximately half their subjects.

It is unclear whether the present data should be regarded as undermatching. The term "undermatching" is often used to describe data in a way that implies the slopes of the fitted lines would equal 1.00 if all other irrelevant variables were controlled (Baum, 1979). For example, Baum (1974b, 1979) and de Villiers (1977) have suggested that

one variable that may contribute to such undermatching is the (inadequate) size of the COD. However, the current experiment found no tendency for the slopes of the fitted lines to get closer to 1.00 (matching) at larger COD values, once a COD was programmed. This is in spite of the fact that the durations of the CODs were increased beyond those durations usually programmed in studies of conc VI VI schedule performance (de Villiers, 1977). Setting confidence intervals of ± 2 SD the slopes of the lines based on the group data were, for the response data, 0.55-0.71, 0.63-0.95, 0.88-1.00, 0.77-0.89, and 0.78-1.10 with no COD, 2-, 4-, 7.5-, and 15-sec CODs, respectively. The corresponding ranges for the slopes of the lines fitted to the time data, from the group, were 0.57-0.73, 0.72-0.92, 0.86-1.00, 0.88-1.00, and 0.75-1.23. These slopes appear to be generally less than 1.00. Taking these data along with those previously summarised by the reviewers (e.g., Wearden & Burgess, 1982) it appears that values of a less than 1.00 may be a feature of the usual procedures for studying conc VI VI schedule performance, regardless of COD value.

One feature that is possibly worth noting is that the goodness of fit of the lines, as measured by r^2, tended to improve with increased COD. In this sense the increased COD makes the generalised matching law a better description of the data (although a is not, of course, constant). However the goodness of fit as measured by Sy.x did not change consistently with increased COD. The increase in r^2 therefore was (probably) mainly a function of the increased range in both the x and y variables.

In contrast to the present findings procedures employing a changeover-ratio requirement or a relatively large spatial separation of the manipulanda appear to produce fitted lines with slopes both less than 1.00 (as found with COD procedures) and greater than 1.00, depending upon the size of the changeover requirement (e.g., Baum, 1982;

Pliskoff & Fetterman, 1981). This will be discussed in more detail later.

In the present experiment, with no COD programmed, the slopes of the lines fitted to both the log response ratios and the log time ratios were, for four of the six hens and for the group, less than the 0.70 value which de Villiers (1977) used as the cut-off point to distinguish those data which deviated markedly from matching. Nevertheless, the slopes of the fitted lines (0.31 to 0.89) were all significantly greater than 0.00 (Appendix 1.2). It would be wrong to conclude that behaviour, in the present study, was insensitive to changes in the ratios of the reinforcement rates when no COD was programmed. However, it was less sensitive under these conditions than when any COD was programmed. So although all COD values produced undermatching to some degree the use of no COD produced more. It is possible that systematic changes in the degree of matching might have been found with COD values in the range zero to two seconds but this was not investigated. Certainly a COD of, say, 0.01 sec would be expected to produce results more similar to those from the no COD conditions than those from the 2-sec COD conditions. The data found suggest that the generalised matching law provides a useful description of conc VI VI schedule performance, and that results should not be categorised as either matching or not matching. Any attempt to categorise results in this way raises the problem of where the cut-off point should lie. This has meant, for example, that different experimenters have reported both matching and lack of matching when no COD was programmed (cf. Herrnstein, 1961; Heyman, 1979).

It has been suggested that when conc VI VI schedules are programmed with no COD animals will simply alternate between the schedules and their responding will be insensitive to the ratios of the reinforcement rates (de Villiers, 1977; Herrnstein, 1961). In the present experiment the rates of changeover were certainly highest in those conditions where

no COD was programmed. However, even at these high changeover rates the hens spent around four to seven seconds on each schedule (group data). This would not easily be described as simple alternation. Possibly the difference between this study and those which have reported alternation (e.g., Herrnstein, 1961) lie in the patterns of responding established in the conditions preceding the no COD conditions. In the present study the no-COD conditions followed (extensive) exposure to other COD values (either 2 seconds or 2 and 7.5 seconds).

Responding during the COD. The second major finding of this experiment was that responding during the COD periods was insensitive to changes in the ratios of the reinforcement rates. The slopes of the lines fitted to the log ratios of responses made during the COD periods, as a function of the log reinforcement ratios, were close to 0.00 at all COD values (Table 1.3; Figures 1.3 (a-d)). Including the responses made during the COD, therefore, has the effect of adding a constant to both sides of the ratio which will, necessarily, reduce the absolute value of the ratio and presumably may contribute to the undermatching found.

It is not clear quite what to do with such insensitive responding. Although it is usual practice to include these as responses made on the schedules there may be arguments for excluding them from measures of preference. As mentioned previously procedures using devices other than a COD to separate the schedules (e.g., a changeover ratio, time-out, or spatial separation of the keys) have usually not included the responses or the time required to change over in the measures of behaviour on the schedules (e.g., Baum, 1982; Pliskoff & Fetterman, 1981; Todorov, 1971). These different methods for treating the data generated make comparisons between studies employing the different procedures more difficult. So far there have been no clear justifications of either treatment.

The practice of excluding changeover-ratio responses has had some face validity because the changeover responses have been able to be seen as distinct from those on the schedules, either because they were physically distinct or involved a separate manipulandum or both. However, in order to be totally analogous to "ordinary" concurrent schedule performance perhaps these changeover responses should be added to the post-changeover responses made on the schedules. It would be expected that this would lead to a reduction in the amount of overmatching found. Therefore results like those normally found on conc VI VI schedules might have been expected if the responses made on the changeover ratio (COR) were added in to the schedule responses.

Taylor and Davison (1983) have done this exercise, using data from a study by Pliskoff, Cicerone, and Nelson (1978). They found that the slopes of the lines fitted to the adjusted data ranged between 0.58 and 0.98, which compared with the slopes of 1.16 to 1.96 reported by Pliskoff, Cicerone, and Nelson (1978) which were based on the post-COR responses.

In contrast to the above suggestion, it might just as easily be argued that responding during the COD is distinct from responding at other times in that it is insensitive to the relative reinforcement rates on the schedules and that, therefore, it should be seen as part of the changeover and excluded from the measures of schedule performance. However it would seem that the closeness to perfect matching, rather than any other consideration, has determined how COD responses (or times) have been treated. For example, Baum and Rachlin (1969) excluded the COD period (signalled) from the measures of the times spent on each schedule. When the COD periods were added into the time measures the average slope of the fitted lines fell from approximately 1.00 to 0.42. In contrast Silberberg and Fantino (1970) concluded that both those responses made during the COD and those made after the COD were

necessary for matching.

It is questionable whether "matching" should be the criterion used to decide which data either are or are not included in the measures of behaviour used to assess whether "matching" has occurred. Depending upon the starting point adding approximately equal numbers of responses (or equal times) to those made on each schedule will (by reducing the slope of the fitted line) produce either a shift towards closer matching (less overmatching) or a shift towards greater undermatching (away from matching).

In the present study the log ratios of the responses made within the first two seconds following a changeover were insensitive to the log reinforcement ratios (Table 1.4), as were the log ratios of the COD responses. This insensitivity during the first two seconds after a changeover was found at all COD values, including no COD. If it was the changeover itself and not the COD which altered behaviour then responding later in the COD periods would not be expected to be (so) insensitive to changes in the log reinforcement ratios. However, although there may have been a very slight increase, sensitivity in the remainder of the COD period (after the first two seconds) was still close to 0.00 (Table 1.4). Although the units of time over which responses were recorded were fairly gross (the first two seconds following a changeover and the remainder of the COD period) there is no reason to suspect that responding was any more sensitive near the end of the longer COD periods. As the percentage of the COD period remaining after the first two seconds increased (to 50%, 73%, and 87% with COD values of 4, 7.5, and 15 seconds) responding in these increasingly long periods remained equally insensitive to the changes in the ratios of the reinforcement rates. This suggests that one effect of the COD was to extend the period of insensitivity following a changeover. It is impossible to make more accurate statements about the changes in the

sensitivity of responding as the time from the changeover increased without a record of the responses made within smaller time periods. However Baum's (1979) suggestion that undermatching occurred when the CODs programmed were shorter than the constant-length periods of uninterrupted responding (bouts) which typically follow a changeover cannot account for these data.

The proportions of total responses made during the COD were greatest when the CODs were small and the rates of changeover high (Figure 1.5). The insensitive COD responding has, therefore, a disproportionately large effect on the response ratios at smaller COD values (cf. de Villiers, 1977). The insensitive responding following a changeover when no COD was programmed will, similarly, have a large influence on the total response ratios. This may, partly, explain why the slopes of the lines fitted to the log response ratios (as a function of the log reinforcement ratios) are lower, typically, when either no COD or very small (close to 0.00 seconds) CODs are programmed.

The number of changeovers per minute was found to be a function of both COD length and the absolute value of the reinforcement rate ratio. As these increased the rate of changing over between the schedules decreased (Figure 1.4). This finding agrees with those of earlier studies summarised by Stubbs, Pliskoff, and Reid (1977).

Although behaviour in the two seconds immediately following a changeover was insensitive to changes in the ratios of the reinforcement rates the effect was limited to this short period unless a COD was programmed. With no COD any differential responding must, necessarily, have occurred in the next two to five seconds (from the group data) that the hens stayed on the schedules before changing over.

The fits of the lines to the log ratios of the responses made either during the COD (Table 1.3) or in the first two seconds following a changeover (Table 1.4), as measured by r^2, were variable. The fitted

lines often accounted for little more of the y-variance than did the mean y-values (r^2 ranged between 0.00 and 0.96 for the lines fitted to the individual hens' data). However, when the slope of the fitted line is approximately 0.00 r^2 is probably not an appropriate measure of the degree of fit of the line to the data. The value of r^2 is an estimate of the increased predictive power of the line compared with the mean y-value (i.e. the reduction in the variation of the y-values around the line compared with around the mean y-value). Its size is related to the slope of the line and the x- and y-variances. The closer the slope is to 0.00 the smaller the y-variance must be, in relation to the x-variance, if r^2 is to be large. For a particular relation between the two variances r^2 and the slope of the line will covary. Therefore, if the slope of the line is close to 0.00 the mean value of y becomes virtually as good a predictor of y as the line (Lindeman, Merenda and Gold, 1980). In this case the standard error of the estimate (Sy.x) provides, perhaps, more information about the fit of the line to the data. It is a measure of the size of the differences between the observed y-values and those predicted from the line, taken over all x-values (Lindeman, Merenda and Gold, 1980). The values of Sy.x were in the range 0.01 to 0.17 (Tables 1.3 and 1.4). Comparing these values with those obtained for the lines fitted to total responses and to times (0.04 to 0.29; Table 1.2) suggests that the data were generally well described by the lines and supports the conclusion of insensitivity of COD responding (and responding in the first two seconds following a changeover) to changes in the ratios of the reinforcement rates.

It appears, therefore, that any changes in the ratios of the total responses which occur with changes in the ratios of the obtained reinforcements must be due, mainly, to responding which occurs after either the COD or, when no COD is programmed, after the period immediately following the changeover.

Responding after the COD. The third major finding of this experiment was that the ratios of responses made after the COD were, always, more sensitive to the changes in the reinforcement rate ratios than were the ratios of total responses. This follows logically from the finding of insensitive responding during the COD. There was no tendency, across hens, for the slopes of the lines fitted to the log ratios of the post-COD responses to increase with increasing COD value. At all COD values the log ratios of the post-COD responses tended to "overmatch" the log ratios of the reinforcements obtained. Although the slopes of the fitted lines were generally not significantly greater than 1.00 such tests may not be appropriate for deciding whether over- (or under-) matching has occurred (Mullins, Agunwamba, & Donohoe, 1982). Setting confidence intervals (± 2 SD) for the values of these slopes for the group suggests the slopes found lie within the ranges 0.79-1.39 (2-sec COD), 1.05-1.31 (4-sec COD), 1.02-1.22 (7.5-sec COD), and 0.94-1.34 (15-sec COD). Whereas the slopes of the lines fitted to the total response data tend to be less than 1.00 the slopes of the lines fitted to post-COD responses tend to be greater than 1.00. Either result presents a problem for the simple matching law. It is the view of the present author that neither finding (or behaviour measure) can be taken as more valid than the other at present. In order to understand the effects of the various methods of separating the schedules all responding and time spent should be recorded in ways that enable local differences to show.

Probability of Reinforcement

Catania (1966), Dreyfus, Dorman, Fetterman, and Stubbs (1982), Shull and Pliskoff (1971), and Silberberg and Fantino (1970) have noted that, on conc VI VI schedules, the probability of reinforcement on a schedule increases as a function of the time spent on the other schedule. There is, therefore, a higher momentary probability of

reinforcement immediately following a changeover (and completing the COD). This increased probability has been suggested as a possible explanation for the higher than average rates of responding which are found either immediately following the changeover or during and immediately after the COD (Bourland & Miller, 1978; Baum, 1974b; Killeen, 1972; Menlove, 1975; Pliskoff, 1971). The implication (Silberberg & Fantino, 1970) has been that this increased rate of responding, produced by the higher momentary probability of reinforcement, is (at least part of) the explanation for the reported insensitivity of responding during the COD. This suggestion contains two distinct parts. First, that the response burst can explain the insensitivity of COD responding to the relative reinforcement rates and, second, that the response burst is a product of the momentarily higher probability of reinforcement following the COD.

Accurate estimates of local response rates were not available in the present experiment. However, there was the suggestion that the local rates of responding in the COD (the burst) and post COD became more similar at longer CODs. This is similar to Silberberg and Fantino's (1970) findings (reported by Dreyfus, Dorman, Fetterman, and Stubbs, 1982) and to those of Pliskoff (1971). This suggests that pronounced response bursts during the COD periods may not be necessary to produce the insensitivity of COD responding to the relative reinforcement rates. However accurate estimates of local response rates are needed before this can be concluded with any certainty.

Despite the above suggestion "bursting" does occur to some degree at all COD values and has been attributed to the higher momentary probability of reinforcement. This latter suggestion raises problems in assessing the probability of reinforcement at the end of a COD. There are probably at least two related, but different, overall measures, both of which vary with (among other things) the interchangeover times on the

schedules. The first of these (Menlove, 1975) is the proportion of changeovers which are closely followed by a reinforcer (upon completion of the COD). This measure is likely to be inversely related to changeover rate and directly related to COD length. It is to be expected (Menlove, 1975) to be reactive to the animal's behaviour. The second overall measure of reinforcement probability is the proportion of all reinforcements obtained on a schedule which closely follow a COD completion. This measure has been suggested by Dreyfus, Dorman, Fetterman, and Stubbs (1982) and might be expected also to be reactive to the animal's behaviour. It is likely to be high on the leaner of two schedules and also to be higher when CODs are short (and changeover rates are high), in contrast to the first measure. It is not clear which (if either) of these two measures would give more useful understanding or prediction(s). It must be noted that neither measure represents a true moment-by-moment analysis of reinforcement probability over session time.

The proportion of changeovers to a schedule followed closely by reinforcement (within two seconds of COD completion) was, as expected, highest at high COD values and lowest when no COD was programmed, and was not greatly affected by the relative reinforcement rates (Figure 1.6). For any schedule pair the proportions of "reinforced" changeovers to either schedule was approximately equal.

The proportion of all reinforcements delivered on either schedule within two seconds of COD completion was an orderly function of the reinforcement rate ratio (Figure 1.7). It was, as expected, higher on the leaner of two schedules (within the range 0.41-0.96, as compared to 0.03-0.27) at all COD values. Once a COD was programmed this proportion did not change markedly with COD value but was, as expected, generally higher (at all reinforcement rate ratios) when no COD was programmed.

Both measures appear to have changed as might have been expected. The first was sensitive to COD length and less sensitive to relative reinforcement rate. The second was sensitive to relative reinforcement rate and, except for the difference between no COD and COD conditions, was relatively insensitive to COD value. To be useful one or the other of these two measures must predict some feature of the response bursting or insensitivity of COD responding to the relative reinforcement rates found. Unfortunately accurate measures of local COD and post-COD response rates were not obtained in this experiment. However it appears that the insensitivity of COD responding, which might function as a measure (or a by-product) of response bursting (but note above), did not vary systematically with either COD length or relative reinforcement rate and, therefore,did not vary with either proposed measure. Overall sensitivity to reinforcement (for both log time ratios and log total response ratios) did, however, show a similar pattern of change between no COD and COD conditions to that shown by the two measures. It is not clear that either measure could necessarily be used predictively.

Conclusion

The overall finding of undermatching, for both the response and time data, agrees with the findings of the majority of studies employing conc VI VI schedules. The finding that no COD produced greater undermatching than occurred when any COD was programmed is in line with the suggestion from the literature that some minimum COD may be necessary for matching (Baum, 1979; de Villiers, 1977). Against this suggestion is the finding that increased COD duration did not lead to closer approximations to matching.

It appears to the present author that no adequate explanation of conc VI VI schedule performance presently exists. Many possible explanations have been suggested but most have not been systematically tested. A burgeoning number of different procedures (producing data that

are not always comparable across studies) are adding to the confusion. Some filling of the holes that exist in our understanding of the concurrent schedule data and the procedures used to obtain these data seems necessary.

The usual concurrent schedule procedure appears to generate a period of responding following a changeover which is insensitive to the relative rates of reinforcement obtained. This period is extended with larger CODs. The controlling variables are not clear. One suggestion will be investigated in the following experiment.

EXPERIMENT 2

The results of the previous experiment showed clearly that responding during the COD was approximately equal on both schedules over all schedule pairs and COD values studied. Changes in the ratios of total responses with changes in the reinforcement ratios were, therefore, a result of changes in the ratios of responses made after the COD. Subtracting the COD responses from the responses made to each schedule resulted, in all cases, in a measure that was more sensitive to changes in the reinforcement ratio than was the ratio based on total responses. However, such a measure can only be arrived at post-hoc. There may be procedural means to reduce the effect of insensitive COD responding on conc VI VI schedule performance. For example, Stubbs, Pliskoff and Reid (1977) and Baum (1972, 1974b, 1979) have reported that reduced changeover rates (whether produced by increased CODs or low deprivation levels) lead to closer approximations to matching. However the data from Experiment 1 suggest that small reductions in the rates of changeover, as occurred with increased COD duration, do not affect consistently the degree of matching observed. The only consistent improvement in the approximation to matching was between no COD conditions and conditions where any COD was programmed. No COD conditions were associated with relatively large rates of changeover in comparison to conditions where any COD was programmed.

Another way of reducing the contribution of COD responding might be to eliminate (or reduce) the response burst which is reported (e.g., Menlove, 1975) to occur during the COD. White (1979) has pointed out that those studies using a fixed-ratio requirement on the changeover key rather than a COD to separate the two conc VI VI schedules (e.g., Findley, 1958; Guilkey, Shull & Brownstein, 1975; Stubbs & Pliskoff, 1969; and White, 1979) do not result in the post-changeover response

burst common when CODs are programmed and, typically, have not found undermatching. White (1979) has suggested that this difference may be explained by a higher probability of reinforcement following completion of a COD than following completion of a changeover ratio but, as previously discussed, other explanations are more likely. One major difference between those procedures using a changeover ratio and those using a COD is the distinctiveness of the period during which reinforcers are not available (during completion of the changeover ratio and of the COD).

The COD is a period during which responses are never reinforced, although responses immediately after the COD have a higher than average probability of producing reinforcement (Menlove, 1975). Possibly the COD period is not discriminable as a period of no reinforcement. Adding stimuli to signal the COD period (other than the temporal stimuli that may be involved already in that it immediately follows a changeover and a change in the key position or colour of the key) might do one of three things: 1) reduce responding during the COD, 2) produce no change, either because the stimuli did not make the COD discriminable or because the COD is already discriminable under the standard procedure or, 3) increase responding during the COD, presumably by making it (more) discriminable as a period followed by a higher than average probability of reinforcement delivery. Either the first or third possibilities might be expected to lead to systematic changes in the relation between the log response ratios and the log obtained reinforcement ratios.

There are several studies utilising a COD procedure which bear on this. Silberberg and Fantino (1970) have programmed blackout during the COD. During the COD the key lights and general illumination in the chamber were turned off although responses received auditory feedback and were recorded. Silberberg and Fantino (1970) reported that for all three pigeons responding during the COD was effectively eliminated.

Their data showed overmatching. Very similar to the use of blackout during the COD by Silberberg and Fantino (1970) was the programming of a period of time-out contingent upon a changeover by Todorov (1971). Todorov (1971) reported finding overmatching also. However timeout (as used by Todorov) involved not only a period during which the key lights and other lights in the chamber were off but a period during which all scheduling and recording devices were stopped. Todorov (1971) did not record responses which may have occurred during the COD. In that sense this procedure may be closer to those employing a changeover ratio or some other changeover requirement which is considered off-schedule. Whether blackout during the COD (no key lights or general illumination) should be seen simply as a discriminative stimulus for the COD or as time when the animal is forced off-schedule because it does not (cannot) respond is not clear.

Bourland and Miller (1978) have also varied the stimuli usually associated with the COD. Using a CO-key procedure changeover responses either changed the schedule on the main key and produced the usual concomitant stimulus change or just produced the schedule change. Their results (only slightly lower changeover rates and slightly less pronounced response bursts during the COD when a changeover produced no stimulus change) suggested that the usual key light change added very little to the other discriminative stimuli that were (presumably) there when an animal changes over (e.g., temporal stimuli, CO-key response).

In the present experiment behaviour under concurrent VI VI schedules was studied while the stimuli programmed during the COD were systematically varied by adding distinctive colours or blackout.

Method

Subjects

Six domestic hens (Scientific Poultry Breeders' Queens), numbered 51 through 56, served. Hen 56 developed a leg tumour early in the study and did not complete the full number of days shown for Conditions two to four. She was replaced by Hen 56a for the fifth and later conditions. The hens were one year old and experimentally naive at the start of the experiment. Their management was as described for Experiment 1.

Apparatus

The experimental chamber was as described for Experiment 1 except that the right-hand-side key could be lit red, green, yellow or blue. The left-hand-side key could be lit white only.

The control and recording equipment were as described for Experiment 1 except that the variable-interval generators utilised fifteen intervals arranged in pseudo-random order. The intervals were based on the arithmetic series $a + bx$, where a was the smallest interval, $b = 2a$, and $x = 0, 1, 2, \ldots, 14$. For VI 15-sec the minimum interval (a) was 1 second and the maximum interval was 29 seconds.

Procedure

Pre-Training. The hens were magazine trained and then trained, by the method of successive approximations, to peck the right-hand key. The key was lit successively (for one minute) by each of four colours (red, green, yellow and blue). Once responding was established on a VI 60-sec schedule two independent concurrently available VI 60-sec schedules, associated with the red and green key colours respectively, were made available on the right-hand key. To change between the two schedules a response on the white left-hand key (the changeover key) was required. A 3-sec COD, timed from a peck on the changeover key, was programmed.

Experimental Conditions. Sessions, which began and ended in blackout, were run seven days a week. Sessions ended after either 30 reinforcements (36 or 40 for the first five conditions) or 45 minutes, whichever was the shorter time.

Two independent concurrently available variable-interval schedules were arranged using a changeover-key (CO-key) procedure as described. A green key-light on the main key was always associated with a VI 90-sec schedule. A red key-light was associated with a second VI schedule which was varied from VI 30-sec to VI 480-sec. The variable-interval generators timed only during session time (which excluded magazine time). A 3-sec COD was programmed throughout.

A response on the changeover key changed the schedule (and the stimulus) on the main key, darkened (and made inoperative) the changeover key itself and started the COD timer. A response on the main key was required after a changeover peck before the changeover key was available again.

Five pairs of schedules were presented in two series of repeating conditions. Once presented any particular pair of schedules remained in effect for three phases: Baseline (1), stimulus presentation (or blackout in the second series) during the COD, and a return to baseline (2) conditions. Behaviour was allowed to stabilise during each phase (or condition) according to the criterion described in Experiment 1.

Baseline phases (for both series of conditions) presented the ordinary schedule stimuli (red or green key lights) during the changeover delay.

During the second phases of the first series of conditions the main key was lit, for the duration of the COD, either blue (when changing into the schedule associated with the red key colour) or yellow (when changing to the schedule associated with the green key colour). Over the first fifteen experimental conditions each pair of conc VI VI schedules

was presented without, then with, and then without different main-key colours during the COD, before the next pair of schedules was presented.

Over conditions 15 to 29 the five schedule pairs were presented as before but with blackout during the COD in the second phases. Condition 15 was the first baseline (1) condition in the second series as well as the last baseline (2) condition in the previous series. During blackout conditions a changeover response darkened and made inoperative the main key for the duration of the COD. A response on the main key (once it was operative) was still required before the changeover key was available again. Therefore, once a changeover had been made another could not be made before the end of the COD. This was a change from the baseline procedure.

The series of conditions, the schedule values, the stimuli presented during the COD (the phase), the order in which the conditions occurred, and the number of days each condition was in effect are given in Table 2.1.

The total numbers of responses made on each schedule, the numbers of responses made on each schedule during the COD (including pecks made during blackout), the amounts of time spent responding on each schedule (timed from one changeover response to the next), the numbers of reinforcements obtained on each schedule, and the numbers of changeovers between the two schedules were recorded each session for each hen. On at least one of the last five days of each condition an event record was taken, for all hens, of responses made, times spent, and the availability and delivery of reinforcement.

Table 2.1

The sequence of experimental conditions (two series), the schedule pairs, the stimuli programmed during the COD within each experimental phase (the usual schedule stimuli were programmed during baseline conditions), and the number of days each condition was in effect.

Cond	Series	VI Sched(sec) Red	VI Sched(sec) Green	Phase	Days in Effect
1	1	30	90	1: baseline 1	36
2				2: 2nd colour	53*
3				3: baseline 2	25*
4		240	90	1: baseline 1	24*
5				2: 2nd colour	27**
6				3: baseline 2	28
7		120	90	1: baseline 1	18
8				2: 2nd colour	18
9				3: baseline 2	16
10		480	90	1: baseline 1	20
11				2: 2nd colour	26
12				3: baseline 2	18
13		60	90	1: baseline 1	24
14				2: 2nd colour	23
15				3: baseline 2	21
16	2	60	90	2: blackout	20
17				3: baseline 2	14
18		30	90	1: baseline 1	23
19				2: blackout	20
20				3: baseline 2	18
21		240	90	1: baseline 1	22
22				2: blackout	23
23				3: baseline 2	17
24		120	90	1: baseline 1	18
25				2: blackout	20
26				3: baseline 2	18
27		480	90	1: baseline 1	26
28				2: blackout	17
29				3: baseline 2	15

* Hen 56 did not complete this number of days.
**Hen 56 was replaced by Hen 56a for the fifth and later conditions.

Results

The last five days data from all conditions for all hens are given in Appendix 2.1. Hen 56 died of a leg tumour at the beginning of the fifth experimental condition. Her data (from the first four conditions) are not presented when individual birds' data are analysed but are included in the group data. She was replaced by Hen 56a for the fifth and subsequent conditions and it is this bird's data which are presented. The sums of the daily data over the last five days of each condition were used in all analyses. The group data were obtained by summing the daily data from each hen over the last five days of each condition. Figures 2.1 to 2.6 are drawn from these summed data.

Lines were fitted (by the method of least squares) to the logarithms (to the base 10) of the ratios of the behaviours measured on the two schedules as functions of the logarithms of the ratios of the obtained reinforcement rates. The ratios were taken to the varied (red) schedule. The lines were fitted to data from each experimental phase within both series of conditions. Tables 2.2 and 2.3 summarise the slopes and intercepts of the fitted lines, the amounts of the y-variance accounted for (r^2), and the standard errors of the estimates (Sy.x) from the first and second series of conditions, respectively. The slopes and intercepts of the lines together with their standard deviations (SD) and the results of t-tests (two-tailed; Student's) for the significance of differences of the slopes from 1.00 and 0.00 and of the intercepts from 0.00 are presented in Appendix 2.2.

Total Responses

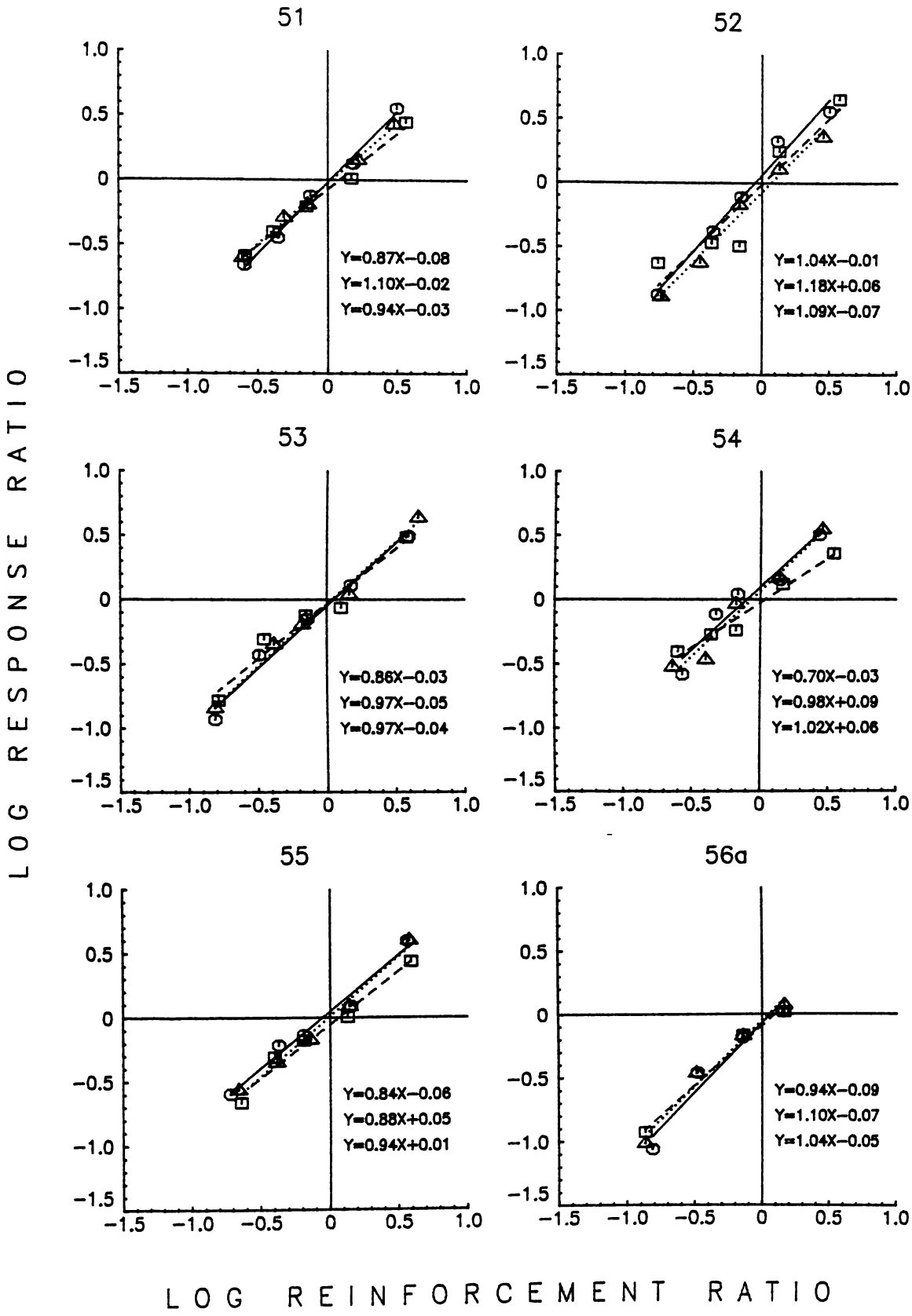
The log ratios of the total responses made on the two schedules are presented, for each hen and each experimental phase, in Figure 2.1 (a) for the first series of conditions (baseline, discriminative stimuli, return to baseline) and in Figure 2.1 (b) for the second series (baseline,

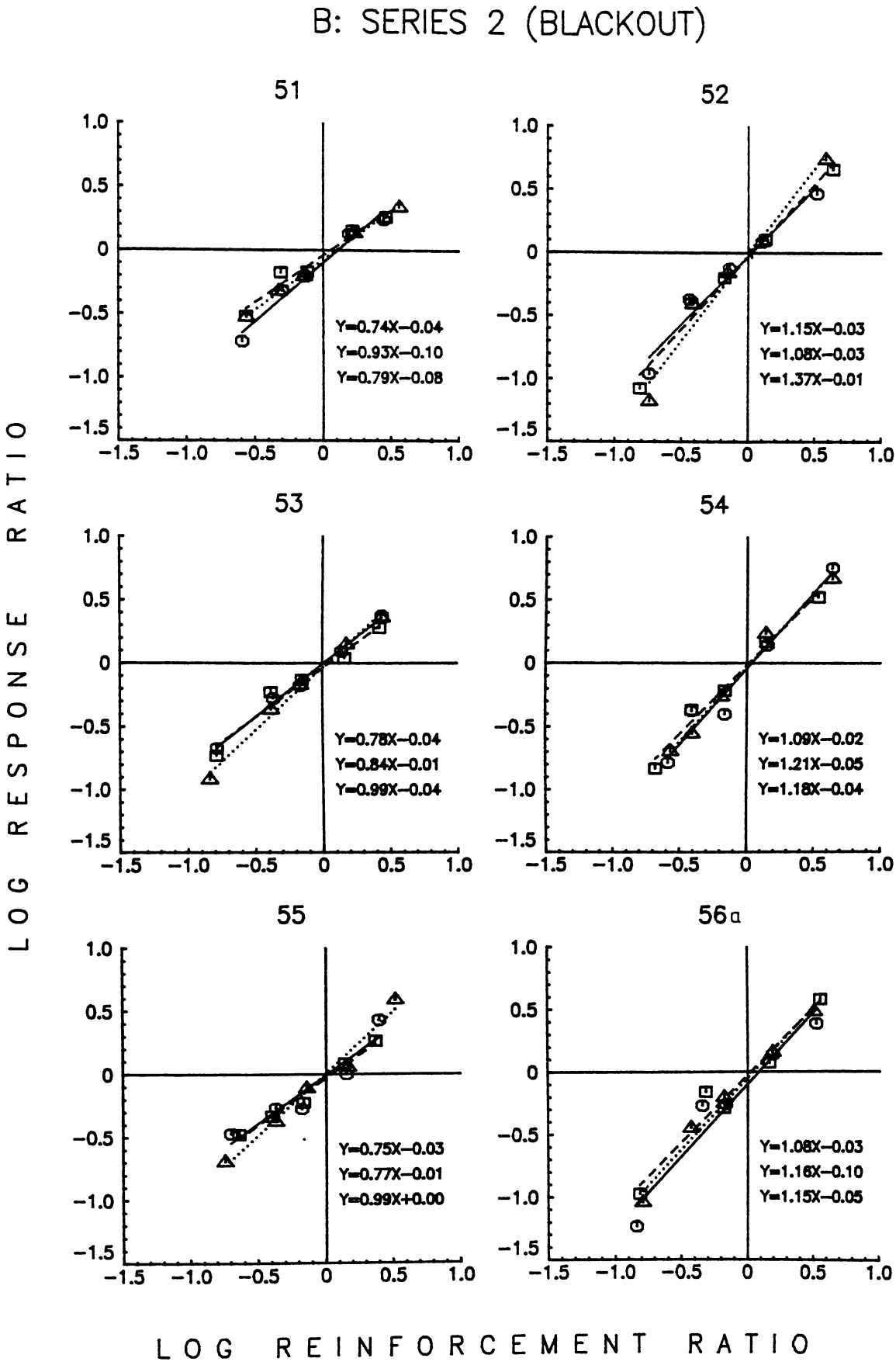
Figures 2.1 (a) and 2.1 (b)

The logarithms of the ratios of the total responses plotted, for each hen, against the logarithms of the ratios of the obtained reinforcements. Data from Phase 1 (baseline), Phase 2 (treatment), and Phase 3 (baseline) conditions are shown by squares, octagons, and triangles, respectively. The lines fitted by the method of least-squares, and their equations, are shown for each phase. The three equations presented on each plot (from top to bottom) describe the lines fitted to the data from Phase 1 (dashed line), Phase 2 (solid line), and Phase 3 (dotted line) conditions.

a) Series 1 (discriminative stimulus)

b) Series 2 (blackout)


A: SERIES 1 (DISCRIMINATIVE STIMULI)
51
52
53
54
55
56a
Y=0.87X−0.08
Y=1.10X−0.02
Y=0.94X−0.03
Y=1.04X−0.01
Y=1.18X+0.06
Y=1.09X−0.07
Y=0.86X−0.03
Y=0.97X−0.05
Y=0.97X−0.04
Y=0.70X−0.03
Y=0.98X+0.09
Y=1.02X+0.06
Y=0.84X−0.06
Y=0.88X+0.05
Y=0.94X+0.01
Y=0.94X−0.09
Y=1.10X−0.07
Y=1.04X−0.05
LOG RESPONSE RATIO
LOG REINFORCEMENT RATIO


B: SERIES 2 (BLACKOUT)
51
52
53
54
55
56a
Y=0.74X−0.04
Y=0.93X−0.10
Y=0.79X−0.08
Y=1.15X−0.03
Y=1.08X−0.03
Y=1.37X−0.01
Y=0.78X−0.04
Y=0.84X−0.01
Y=0.99X−0.04
Y=1.09X−0.02
Y=1.21X−0.05
Y=1.18X−0.04
Y=0.75X−0.03
Y=0.77X−0.01
Y=0.99X+0.00
Y=1.08X−0.03
Y=1.16X−0.10
Y=1.15X−0.05
LOG RESPONSE RATIO
LOG REINFORCEMENT RATIO

blackout, return to baseline). The fitted lines (and their equations) from the three phases within each series are shown in the figures, and are summarised in Tables 2.2 and 2.3.

From Tables 2.2 and 2.3 (and Figures 2.1 (a) and 2.1 (b)) it can be seen that the lines fitted to the log ratios of total responses when either additional discriminative stimuli (key lights) or blackout were programmed during the COD were generally (in 11 out of 12 cases) steeper than those fitted to the same data from the first baseline conditions (from the appropriate series). The exception was the data obtained from Hen 52 when blackout during the COD was programmed (the slope of the line was less than the slope of the line fitted to the data from the first baseline conditions, Series 2). However, the slopes of the lines fitted to the total response data from the third phase conditions (return to baseline) were also greater than those of the lines fitted to the data from the first baseline phases, for all hens (including Hen 52) and both series of conditions. There was no consistent direction to the differences between the slopes of the lines fitted to the log ratios of total responses from the second (treatment) and third (return to baseline) phases, for either series of conditions.

The slopes of the lines fitted to the data from individual hens during the first series of conditions ranged from 0.70 to 1.04 (Phase 1), 0.88 to 1.18 (Phase 2), and 0.94 to 1.09 (Phase 3). The corresponding ranges from the second series were 0.74 to 1.15, 0.77 to 1.21, and 0.79 to 1.37. The slopes were not significantly different from 1.00 (Appendix 2.2) in 32 of the 36 cases (and all but one were significantly different from 0.00). Those different from 1.00 came from different hens and different phases. The slopes of the lines fitted to the group data were within the range 0.87 to 1.08. Only one was significantly different from 1.00 and all were significantly different from 0.00 (Appendix 2.2).

Table 2.2

The slopes, intercepts, amounts of the y-variance accounted for (r^2), and the standard errors of the estimates (Sy.x) of the lines fitted to the log ratios of each of the behaviour measures as a function of the log ratios of the obtained reinforcement rates, for the individual hens and the group for the phases from the first series of conditions (Baseline 1, distinctive key colours during the COD, and Baseline 2). The lines fitted to Hen 56a's data were based on three (Baseline 1) or four (colour and Baseline 2) points only.

		Total Responses				Times				Responses during COD				Responses after COD			
Hen	phase	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x
51	b/l 1	0.87	-0.08	0.99	0.04	0.92	-0.12	0.98	0.07	0.01	0.05	0.00	0.08	1.19	-0.09	0.97	0.11
51	colour	1.10	-0.02	0.99	0.05	1.03	0.02	0.97	0.09	0.18	-0.02	0.76	0.05	1.53	0.03	0.98	0.12
51	b/l 2	0.94	-0.03	1.00	0.03	1.01	-0.01	0.99	0.04	0.00	0.02	0.00	0.04	1.30	0.00	0.98	0.08
52	b/l 1	1.04	-0.01	0.88	0.23	0.97	0.00	0.95	0.13	-0.18	-0.15	0.13	0.28	1.24	0.00	0.88	0.27
52	colour	1.18	0.06	0.98	0.09	1.07	0.00	0.99	0.06	-0.36	0.39	0.31	0.30	1.51	0.01	0.99	0.06
52	b/l 2	1.09	-0.07	0.99	0.07	1.06	-0.06	1.00	0.03	-0.15	-0.07	0.50	0.08	1.41	-0.05	0.99	0.08
53	b/l 1	0.86	-0.03	0.96	0.11	0.95	-0.02	0.97	0.09	-0.13	-0.13	0.90	0.03	1.07	-0.01	0.97	0.11
53	colour	0.97	-0.05	0.98	0.08	0.95	-0.01	0.99	0.05	-0.02	0.03	0.26	0.02	1.27	-0.05	1.00	0.04
53	b/l 2	0.97	-0.04	0.99	0.06	0.99	0.02	0.97	0.11	-0.06	-0.12	0.68	0.03	1.26	0.02	0.98	0.11
54	b/l 1	0.70	-0.03	0.97	0.06	0.72	-0.03	1.00	0.03	0.02	0.13	0.00	0.28	0.89	-0.04	0.99	0.06
54	colour	0.98	0.09	0.93	0.12	0.83	0.06	0.96	0.08	-0.43	0.28	0.34	0.27	1.22	0.07	0.97	0.11
54	b/l 2	1.02	0.06	0.97	0.10	0.78	0.05	0.98	0.05	0.02	0.16	0.00	0.23	1.14	0.04	0.97	0.09
55	b/l 1	0.84	-0.06	0.98	0.07	0.81	-0.06	0.99	0.05	0.40	-0.02	0.89	0.08	1.02	-0.07	0.97	0.10
55	colour	0.88	0.05	0.98	0.07	0.77	0.00	0.97	0.08	0.13	0.13	0.68	0.05	1.13	0.02	0.98	0.10
55	b/l 2	0.94	0.01	0.99	0.06	0.83	0.00	0.98	0.07	0.33	0.01	0.84	0.08	1.14	0.02	0.97	0.10
56a	b/l 1	0.94	-0.09	0.99	0.08	0.84	-0.04	0.99	0.06	0.15	-0.03	0.99	0.01	1.00	-0.11	0.99	0.06
56a	colour	1.10	-0.07	0.95	0.13	0.92	-0.03	0.95	0.10	0.03	-0.10	0.15	0.04	1.29	-0.09	0.98	0.08
56a	b/l 2	1.04	-0.05	0.98	0.09	0.99	-0.03	0.95	0.12	0.03	0.01	0.04	0.07	1.22	-0.08	0.99	0.05
GP	b/l 1	0.87	-0.05	1.00	0.03	0.87	-0.05	1.00	0.03	0.13	-0.01	0.50	0.07	1.08	-0.05	0.99	0.07
GP	colour	1.04	0.00	0.99	0.05	0.91	0.00	0.99	0.05	0.03	0.10	0.08	0.06	1.33	-0.01	1.00	0.05
GP	b/l 2	1.01	-0.03	1.00	0.03	0.92	-0.01	0.99	0.05	0.04	-0.02	0.14	0.06	1.25	-0.01	0.99	0.06

Table 2.3

The slopes, intercepts, amounts of the y-variance accounted for (r^2), and the standard errors of the estimates (Sy.x) of the lines fitted to the log ratios of each of the behaviour measures as a function of the log ratios of the obtained reinforcement rates, for the individual hens and the group for the phases from the second series of conditions (Baseline 1, blackout during the COD, and Baseline 2).

		Total Responses				Times				Responses during COD				Responses after COD			
Hen	phase	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x	slope	intcpt	r^2	Sy.x
51	b/l 1	0.74	-0.04	0.96	0.08	0.78	-0.01	0.96	0.08	0.14	0.04	0.43	0.08	0.96	-0.04	0.95	0.10
51	b/out	0.93	-0.10	0.97	0.07	0.73	-0.08	0.93	0.09	0.08	0.01	0.83	0.02	1.00	-0.10	0.98	0.07
51	b/l 2	0.79	-0.08	1.00	0.03	0.79	-0.04	0.99	0.04	0.08	0.04	0.19	0.08	0.97	-0.08	0.99	0.04
52	b/l 1	1.15	-0.03	0.98	0.10	1.03	-0.05	0.97	0.11	0.02	-0.06	0.01	0.15	1.28	-0.02	0.98	0.11
52	b/out	1.08	-0.03	0.97	0.12	0.86	-0.06	0.97	0.09	-0.35	0.09	0.99	0.02	1.21	-0.01	0.98	0.10
52	b/l 2	1.37	-0.01	0.97	0.14	1.06	-0.04	0.96	0.12	-0.03	-0.13	0.01	0.26	1.51	-0.01	0.97	0.17
53	b/l 1	0.78	-0.04	0.96	0.08	0.75	-0.05	0.96	0.08	0.09	-0.04	0.18	0.11	0.88	-0.04	0.97	0.08
53	b/out	0.84	-0.01	1.00	0.03	0.66	0.00	1.00	0.02	0.07	-0.03	0.86	0.01	0.93	-0.01	1.00	0.03
53	b/l 2	0.99	-0.04	0.99	0.05	0.91	-0.02	0.99	0.04	0.03	-0.09	0.11	0.04	1.13	-0.03	0.99	0.06
54	b/l 1	1.09	-0.02	0.98	0.08	0.94	0.00	0.99	0.05	0.36	0.17	0.36	0.26	1.12	-0.03	0.98	0.08
54	b/out	1.21	-0.05	0.96	0.13	0.90	0.02	0.98	0.08	-0.08	0.40	0.06	0.18	1.22	-0.05	0.96	0.13
54	b/l 2	1.18	-0.04	0.99	0.07	0.95	0.00	1.00	0.02	-0.08	0.29	0.01	0.56	1.30	-0.05	0.99	0.06
55	b/l 1	0.75	-0.03	0.98	0.05	0.69	-0.06	0.97	0.06	0.37	0.09	0.78	0.09	0.83	-0.07	0.98	0.06
55	b/out	0.77	-0.01	0.89	0.13	0.61	0.00	0.91	0.10	0.01	-0.02	0.04	0.03	0.89	0.00	0.87	0.17
55	b/l 2	0.99	0.00	0.98	0.08	0.96	0.00	0.98	0.08	-0.07	0.01	0.85	0.02	1.19	0.01	0.98	0.10
56a	b/l 1	1.08	-0.03	0.95	0.14	0.91	-0.01	0.95	0.12	0.02	0.04	0.04	0.06	1.21	-0.03	0.96	0.16
56a	b/out	1.16	-0.10	0.94	0.17	0.84	-0.08	0.93	0.14	-0.22	0.01	0.49	0.13	1.20	-0.11	0.94	0.18
56a	b/l 2	1.15	-0.05	0.99	0.08	0.91	-0.07	0.99	0.06	0.43	0.20	0.55	0.23	1.26	-0.07	0.98	0.10
GP	b/l 1	0.95	-0.03	0.98	0.07	0.86	-0.03	0.98	0.07	0.18	0.03	0.76	0.06	1.07	-0.03	0.98	0.08
GP	b/out	0.97	-0.04	0.99	0.06	0.76	-0.03	0.98	0.05	-0.03	0.00	0.20	0.03	1.07	-0.04	0.99	0.06
GP	b/l 2	1.08	-0.04	0.99	0.05	0.93	-0.03	0.99	0.04	0.08	0.01	0.37	0.06	1.23	-0.04	0.99	0.06

In all cases the lines fitted to the log total response ratios described the data well (r^2 ranged from 0.88 to 1.00 and the standard errors of the estimates ranged from 0.03 to 0.23; Tables 2.2 & 2.3). Biases in the individual hens' data were generally (30 of 36 cases) in the direction of the constant schedule but were small (the intercepts of the fitted lines were less than $\pm$ 0.10) and were not significantly different from 0.00 in 34 of the 36 cases (Appendix 2.2).

Times

The log ratios of the times spent on the two schedules and the lines (and their equations) fitted to the data from each of the three phases within the two series of conditions are shown, for each hen, in Figures 2.2 (a) and 2.2 (b). The lines are summarised in Tables 2.2 and 2.3. In all cases the fitted lines described the data well (r^2 ranged from 0.91 to 1.00 and the standard errors of the estimates were between 0.02 to 0.14). Individual biases for one or other schedule were minimal (the y-intercepts of the lines ranged between -0.12 and 0.06), were not significantly different from 0.00 in 34 of the 36 cases (Appendix 2.2), and were unsystematic across hens and conditions.

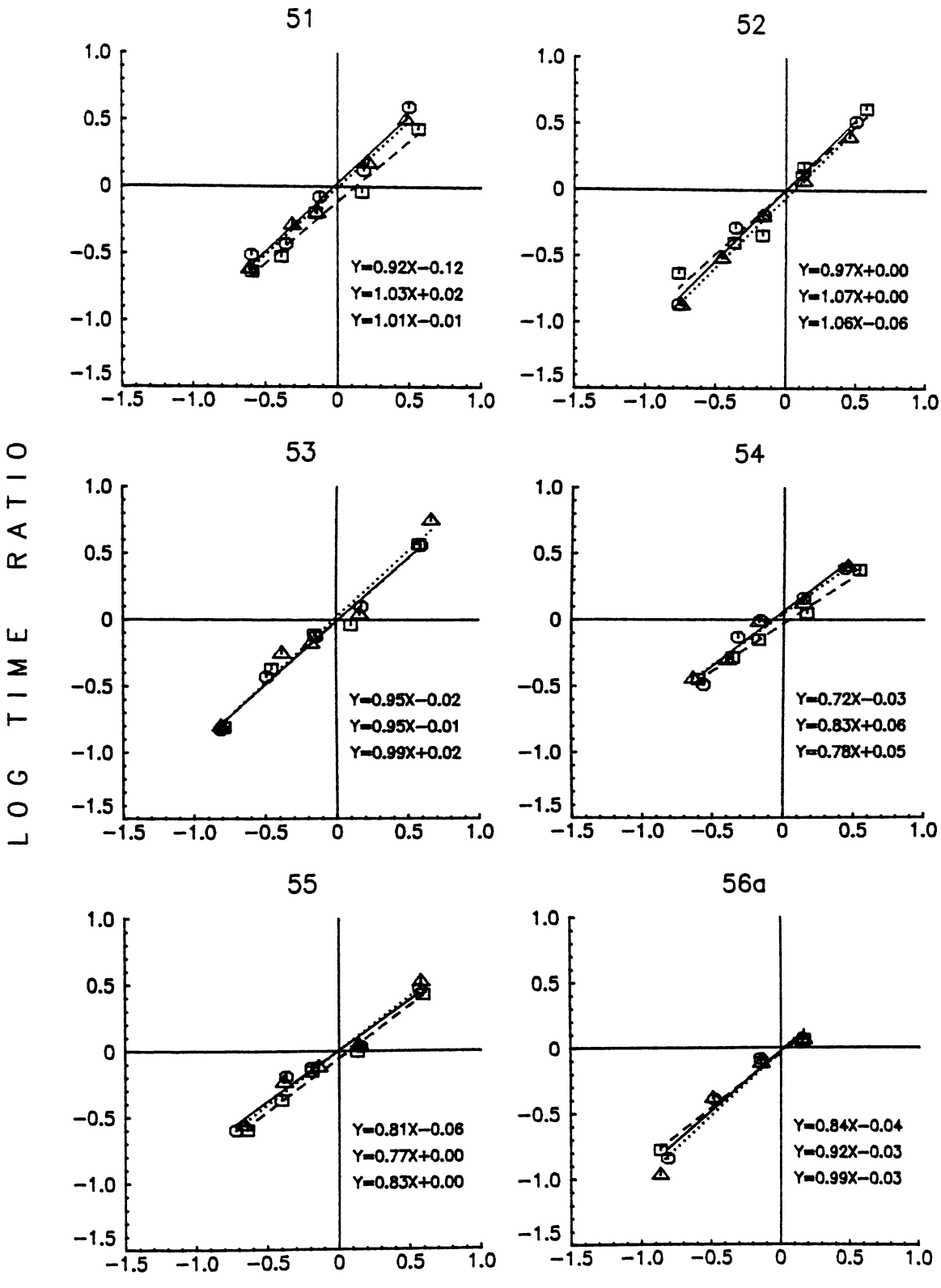
Figure 2.2 (a) and Table 2.2 show that the slopes of the lines fitted to the log time ratios from conditions where distinct key colours were programmed during the COD were, in four of the six cases (the exceptions were Hens 53 and 55), steeper than were those fitted to the data from the first baseline conditions (Series 1). In only one case (Hen 55) was the fitted line from the first baseline conditions steeper than that from the Phase 2 conditions. However the lines fitted to the time data from the second baseline conditions were all steeper than those fitted to the data from the first baseline conditions and, in three of the six cases were steeper than those fitted to the data from the discriminative stimuli conditions. The slopes of the lines ranged from 0.72 to 0.97 (Baseline 1 conditions), 0.77 to 1.07 (distinct key

Figures 2.2 (a) and 2.2 (b)

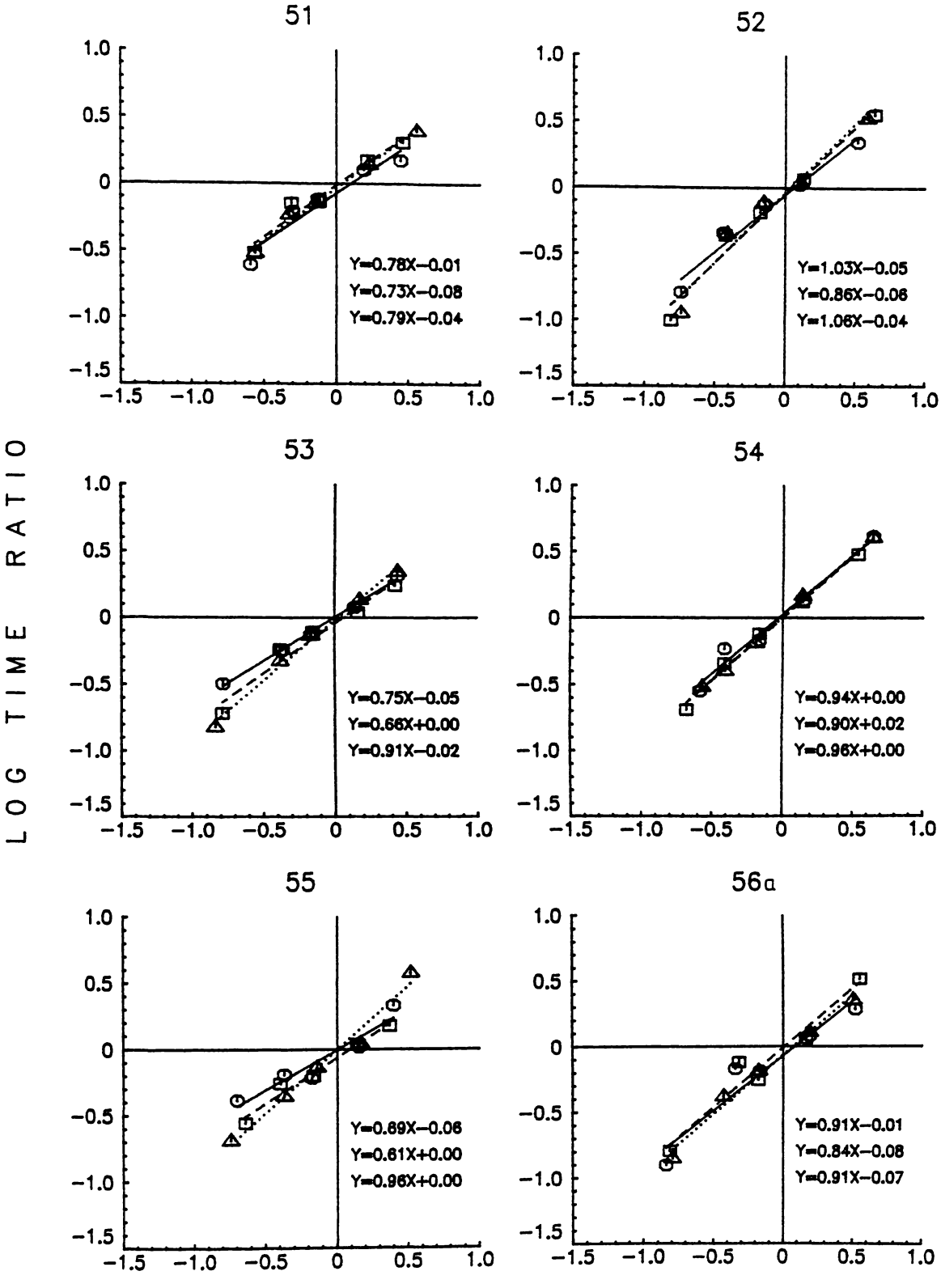
The logarithms of the ratios of the times spent plotted, for each hen, against the logarithms of the ratios of the obtained reinforcements. Data from Phase 1 (baseline), Phase 2 (treatment), and Phase 3 (baseline) conditions are shown by squares, octagons, and triangles, respectively. The lines fitted by the method of least-squares, and their equations, are shown for each phase. The three equations presented on each plot (from top to bottom) describe the lines fitted to the data from Phase 1 (dashed line), Phase 2 (solid line), and Phase 3 (dotted line) conditions.

a) Series 1 (discriminative stimulus)

b) Series 2 (blackout)


A: SERIES 1 (DISCRIMINATIVE STIMULI)
51
52
53
54
55
56a
Y=0.92X−0.12
Y=1.03X+0.02
Y=1.01X−0.01
Y=0.97X+0.00
Y=1.07X+0.00
Y=1.06X−0.06
Y=0.95X−0.02
Y=0.95X−0.01
Y=0.99X+0.02
Y=0.72X−0.03
Y=0.83X+0.06
Y=0.78X+0.05
Y=0.81X−0.06
Y=0.77X+0.00
Y=0.83X+0.00
Y=0.84X−0.04
Y=0.92X−0.03
Y=0.99X−0.03
1.0
0.5
0
−0.5
−1.0
−1.5
−1.5 −1.0 −0.5 0 0.5 1.0
LOG TIME RATIO
LOG REINFORCEMENT RATIO

B: SERIES 2 (BLACKOUT)



colours during COD), and 0.78 to 1.06 (Baseline 2 conditions). These slopes were generally (15 of 18 cases) not significantly different from 1.00 (Appendix 2.2). Baseline 1 conditions produced the three lines with slopes significantly less than 1.00. All but one of the slopes were significantly greater than 0.00 (Appendix 2.2). The group data reflected the general trends seen in the individual hens' data (Table 2.2). The slope of the line fitted to the log time ratios increased from Baseline 1 conditions (0.87) to Phase 2 conditions (0.91) and then increased very slightly with the return to baseline conditions (0.92). Of the three slopes only that based on data from Baseline 1 conditions was significantly less than 1.00 (Appendix 2.2).

The effects of blackout during the COD on the slopes of the lines fitted to the time data may be seen in Figure 2.2 (b) and Table 2.3. In all cases the lines fitted to the data from Phase 2 conditions (blackout) were less steep than those fitted to the data from either Phase 1 or Phase 3 conditions (baseline and return to baseline). The lines fitted to the time data from the second baseline conditions were at least as steep as those fitted to the data from the first baseline conditions, and were generally (in five out of six cases) steeper. In the cases of four of the hens the slopes of the lines fitted to the data from the two baseline phases were within 0.01 to 0.03 of each other. For the other two hens (Hens 53 and 55) the slopes were greater (by 0.16 and 0.27) in the second baseline phase.

The ranges of the slopes of the lines fitted to the log time ratios from the second series of conditions for individual hens were 0.69 to 1.03 (Phase 1), 0.61 to 0.90 (Phase 2), and 0.79 to 1.06 (Phase 3). The reduction in the slopes with blackout (from either baseline phases) ranged between 0.04 and 0.35 (in eight of the twelve comparisons this reduction was between 0.04 and 0.09). In all but 4 cases (of 18) the slopes of the lines were not significantly different from 1.00 (Appendix

2.2). The four that were significantly less than 1.00 came from different hens and different experimental phases. All but one of the lines had slopes that were significantly greater than 0.00 (Appendix 2.2).

Again the group data reflected the trends seen in the individual birds' data. The slopes of the lines fitted to the log time ratios from the second series of conditions were lower when blackout was programmed during the COD than during the first baseline conditions (0.76 and 0.86, respectively). The slope of the line fitted to the data from the return to baseline (Phase 3) conditions increased (to 0.93) beyond that obtained from the first baseline conditions (Table 2.3). Only the slope of the line fitted to the data from the blackout conditions was significantly different from 1.00 (Appendix 2.2). All were significantly different from 0.00 (Appendix 2.2).

Responses versus Times

Overall the slopes of the lines fitted to the log time ratios were generally (in 29 of 36 cases) lower than the slopes of those fitted to the log total response ratios (Tables 2.2 and 2.3). In only the first baseline phase of the first series of conditions were the slopes of the two lines (responses or times) equally likely to be the the steeper.

Responses during the COD

For all hens the slopes of the lines fitted to the log ratios of the responses made during the COD are presented in Tables 2.2 and 2.3. The slopes were low, ranging from -0.43 to 0.43 (-0.15 to 0.15 for 25 of the 36 cases), and were generally (28 out of 36 cases) not significantly different from 0.00 (Appendix 2.2). Of the eight slopes greater than 0.30 (or less than -0.30) only four were significantly different from 0.00. The standard deviations of the slopes were sometimes quite large (e.g., 0.58) so that in four cases the slopes of the lines fitted to the

log COD response ratios (not necessarily the largest slopes) are also not significantly different from 1.00 (Appendix 2.2)

From Table 2.2 it can be seen that adding a discriminative stimulus during COD had no common effect across hens on the slopes of the lines fitted to the log ratios of the responses made during the COD. However in four of the six cases the slopes were lower when discriminative stimuli during the COD were programmed than they were under the first baseline conditions (Phase 1). Regardless of the direction of this change in slope it tended (in five of the six cases) to be reversed in the second baseline conditions. The fitted lines had slopes ranging from -0.18 to 0.40 (Phase 1), -0.43 to 0.18 (Phase 2) and -0.15 to 0.33 (Phase 3).

Table 2.3 shows that the slopes of the lines fitted to the log COD responses were, in every case, lower when blackout during the COD was programmed than they were under Baseline 1 conditions (Series 2). The slopes ranged from 0.02 to 0.37 in Baseline 1 conditions and -0.35 to 0.08 in blackout conditions. In four of the six cases the slopes of the fitted lines from the second baseline conditions were equal to or even lower than those fitted in the blackout conditions.

The group data reflected the general reduction, between Phase 1 conditions and Phase 2 conditions (whether discriminative stimuli or blackout), seen in the slopes of the lines fitted to the log COD response ratios. In the cases of the individual hens' data this reduction was not consistently associated with a move towards (or away from) 0.00.

The fits of the lines to the data, as measured by r^2, were variable (0.00 to 0.99). The fitted lines often accounted for little more of the y-variance than did the mean y-values. The standard errors of the estimates (which ranged from 0.01 to 0.56) provide, perhaps, more information about the variation about the lines in the data since the

lines were so flat (as discussed previously). There was considerable variation in the data (Sy.x greater than 0.10) from two hens (Hens 52 and 54) in the first series of conditions and from three hens (Hens 52, 54 and 56a) in the second series. The variations were smaller (Sy.x less than 0.10) in the data from the other hens.

The intercepts of the lines varied to both sides of 0.00 (the range was -0.15 to 0.40 with 23 of the 36 cases between -0.10 and 0.10) but were generally (29 out of the 36 cases) not significantly different from 0.00 (Appendix 2.2). Hen 54 was the only bird with a relatively large (the intercepts ranged from 0.13 to 0.40) and consistent (towards the varied schedule) bias. However, the intercepts were not significantly different from 0.00 except in the blackout phase.

Responses after the COD

Figures 2.3 (a) and 2.3 (b) show, for the individual hens and the phases from both series of conditions, the log ratios of the post-COD responses plotted against the log reinforcement ratios. The lines (and their equations) fitted to these data are shown on the graphs and in Tables 2.2 and 2.3. The slopes of the lines ranged from 0.83 to 1.53 and were steeper, in every case, than the lines fitted to the total response data. The fits of the lines to the data were good (r^2 was greater than 0.86 and Sy.x ranged from 0.03 to 0.27).

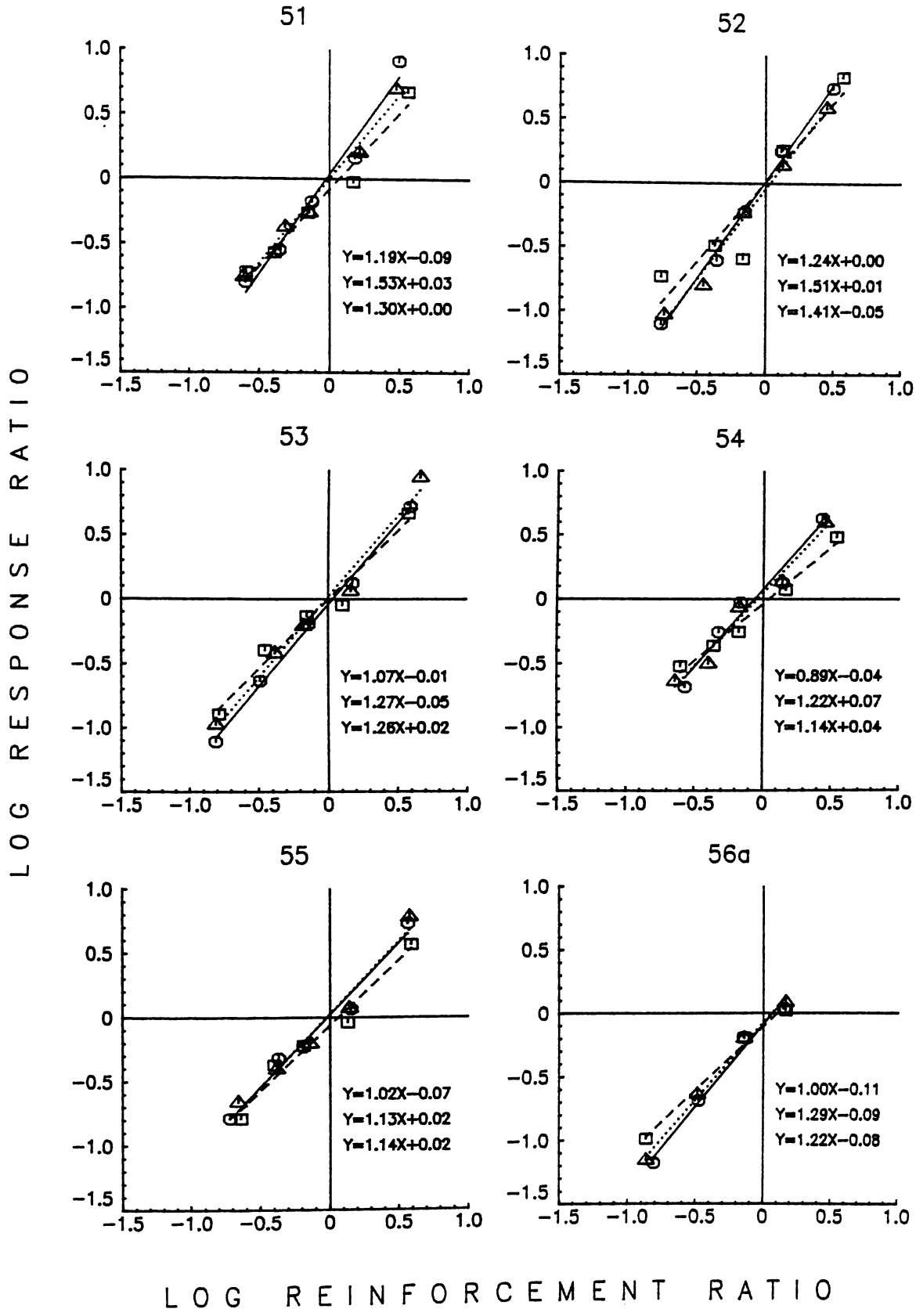
The effects of the distinctive key colours during COD on the slopes of the lines (Table 2.2) were as described for the total response data in that the slopes from the second phase conditions were higher (by 0.11 to 0.34), for all hens, than those from the first baseline conditions. So too were those from the second baseline conditions (by 0.11 to 0.25). The slopes ranged between 0.89-1.24 (Phase 1), 1.13-1.53 (Phase 2), and 1.14-1.41 (Phase 3). In spite of the fact that all but two of the slopes exceeded 1.00 only four (three from Phase 2 conditions) were significantly different from (greater than) 1.00 (Appendix 2.2). The

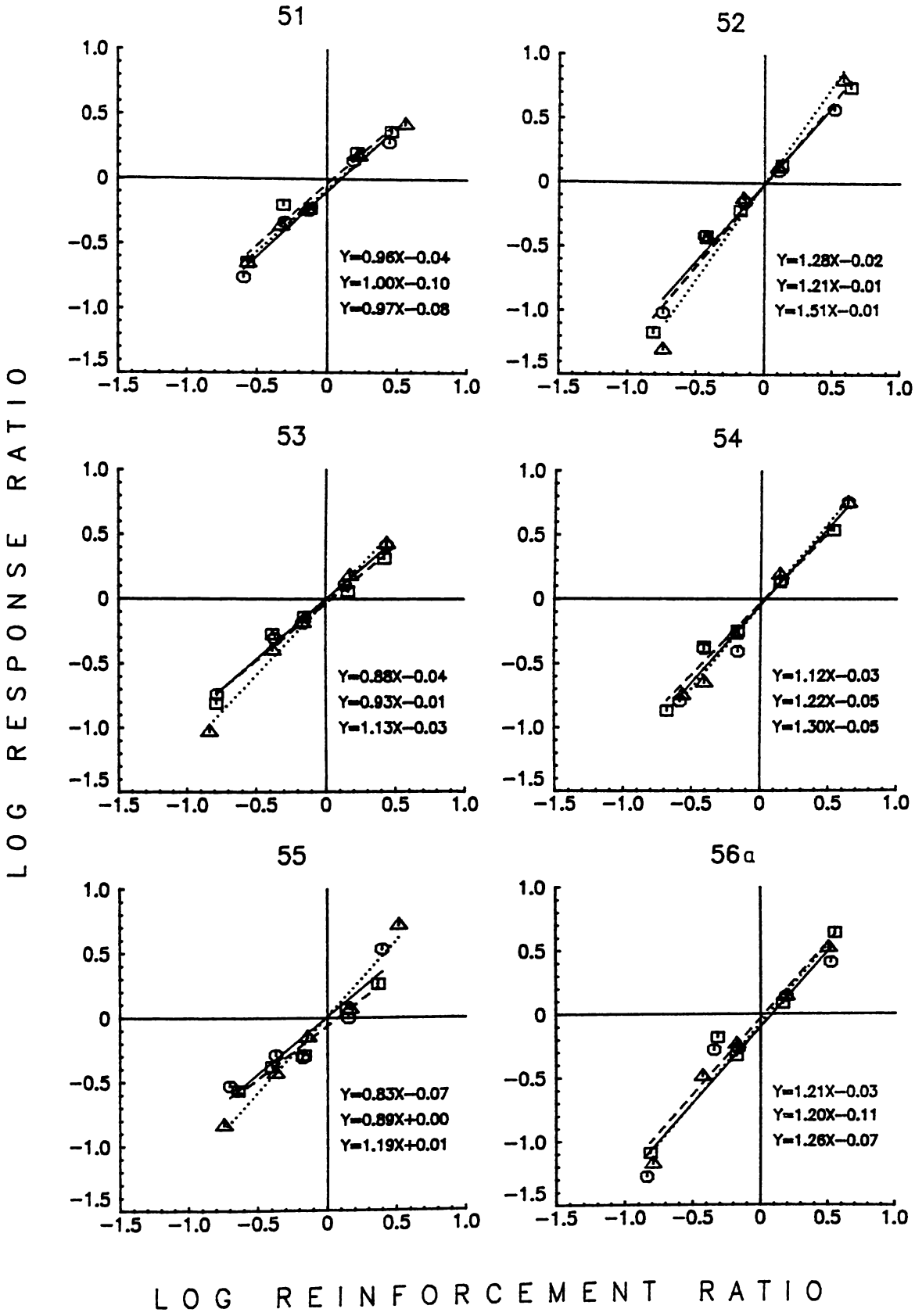
Figures 2.3 (a) and 2.3 (b)

The logarithms of the ratios of the responses made after the COD plotted, for each hen, against the logarithms of the ratios of the obtained reinforcements. Data from Phase 1 (baseline), Phase 2 (treatment), and Phase 3 (baseline) conditions are shown by squares, octagons, and triangles, respectively. The lines fitted by the method of least-squares, and their equations, are shown for each phase. The three equations presented on each plot (from top to bottom) describe the lines fitted to the data from Phase 1 (dashed line), Phase 2 (solid line), and Phase 3 (dotted line) conditions.

a) Series 1 (discriminative stimulus)

b) Series 2 (blackout)


A: SERIES 1 (DISCRIMINATIVE STIMULI)
51
Y=1.19X−0.09
Y=1.53X+0.03
Y=1.30X+0.00
52
Y=1.24X+0.00
Y=1.51X+0.01
Y=1.41X−0.05
53
Y=1.07X−0.01
Y=1.27X−0.05
Y=1.26X+0.02
54
Y=0.89X−0.04
Y=1.22X+0.07
Y=1.14X+0.04
55
Y=1.02X−0.07
Y=1.13X+0.02
Y=1.14X+0.02
56a
Y=1.00X−0.11
Y=1.29X−0.09
Y=1.22X−0.08
LOG RESPONSE RATIO
LOG REINFORCEMENT RATIO


B: SERIES 2 (BLACKOUT)
51
52
53
54
55
56a
Y=0.96X−0.04
Y=1.00X−0.10
Y=0.97X−0.08
Y=1.28X−0.02
Y=1.21X−0.01
Y=1.51X−0.01
Y=0.88X−0.04
Y=0.93X−0.01
Y=1.13X−0.03
Y=1.12X−0.03
Y=1.22X−0.05
Y=1.30X−0.05
Y=0.83X−0.07
Y=0.89X+0.00
Y=1.19X+0.01
Y=1.21X−0.03
Y=1.20X−0.11
Y=1.26X−0.07
LOG RESPONSE RATIO
LOG REINFORCEMENT RATIO

slope of the line fitted to the group post-COD data from the first series of conditions increased (from 1.08) with the addition of discriminative stimuli during the COD (to 1.33) and decreased slightly (to 1.25) with the return to baseline conditions. Only the slope of the line fitted to the data from the first baseline conditions was not significantly different from 1.00.

The slopes of the lines fitted to the individual hens' post-COD data from the blackout phase (Table 2.3) were steeper, in four of the six cases, than the slopes of the lines fitted to the same data from Phase 1 (baseline) conditions. The exceptions were found in the data from Hens 52 and 56. The differences in the slopes ranged between a decrease of 0.07 and an increase of 0.10. The slopes fitted to the post-COD data in Phase 3 were higher than the slopes of the lines from both the other phases for five of the six hens. The ranges of the slopes were 0.83 to 1.28 (Phase 1), 0.89 to 1.22 (Phase 2), and 0.97 to 1.51 (Phase 3). In only one case was the slope of a line significantly different from 1.00 (Appendix 2.2). The slope of the lines fitted to the post-COD data for the group did not change between Baseline 1 conditions and blackout conditions (1.07) but did increase with a return to baseline (1.23). Only this last slope was significantly different from 1.00 (Appendix 2.2).

Local Response Rates

Table 2.4 presents, for each hen, the local rates of responding on each schedule both during and after the COD for each experimental phase of both series of conditions. The local rates were calculated as the number of responses made on a schedule during (or after) the COD divided by the time (estimated) spent in the COD (or post-COD) on a schedule. The actual time spent on a schedule while the COD was in effect was not recorded. It was estimated by halving the number of changeovers made and

Table 2.4

The local rates of responding, for each hen, both during the COD and, in brackets, after the COD on both the varied and the constant schedules, for each experimental phase in both series of conditions. Five schedule pairs were programmed and are identified by the value of the varied schedule (the constant schedule was VI 90-sec). Rates are given as responses per minute rounded to the nearest whole number except if less than 1.00 when they were rounded to one decimal place.
* Hen 56a had not replaced Hen 56 for these experimental conditions.

HEN	SCHED:	VI 30-sec			VI 60-sec			VI 120-sec			VI 240-sec			VI 480-sec		
	PHASE:	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
SERIES 1 (DISC STIM): VARIED SCHEDULE																
51		81(43)	84(35)	70(32)	57(28)	51(24)	69(28)	39(23)	29(20)	32(21)	49(24)	30(20)	34(25)	44(27)	33(19)	44(22)
52		20(43)	64(38)	37(44)	50(35)	63(38)	47(30)	31(32)	46(34)	47(28)	23(46)	56(28)	47(29)	55(32)	57(25)	53(36)
53		37(25)	64(25)	55(41)	27(47)	27(49)	28(51)	51(33)	40(37)	36(39)	51(18)	65(21)	49(21)	43(37)	33(24)	36(30)
54		62(38)	29(43)	19(41)	27(30)	19(24)	23(25)	11(16)	23(20)	18(23)	30(23)	21(14)	10(11)	25(24)	14(18)	17(16)
55		84(33)	75(41)	94(40)	42(31)	35(31)	35(32)	44(33)	44(32)	37(29)	54(35)	59(27)	41(22)	38(33)	41(30)	33(35)
56a		*	*	*	20(31)	22(33)	24(33)	47(29)	17(22)	24(33)	*	44(17)	44(21)	14(19)	17(18)	30(22)
SERIES 1 (DISC STIM): CONSTANT SCHEDULE																
51		69(33)	80(24)	74(27)	46(26)	45(24)	60(29)	45(24)	30(23)	28(22)	37(21)	35(22)	35(26)	38(27)	49(29)	43(25)
52		50(34)	50(31)	61(39)	33(30)	12(30)	47(26)	42(45)	21(33)	46(27)	55(46)	34(48)	51(43)	47(35)	9(34)	52(41)
53		57(25)	60(22)	84(38)	41(47)	27(48)	34(50)	62(33)	36(41)	47(50)	61(17)	62(28)	65(29)	45(36)	30(34)	42(35)
54		57(37)	39(30)	18(31)	9(29)	8(29)	9(26)	16(18)	9(21)	11(26)	28(24)	5(18)	14(15)	14(22)	8(22)	9(21)
55		60(29)	47(27)	63(28)	31(34)	25(30)	25(30)	50(35)	34(37)	45(33)	83(29)	58(33)	65(29)	78(37)	34(33)	47(33)
56a		*	*	*	20(35)	26(33)	24(33)	53(34)	24(27)	20(37)	*	53(26)	52(30)	20(25)	23(29)	29(26)
SERIES 2 (BLACKOUT): VARIED SCHEDULE																
51		69(21)	16(24)	58(22)	69(28)	9(22)	61(25)	18(18)	14(16)	22(17)	30(23)	7(19)	17(19)	24(13)	10(17)	27(18)
52		31(50)	26(49)	16(50)	47(30)	42(43)	34(39)	30(45)	15(37)	8(40)	19(41)	19(40)	24(45)	27(29)	15(31)	25(26)
53		34(47)	27(50)	32(51)	28(51)	24(46)	31(50)	25(40)	15(38)	26(42)	39(47)	20(34)	23(44)	26(30)	21(27)	29(31)
54		23(27)	.9(30)	14(27)	23(25)	.4(23)	13(21)	11(18)	.9(16)	9(20)	7(26)	2(18)	14(15)	5(17)	1(15)	7(16)
55		51(34)	21(30)	36(30)	35(32)	24(25)	27(32)	22(28)	13(22)	30(29)	24(23)	7(23)	18(26)	24(28)	15(24)	30(31)
56a		31(38)	5(33)	35(40)	24(33)	6(35)	31(32)	13(23)	9(23)	14(23)	19(29)	6(20)	13(26)	12(11)	4(10)	12(13)
SERIES 2 (BLACKOUT): CONSTANT SCHEDULE																
51		55(21)	14(21)	44(24)	60(29)	9(22)	54(25)	14(21)	14(20)	27(19)	37(24)	7(24)	17(24)	25(15)	10(21)	23(20)
52		34(39)	33(36)	18(32)	47(26)	38(37)	36(33)	34(45)	11(36)	26(39)	38(40)	11(41)	27(49)	24(34)	7(42)	23(44)
53		33(44)	27(46)	42(49)	34(50)	26(45)	35(48)	30(41)	18(41)	30(44)	33(46)	22(35)	29(44)	40(30)	25(39)	40(38)
54		10(29)	.3(27)	17(25)	9(26)	.2(25)	1(21)	9(23)	.5(25)	13(23)	15(23)	.8(23)	6(23)	3(20)	.2(22)	4(22)
55		27(31)	24(23)	39(26)	25(30)	23(26)	27(31)	21(29)	13(25)	27(28)	36(26)	8(26)	17(26)	26(22)	16(27)	26(32)
56a		25(35)	7(28)	18(35)	24(33)	5(32)	16(31)	12(24)	9(26)	5(24)	20(31)	6(25)	18(27)	10(18)	2(19)	19(20)

multiplying this number by the length of the COD. If the hens did not always wait out the COD on a schedule before changing back to the other schedule the amount of time spent in the COD will have been overestimated (and the time post-COD underestimated) and, consequently, the rates of responding during the COD will have been underestimated (and those post-COD overestimated). Visual inspection of the event records taken suggest that any such errors will have been small as most CODs were completed before another changeover was made.

Overall there were no systematic differences between the local response rates during the CODs on the constant and the varied schedules. The differences ranged from fifty responses per minute more on the varied schedule to forty responses per minute more on the constant schedule but in 167 of the 180 cases the difference was less than twenty per minute in either direction. After the COD the local rates of responding tended to increase on the varied schedule as that schedule got richer. The local rates of responding after the COD on the constant schedule did not change consistently with changes in the reinforcement rate programmed on the other schedule.

From Table 2.4 it may be seen that the addition of a discriminative stimulus during the COD appears to have affected the local rates of responding during and after the COD on the constant schedule differentially. The rates of responding after the COD were essentially unchanged across experimental phases while those during the COD tended, particularly on the constant schedule, to be lower in those conditions in which the discriminative stimuli were programmed than in Baseline 1 conditions. The response rates during Baseline 2 conditions tended to lie between those from Baseline 1 and discriminative stimulus conditions. There were no consistent effects, across hens, on the rates of responding on the varied schedule.

The addition of blackout during the COD affected responding on both the constant and the varied schedule similarly (Table 2.4). The local rates of responding after the COD were essentially unchanged while those during the COD were, for all hens, generally lower in conditions for which blackout was programmed than for Baseline 1 conditions. The size of this reduction was variable but was around ten responses per minute on average with a maximum value of sixty responses per minute. However, only in the case of Hen 54 did responding during blackout approach zero (0.22-1.87 responses/min). The local rates of responding during the COD in Baseline 2 conditions were, overall, higher than those from blackout conditions and, sometimes, higher than those from the first baseline phase.

It can also be seen from Table 2.4 that in the second series of conditions the local rates of responding during the COD tended (154 out of 180 cases) to be lower than the rates of responding after the COD. It appears that experimental phase may have had a slight effect on this: A slightly higher proportion of cases were found during the blackout conditions. Higher local rates of responding after the COD rather than during the COD were found for only 59 of the 172 cases in the first series of conditions and there appeared to be no change in the incidence of this finding across phases.

Absolute Response Rates

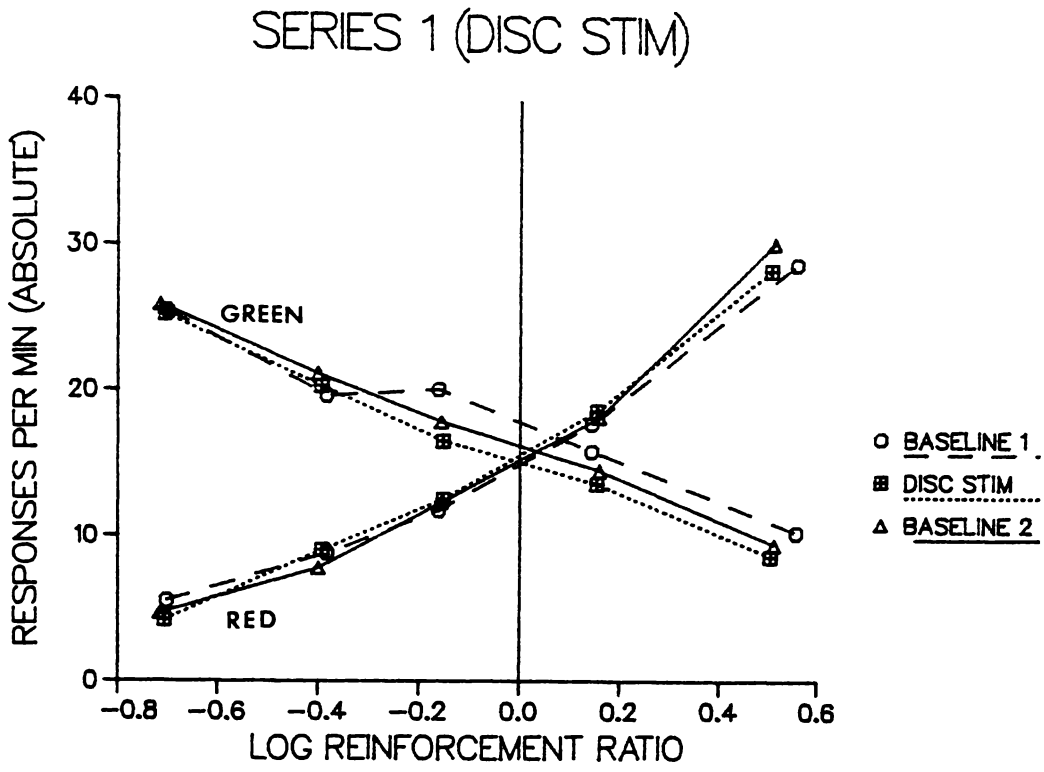
Figure 2.4 shows, for the group, the numbers of responses made per minute (over total session time) plotted against the log reinforcement rate (obtained) ratios. For all hens the absolute response rates increased on the varied schedule (red) and decreased on the constant schedule (green) as the log reinforcement ratios increased. The rates found varied within the range 3.0 to 30.0 responses per minute. There were no systematic differences across hens in response rates between Phase 2 (discriminative stimuli or blackout) conditions and baseline

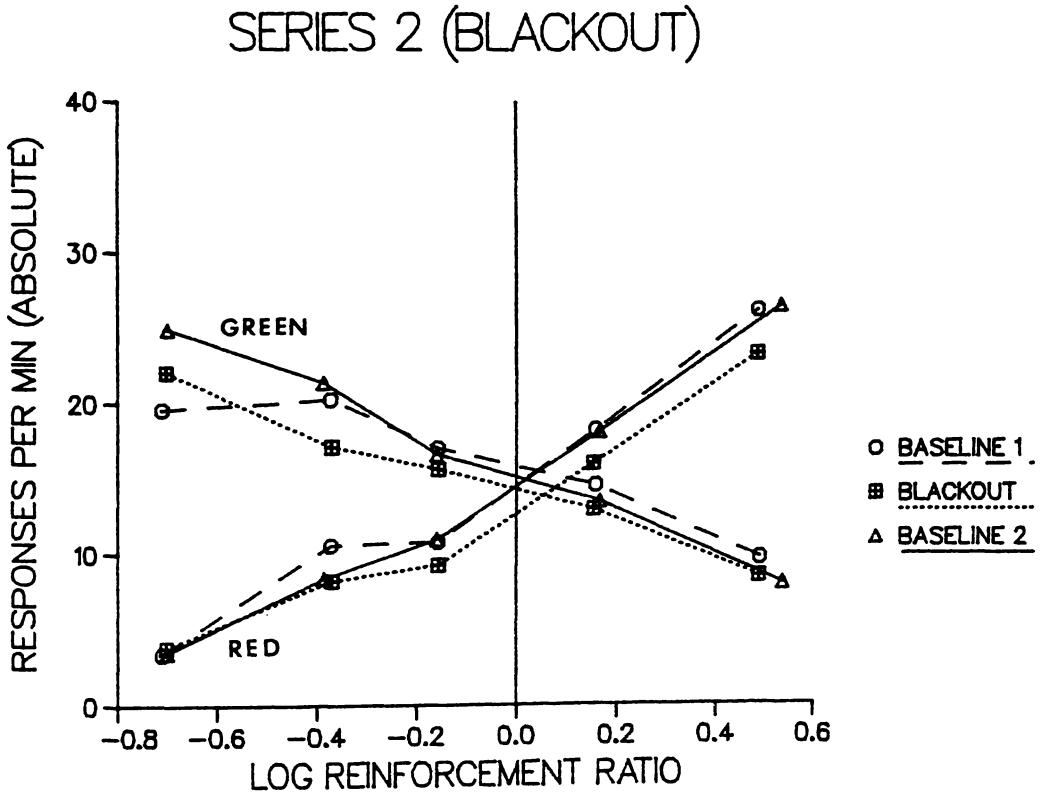
Figures 2.4 (a) and 2.4 (b)

The absolute rates of responding (number of responses made on a schedule divided by total session time) on the red (varied) and the green (constant) schedules plotted, for the group, against the logarithms of the ratios of obtained reinforcements.

a) Series 1 (discriminative stimulus)

b) Series 2 (blackout)


SERIES 1 (DISC STIM)
RESPONSES PER MIN (ABSOLUTE)
40
30
20
10
0
GREEN
RED
−0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6
LOG REINFORCEMENT RATIO
BASELINE 1
DISC STIM
BASELINE 2


SERIES 2 (BLACKOUT)
RESPONSES PER MIN (ABSOLUTE)
40
30
20
10
0
GREEN
RED
−0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6
LOG REINFORCEMENT RATIO
BASELINE 1
BLACKOUT
BASELINE 2

conditions.

Rate of Changeovers

Figure 2.5 presents the number of changeovers made per minute plotted against the absolute values of the log reinforcement ratios, for the group. These data are representative of those from each of the hens. Neither treatment phase (colours or blackout) changed changeover rates systematically across all hens and conditions. For all hens there was a tendency for the rates of changeover to decrease (around four per minute to approximately two per minute) as the rates of reinforcement obtained on the two schedules became more disparate (as the absolute values of the log reinforcement ratios increased from 0.00). The individual hens' rates ranged between 0.84 and 5.48 changeovers per minute. As the numbers of changeovers per minute decreased the interchangeover times also changed so that more time was spent on the richer schedule. The average interchangeover time, for the group, increased from around 12 seconds to approximately 30 seconds on the red (varied) schedule and decreased from around 60 seconds to approximately 10 seconds on the green (constant) schedule as the programmed rate of reinforcement on the red schedule was increased.

Proportion of Total Responses made during COD

Figures 2.6 (a) and 2.6 (b) present, for the group during each experimental phase, the proportions of the total responses on each schedule made during the COD, plotted against the log reinforcement ratios. In both series of conditions there was an overall decrease (from around 0.30-0.40 to approximately 0.15 for the individual data) in the proportion of the total responses made in the COD on the varied (red) schedule and a corresponding increase (from approximately 0.05 to around 0.45 for the individual data) on the constant (green) schedule, as the log reinforcement ratio increased.

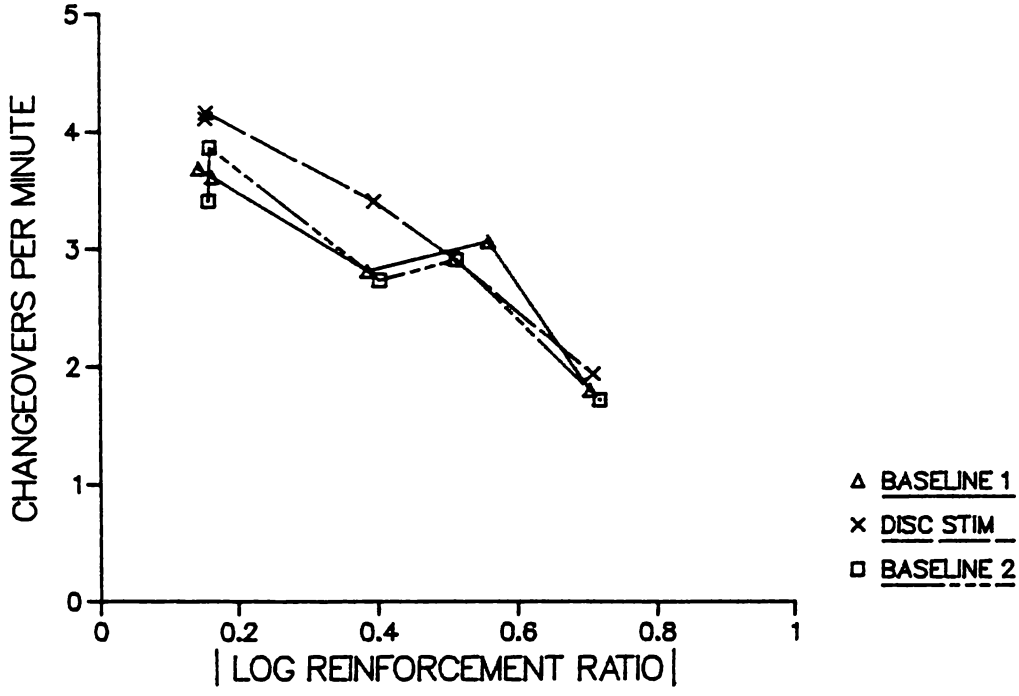
Figures 2.5 (a) and 2.5 (b)

The number of changeovers per minute plotted, for the group, against the absolute value of the logarithms of the ratios of the obtained reinforcements for each series of conditions. The data from Phase 1 (baseline) conditions are shown by triangles joined with a solid line, from Phase 2 (treatment) conditions by crosses joined with a dashed line, and from Phase 3 (baseline) conditions by squares joined with a dash-and-run line).

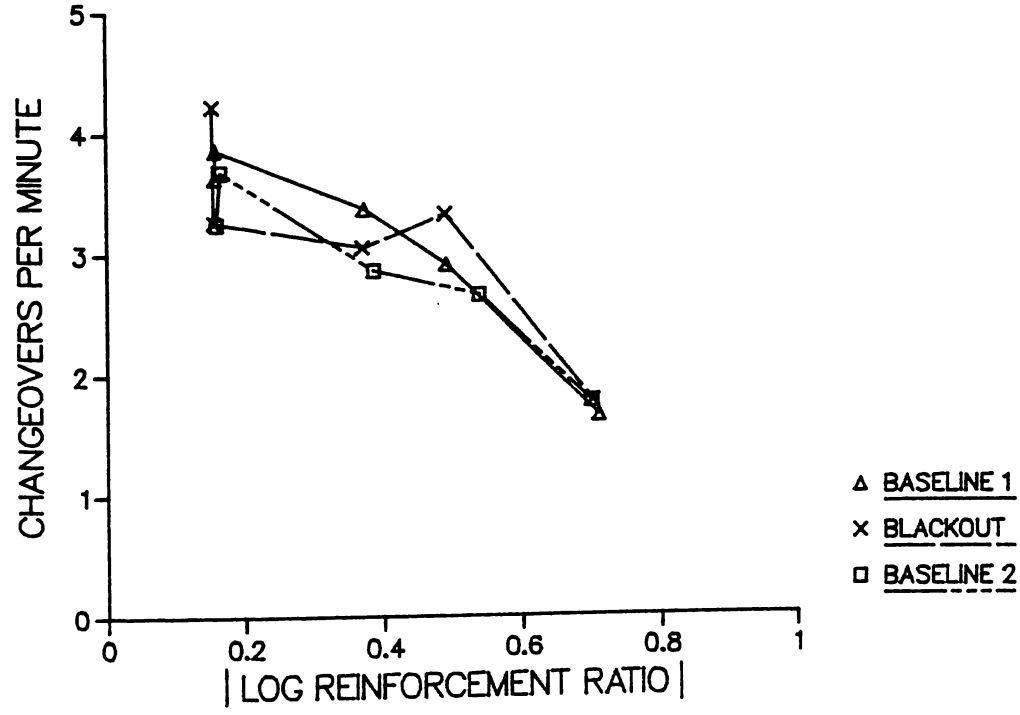
a) Series 1 (discriminative stimulus)

b) Series 2 (blackout)

A
SERIES 1



B
SERIES 2



Figures 2.6 (a) and 2.6 (b)

The proportions of the total responses which were made during the COD plotted, for the group and each experimental phase, against the logarithms of the ratios of obtained reinforcements.

a) Series 1 (discriminative stimulus): varied schedule

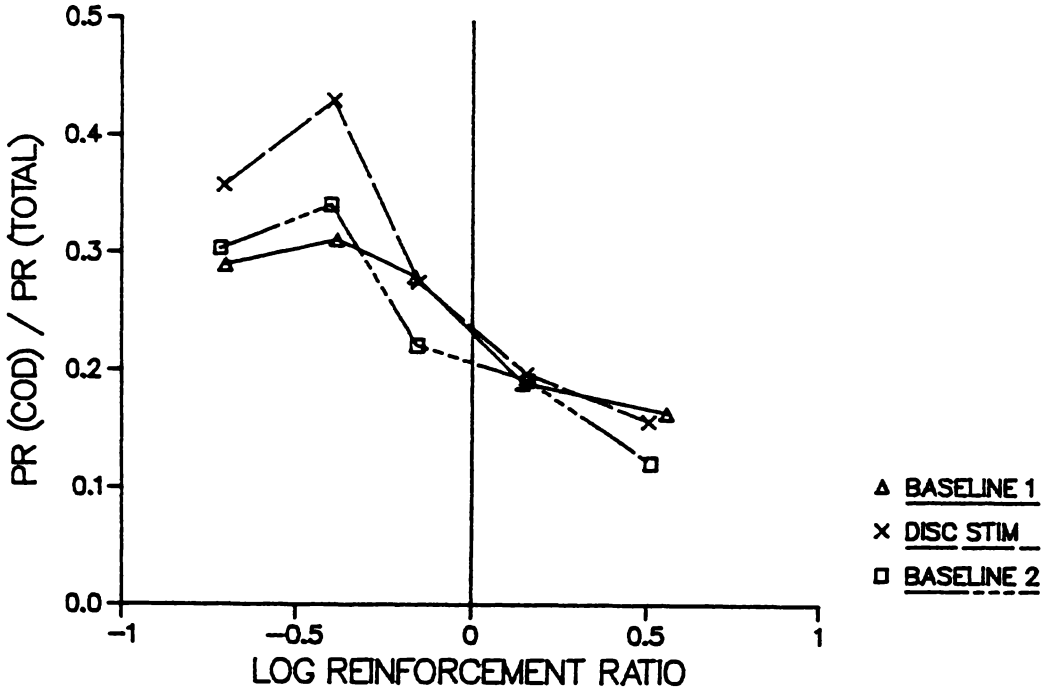
b) Series 1 (discriminative stimulus): constant schedule

c) Series 2 (blackout): varied schedule

d) Series 2 (blackout): constant schedule

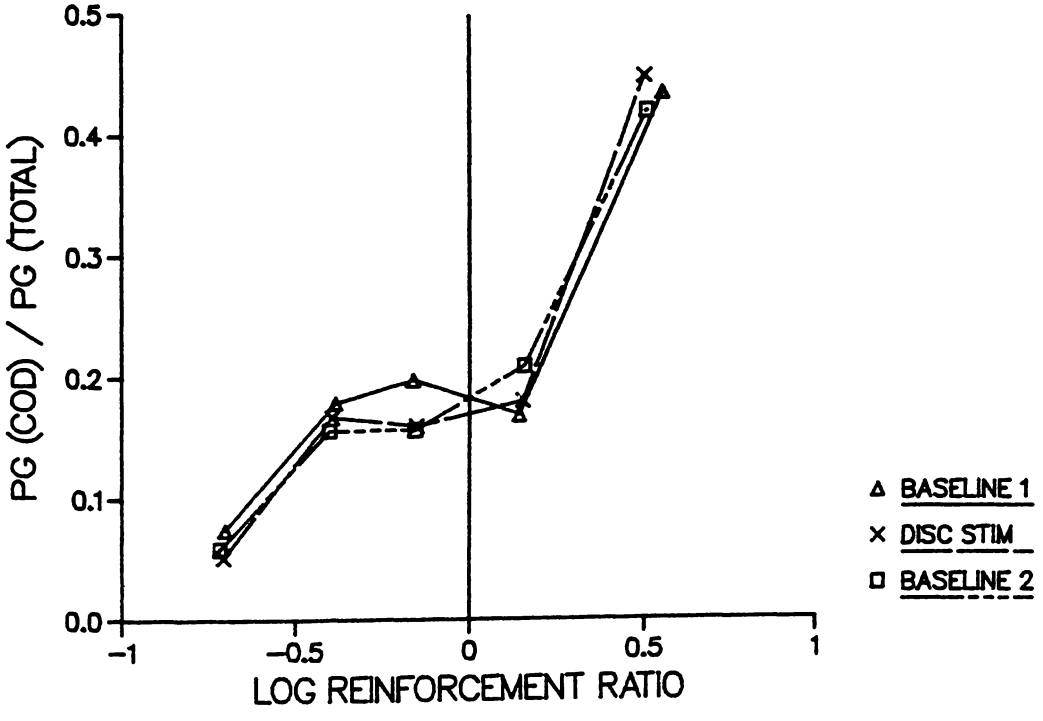
A

SERIES 1: VARIED SCHEDULE



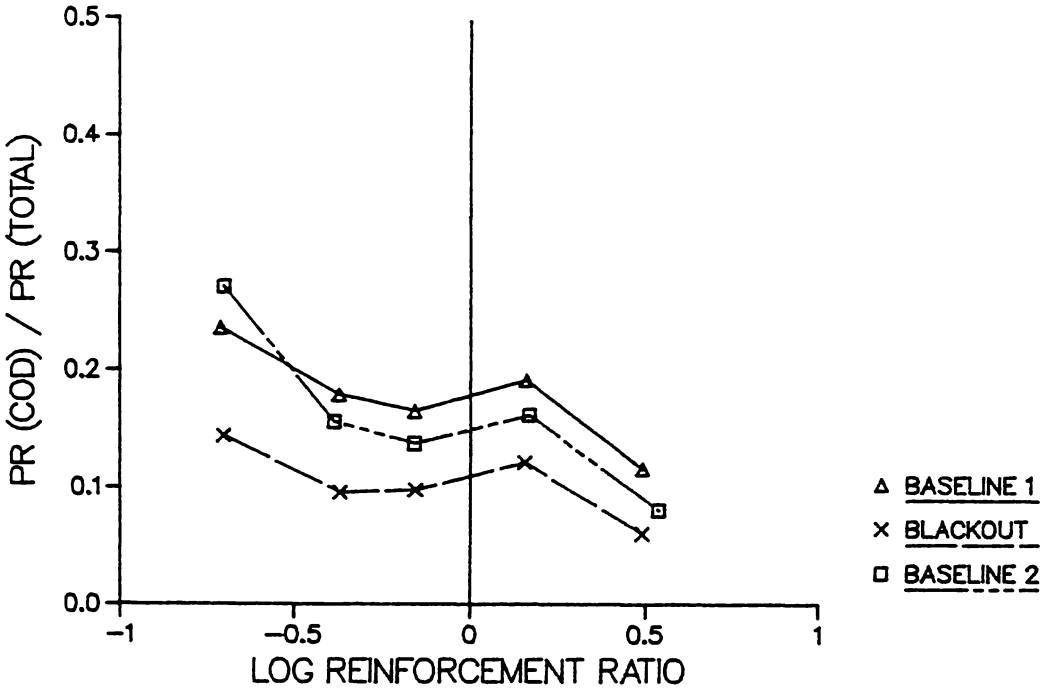
B

SERIES 1: CONSTANT SCHEDULE



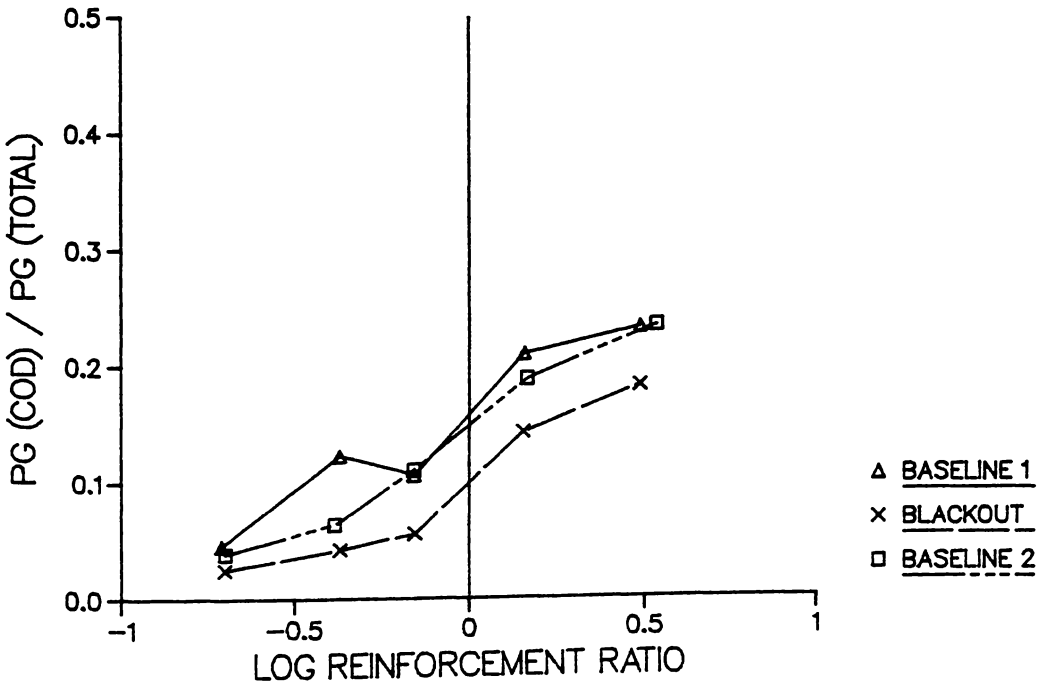
C

SERIES 2: VARIED SCHEDULE



D

SERIES 2: CONSTANT SCHEDULE



The addition of a discriminative stimulus during the COD did not have a consistent effect. Hen 52 was the only exception to this. Her data show a greater proportion of the total responses made on either schedule occurred in the COD when a discriminative stimulus was added to the COD.

The proportions of the total responses made which were made during the COD were lower for those conditions in which blackout during the COD was programmed than for baseline conditions. This was seen in the data for all hens except Hen 52 for whom this proportion was greatest in the blackout conditions for two schedule pairs (VI 30-sec VI 90-sec and VI 60-sec VI 90-sec).

Discussion

Effects of Adding Discriminative Stimuli

For all birds the addition of discriminative stimuli (distinctive key colours) during the COD increased the slopes of the lines fitted to the log response ratios as functions of the log reinforcement ratios. The effects on the log time ratios were generally similar but less pronounced. For all hens this effect carried over into the second baseline conditions. Adding discriminative stimuli appears to have increased the sensitivity to reinforcement rate but the effect does not survive changes in the schedules and is recoverable only when the stimuli are re-introduced.

Adding the discriminative stimuli did not change the proportion of responses made in the COD consistently (Figure 2.5 (a)). Nor was there any tendency for the sensitivity of responding during the COD (near zero) to be affected in a consistent manner for all hens, but four of the six showed decreased $\underline{a}$ values during treatment conditions (Table 2.2). This effect appears generally to have been recovered from in Baseline 2 conditions. It therefore is probably not a major contributor to the overall changes in $\underline{a}$ values found for total responding.

The responding after COD became consistently more sensitive to reinforcement compared with Baseline 1 when discriminative stimuli were added (Table 2.2 and Figure 2.3 (a)). Again this carried through to Baseline 2 conditions. Logically this must follow if the overall responding changes in sensitivity and there are no consistent changes in sensitivity during the COD. The added stimuli must have had their effect by changing responding after the COD. This changed post-COD response pattern appears to have persisted to some degree once the stimuli were removed.

The degree of overmatching shown in the post-COD responding is greatest from the conditions in which the discriminative stimuli were present. Further, the changes in sensitivity between the total response measures and the post-COD response measures are greatest for the discriminative stimuli conditions (Table 2.2).

The rate of changing between the two schedules was not affected consistently for all birds (or all schedule pairs) by the addition of the stimuli but there was a general tendency for the rate to increase (Figure 2.4). One possible explanation for the observed changes might be that the hens were more able to discriminate the end of the COD. This would lead to a greater likelihood of changeovers from the leaner schedule closely following the end of the COD. Whether or not this happened could not be established from the data since the number of CODs completed on a schedule was not collected and it was not, therefore, possible to make accurate measures of the times spent in and after the COD on a schedule. This is likely to vary not only with the rate of changeovers made but also with the times spent on each schedule post COD.

In conclusion, it appears that discriminative stimuli during the COD did affect the sensitivity of behaviour to the reinforcement rates. However it appears also that the cause may have been idiosyncratic to each hen. Because the schedules were arranged independently of each other the obtained reinforcement rates were free to vary. Thus different patterns of responding might result in different patterns of reinforcement delivery which, themselves, would help maintain the different response patterns.

The Effects of Blackout

For five out of six hens the addition of blackout during the COD had the effect of making the total response ratios more sensitive to the reinforcement rate ratios (Table 2.3 and Figure 2.1 (b)). This was similar to the effects found when discriminative stimuli were added. In contrast, all birds showed reduced sensitivity in the log time ratios (Table 2.3 and Figure 2.2 (b)). Again the effects on the response data carried over to the second baseline conditions which all showed greater sensitivity than did the original baseline conditions. The sensitivities of the log time ratios from the second baseline conditions increased from those found during treatment conditions to, or over, the original baseline sensitivities.

The exceptional response data came from Hen 52. For this bird the proportion of total session responses on either schedule made during the COD was not consistently lower in conditions where blackout was programmed than during baseline phases. For all other birds this proportion was consistently lower when blackout was programmed than during baseline conditions. There were no consistent differences, across hens, between the two baseline phases in the proportions of response made during the COD.

It is surprising, in view of the findings from previous studies employing blackout (e.g., Silberberg & Fantino, 1970), that responding did not (generally) stop during blackout in the present experiment. Although the keys were unlit and there were no scheduled consequences for responding (and there were no house lights) responding did still occur. There was some reduction (from Baseline 1 levels) in the rates of responding during the COD when blackout was added to the COD but only in the case of Hen 54 did response rates approach zero closely (Table 2.4). Hen 54's data do not seem exceptional in other measures. This responding during the COD blackout contrasts with the lack of responding observed

(anecdotal observation by three experienced observers) during the periods of blackout that began and ended the daily experimental sessions. Possibly because it is assumed animals will not respond during blackout response counters have often been disabled during periods of blackout (e.g., Todorov, 1971). However responding during the COD, as the stimuli presented in the COD were varied, was of particular interest in the present study. Therefore responses made during the COD blackout were recorded (and included in the total responses). Similarly the measure of time spent on a schedule included the time spent in blackout.

For all hens (including Hen 52) there appears to have been a decrease in the a values for responding in the COD when blackout was programmed. These changes did not consistently carry over to the second baseline conditions. However all a values for responding in the COD were close to 0.00. Responding during the COD remained insensitive regardless of experimental phase.

Responding after the COD did not change consistently in sensitivity across all hens. The group data give identical a values for both Baseline 1 and blackout conditions. Hen 52 (for whom the proportion of total responses which were made during COD was not consistently smaller under blackout conditions) showed reduced sensitivity in post-COD responding when compared with Baseline 1 and Baseline 2 phases. Hen 54 (whose responding virtually stopped during COD in blackout conditions) showed increased sensitivity to reinforcement in post-COD response measures compared with Baseline 1. Similarly to the previous (discriminative stimuli) data responding after the COD was more sensitive in Baseline 2 conditions than in Baseline 1 conditions, for all hens.

For all birds the post-COD responding was always more sensitive to the reinforcement rates than was the total responding. Again this follows logically from the fact that the COD responding was essentially

insensitive for both baseline and blackout conditions. When comparing the total responding with the post-COD responding it is clear that there were no consistent differences in the increases in sensitivity between the total and post-COD responding across baseline and treatment conditions. Blackout appears (except for Hen 54) not to have produced the expected level of reduction in COD responding.

The total response data from Hen 54 (essentially no responding in blackout) are not exceptional (all birds but Hen 52 showed increased a values for total responding). Hen 52 was exceptional in that her total response data showed less sensitivity when blackout was programmed than during Baseline 1. However her post-COD responding (less sensitive than baseline) was not uniquely exceptional. Nor were her time data.

It is difficult from these data to draw any simple single conclusions. As expected the blackout made total responding more sensitive to the reinforcement rates for the five (out of six) hens who consistently made proportionately fewer responses during the COD when blackout was programmed. Ignoring Hen 52's data four of the remaining five hens showed less change in sensitivity between total responding and post-COD responding in blackout conditions than during baseline. Again this follows logically if the contributions of the COD responses during blackout have reduced below baseline levels.

Changeover rates did not change consistently for all birds during blackout conditions. Therefore any changes in sensitivity must, again as was the case for the discriminative stimuli data, have occurred as differences in the post-COD patterns of responding. Again any effects found appear to have been produced in ways that were idiosyncratic to individual hens.

Comparison of the Effects of Discriminative Stimuli and Blackout

One problem with the interpretation of the results from this experiment lies in the slight but reliable changes which took place between the various baseline phases. In both series of manipulations the data from the second set of baseline conditions appear to show greater sensitivity to reinforcement than do those from the first. This applies most clearly to the log response ratios and is present, but less marked, for the log time ratios. It is independent of what changes in sensitivity to reinforcement took place in the intervening treatment phases. It is often assumed that baseline responding will be recoverable. In this experiment conditions were run with one pair of schedules and baseline, stimulus manipulation, and return-to-baseline conditions were run before the schedules were changed. One possible explanation for the changes may lie in the existence of a weak effect of stimulus changes which changes behaviour and lasts through changing of stimuli but does not carry over to new conditions when the reinforcement rates are changed. This conclusion is confused, however, by the data from the blackout conditions in which total responding for Hen 52 became less sensitive during blackout than during Baseline 1 but responding during Baseline 2 was (like that of all other birds) more sensitive than that during Baseline 1.

In all cases the changes in the sensitivity of total responding and post-COD responding between the first baseline and treatment conditions were greater for the discriminative stimuli conditions than for the blackout conditions. Unfortunately these were nearly all (11 out of 12 cases) in the same direction (increases). In this sense the two treatments are more similar than might have been expected if the discriminative stimuli and blackout had had different effects on responding in their presence. Since responding did not (in five out of six cases) stop during blackout it is perhaps better to regard it in

this case as another form of discriminative stimulus which had a reducing effect on responding in its presence for most birds. Neither blackout nor the discriminative stimuli acted as a punisher since the changeover rates did not reduce (cf. Todorov, 1971). Both appear to have weak effects on responding which carry over into the immediately following condition. Both appear to have these effects in the post-COD period.

The two manipulations differed in their effects on the times spent on the two schedules. The effects of discriminative stimuli on times spent on each schedule were similar (but less pronounced) to those on responding. Blackout, however, reduced the sensitivity to reinforcement of the times spent on the schedules for all hens (including Hen 52). This suggests that the effects on all behaviours are not identical. Birds probably stay proportionately longer on the leaner schedule post COD when blackout is programmed during the COD than they do when discriminative stimuli are programmed or "normal" conditions prevail. When discriminative stimuli are programmed during the COD it is possible that the hens stay for a proportionately shorter time post COD on the leaner schedule than they do under the standard procedure.

The goodness of fit of the lines, as measured by both r^2 and Sy.x, did not change consistently with any manipulation. The generalised matching law provided an equally good description of the data regardless of experimental phase (and the changed values of $\underline{a}$).

The data do not, sadly, provide full tests of the original ideas on the possible effects of stimuli in the COD. No one of the three suggested effects of stimuli in the COD was found for any of the conditions. Even blackout did not have clear effects. This lack of any consistent effect might be due to two possibilities. The first is that the COD period was still not able to be discriminated, and the second is that it already was discriminable and the addition of stimuli did not

add to this. Bourland and Miller's (1978) finding that response rates during the COD were greater when a changeover response (Findley procedure) resulted in the usual concomitant stimulus change along with the change of schedule than when no stimulus change occurred is in line with the second suggestion: The key colours associated with the schedules (and their changing) already signal the COD period (the COD may already be quite discriminable without the addition of extra stimuli).

When the COD was made more discriminable the sensitivity of COD responding generally did not change but that of post-COD responding did. In one sense the post-COD responding in this experiment is analogous to the schedule responding when, say, a (longer) changeover ratio is programmed. In both cases the COD (or the changeover time and changeover responding) are clearly discriminable from the schedule responding. Both procedures find overmatching in post-COD or post-COR measures. "Normal" post-COD responding (e.g., Experiment 1 or baseline conditions from the present experiment) also shows overmatching. The treatment conditions generally show more. It is possible that these treatments and the longer CORs are similarly increasing the overmatching in the post-COD or post-COR responding both by separating the periods on the schedules when reinforcement is delivered further in time and by making this separation highly discriminable.

General Findings

Despite the confusing effects of the main variable(s) manipulated in this study there are some findings common to all phases and conditions which relate to previous experimental findings. First, the slopes of the lines fitted to the log response (total) ratios and to the log time ratios, as a function of the log reinforcement ratios, were generally less than 1.00 (particularly for the data from the first phases). Second, responding during the COD periods was insensitive to

the changes in the reinforcement rate ratios (regardless of the stimuli presented during the COD). Third, the slopes of the lines fitted to the log ratios of the post-COD responses, as a function of the log reinforcement ratios, were steeper than those fitted to the log ratios of the total responses. These findings add to the generality of the results from the first experiment in that they involved a CO-key procedure instead of the two-key procedure used in the first experiment, another COD value (within the range of those programmed in the first experiment), a different range of scheduled rates of reinforcement, (and even a different strain of hen).

The slopes of the lines fitted to the data obtained in the present experiment (with a 3-sec COD) were comparable with those found at any COD value other than no COD in Experiment 1. The use of a CO-key procedure appears not to have changed this aspect of the data in spite of the requirement that at least one effective main-key peck occur between changeovers. Of course under a two-key procedure main-key pecks must necessarily occur between changeovers since they define them. It is possible under the CO-key procedure to allow more than one response on the CO-key (and hence more than one changeover) without a main-key response (e.g., Stubbs and Pliskoff, 1969) but this procedure is an even greater departure from the more commonly used two-key procedure.

EXPERIMENT 3

The sensitivity of behaviour to the reinforcement rate ratios on conc VI VI schedules is usually estimated by varying the reinforcement rate ratios and keeping the COD constant (e.g., Experiment 1). When the logarithms of the behaviour ratios are plotted against the logarithms of the obtained reinforcement ratios the slope of the fitted line provides an estimate of the sensitivity to changes in the reinforcement rate ratios and the intercept an estimate of bias (Baum, 1974b). Although the effects on behaviour of varying the reinforcement rate ratios are well known (e.g., Baum, 1979; de Villiers, 1977) and appear to be little disturbed by procedural variations (Wearden and Burgess, 1982) it is not clear that manipulations of the COD will have such consistent effects.

Experiment 1 found greater sensitivity to reinforcement rate when a COD was programmed than when no COD was programmed, but little systematic change as the COD was increased from 2 to 15 seconds. In contrast to the procedure used in Experiment 1 most previous studies which have varied the length of the COD have held the schedules constant. Some of these studies (e.g., Brownstein & Pliskoff, 1968; Shull & Pliskoff, 1967; Silberberg & Schrot, 1974) reported increasingly closer approximations to "matching" with increased COD duration while others (e.g., Allison & Lloyd, 1971; Silberberg & Fantino, 1970; Stubbs & Pliskoff, 1969) did not.

Charman and Davison (1982) have shown that changing the component durations in multiple VI schedules has different effects on performance depending on whether or not the relative reinforcement rates are held constant. They found that when the relative reinforcement rates were varied the sensitivity of behaviour to these changes did not change significantly with changes in the component durations. However, when the relative reinforcement rates were kept constant (but unequal) and the

component durations varied the sensitivity to reinforcement increased as the component durations decreased. This effect did not, however, survive a reversal of the schedules. It is possible that the COD may have a similarly "weak" effect on concurrent VI VI schedule performance, and that the effects of COD duration found when the relative reinforcement rates are held steady will differ from those found when the relative reinforcement rates are varied.

One problem with interpreting the data from those studies which have varied the COD length using constant relative reinforcement rates is that there were many procedural differences between them. These included the range of COD values, the type of reinforcer (brain stimulation or food delivery), the type of schedules (variable interval or variable time), whether the schedules were arranged independently of each other, whether the schedules were equal or unequal, and whether a two-key or CO-key procedure was used. However, no particular procedure seems to be associated with a particular outcome, although the effect of any one of the procedural variables cannot be isolated because they were not varied systematically. If the effect of the COD is weak then it seems likely that its effect might be disrupted also by changes other than changes in the relative rate of reinforcement. The inconsistent findings reported might, possibly, be explained by the fact that the COD may have a weak effect. One of the aims of the present study was, therefore, to provide data collected when only the COD was varied, to compare with the data from Experiment 1 (which were incomplete when this experiment began).

The data reported by Shull and Pliskoff (1967) suggested that the degree of matching observed with a particular COD programmed might improve if in the meantime the animal was exposed to larger COD values (with unequal schedules). They found that the degree of matching observed increased as the COD was increased from 0 to 20 seconds but

that when the COD was then reduced the degree of matching observed remained relatively high and did not return to its previous level at that COD value. No other studies have varied the COD first in an ascending series and then in a descending series. Typically the subjects have been exposed to each COD value only once. A second aim of the present study was to look at whether behaviour on concurrent schedules with a particular COD programmed changed with experience of other COD values.

The present experiment kept the schedules constant (unequal concurrent VI VI schedules) while varying the size of the COD programmed (from no COD to a COD of 12 seconds). This sequence of COD values was to be repeated as necessary until behaviour appeared stable between repeated conditions. The schedules were then reversed on the keys and the sequence repeated once more.

Method

Subjects

Six domestic hens (Ross Tints), numbered 81 through 86, served. They were 12 months old at the start of the experiment. Their management was as described for Experiment 1.

Apparatus

The experimental chamber was as described for Experiment 1 and the control and recording equipment as described for Experiment 2.

Procedure

Pre-Training. Each hen had had approximately two weeks as a subject in an undergraduate laboratory course during which they were magazine trained and then trained to peck a single lit key under various schedules of reinforcement. They had no other experimental experience. Preparation for this study involved one day's exposure (in order) to each of concurrent VI 15-sec VI 15-sec, VI 30-sec VI 30-sec, and VI 30-sec VI 60-sec schedules. The schedules were arranged independently of each other and no COD was programmed.

Experimental Conditions. Standard two-key independent concurrent scheduling was in effect throughout. The schedules programmed were VI 30-sec VI 120-sec for the first two series of conditions (Conditions 1 to 6, and 7 to 12) and VI 120-sec VI 30-sec for the third series (Conditions 13 to 18). Within each series of six conditions the same sequence of increasing COD values was programmed. No COD was programmed for the first condition of each series. Over the next five conditions CODs of 1, 2, 4, 8, and 12 seconds (in that order) were programmed.

Sessions, which began and ended (after 40 reinforcements) in blackout were conducted seven days a week. The hens were run in the same order each day. Each condition was in effect until the data from all six hens had met the stability criterion described previously, and visual inspection showed no trends. The calculation of the five-day medians during Condition 2 included the last four days' data from Condition 1. The minimum period the condition could be in effect under this arrangement was 10 days (instead of 14). This practice was not continued in later conditions.

The order of the conditions, the schedule and COD values involved, and the number of days each condition was in effect are shown in Table 3.1. The last condition (Condition 18) was not continued until the behaviour of all hens had stabilised because the supply of the reinforcer (kibbled wheat) was exhausted. Hens 85 and 86 had satisfied the stability criterion four and three times respectively. All other hens had satisfied the criterion the required five times.

Responses made and times spent, on each schedule, were both totaled over the session and over the periods when the COD was in effect. Also recorded were the reinforcements obtained on each schedule, the number of changeovers, and the number of times the hen stayed on each schedule at least until the COD had finished. Event records were taken for all hens on at least one of the last five days of each condition.

Table 3.1

The order of conditions, the schedule and COD values programmed, and the number of days each condition was in effect.

Cond	Series	VI Sched (sec) left	VI Sched (sec) right	COD (sec)	Days in Effect
1	1	30	120	none	33
2				1	12*
3				2	21
4				4	22
5				8	25
6				12	16
7	2	30	120	none	39
8				1	17
9				2	16
10				4	55
11				8	18
12				12	20
13	3	120	30	none	34
14				1	34
15				2	21
16				4	48
17				8	51
18				12	16**

* It was possible to satisfy the stability criterion in ten days. For all other conditions the minimum period was 14 days.

** Hens 85 and 86 had not satisfied the stability criterion five times (four and three times respectively).

Results

The last five days data from all conditions and all hens are given in Appendix 3.1. The sums of the daily data over the last five days of each condition were used in all analyses. Figures 3.1 to 3.10 were drawn from these summed data. The group data were obtained by summing the data from all hens over the last five days of each condition.

The series of experimental conditions was repeated only once before reversing the schedules on the keys. On the basis of the daily plots of the proportions of total responses made on the VI 30-sec schedule (the data which were used to determine stability within each condition) it appeared (to three experienced observers) that the behaviour observed at each COD value during the first series of conditions was essentially replicated in the second and that, therefore, there were no trends in the data which might suggest further changes would occur with repeated exposure to the COD values. Of course, it is possible that other measures of behaviour (e.g., the proportion of time spent or of reinforcements obtained) were trending. However, inspection of the daily data suggests this was not the case and that by the time the stability criterion (based on total responses) had been met the required number of times other (related) measures of behaviour appeared stable.

Although the (total) response data were plotted as proportions for stability assessment the relative performance measures based on the data summed over the last five days of a condition are presented, in Figures 3.1-3.4, in log ratio form. All ratio measures were taken to the key on which the VI 30-sec schedule was presented. All logarithms were to the base 10. This method of presentation makes visible any changes occurring in the distribution of behaviour between the two schedules which, when the distribution is extreme, would be hidden if the data were presented as proportions.

Using ratio measures has meant that, for individual hens, some differences in performance based on the different series of conditions do show at the larger COD values (8 and 12 seconds). However, although these differences are large in terms of the changes in the ratios (and their logarithms) they represent very small changes in the proportions. It has also meant that the data from some conditions could not be plotted because the log ratios were infinite since responding (summed over the five days) was exclusive. This occurred for Hen 82 who, during the first series of conditions, responded exclusively on the richer schedule when the COD was four seconds or greater. (Since her responding remained exclusive on a return to no COD in Condition 7 she was given one day's training, on the 12th day in this condition, with extinction programmed on the left key.) No other hens responded exclusively on the richer schedule. However, for Hens 81, 85, and 86 (as well as for Hen 82), under some conditions all responses made after the COD (and, therefore, all reinforcements obtained) were on this schedule. For these conditions the log ratios of the post-COD responses and of the reinforcements obtained could not be plotted. Although such exclusive data were excluded from the analyses of the individual hens' data (because the log ratios were infinite) they were included in the group data.

The COD programmed was not increased beyond 12 seconds because at this COD value responding was very nearly exclusive to the richer schedule for all hens. The proportion of total responses made on the richer schedule, summed over the last five days of each of the 12-sec COD conditions, ranged between 0.92 and 1.00 (except for Hen 86 in the third series of conditions). Even when these summed data were not exclusive responding was sometimes exclusive within individual sessions. Once behaviour is exclusive no further changes can be expected to show in the data (expressed in ratio terms) with further increases in the COD.

Total Responses and Times

Figures 3.1 (a) and 3.1 (b) present the log ratios of the total responses made and the times spent, on the two schedules, plotted against the COD value, for all hens and each series of conditions. There are several data points missing for Hen 82 because, as already mentioned, she responded exclusively on the VI 30-sec schedule during the first series of conditions when the COD was 4 seconds or greater. All other hens spent some time and made some responses on both schedules at all values of the COD.

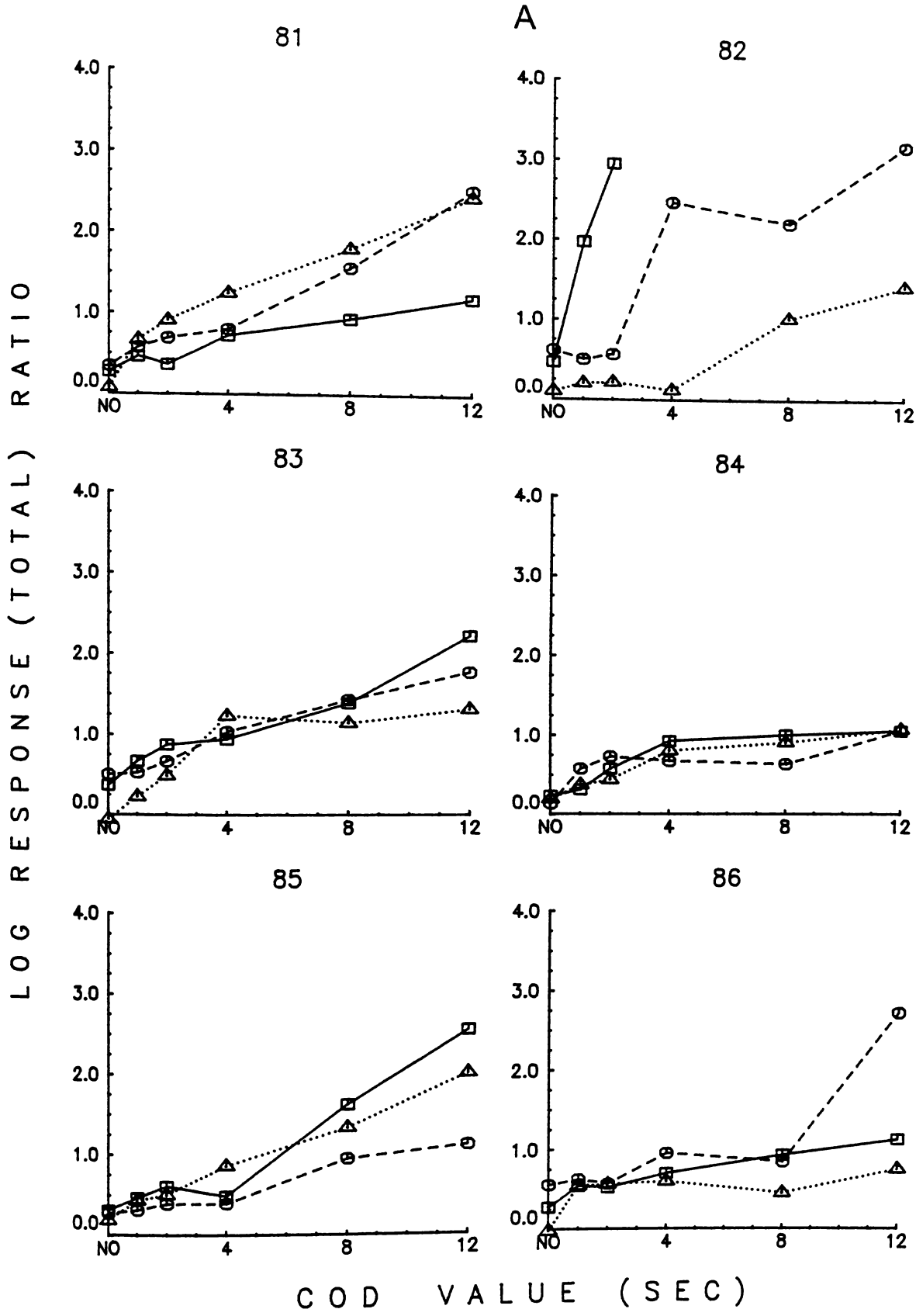
Figures 3.1 (a) and 3.1 (b) show that for all hens and each series of conditions the log ratios of the total responses made (Figure 3.1 (a)) and the log ratios of the times spent (Figure 3.1(b)) increased as the COD value increased. There were no consistent differences in the way the log ratios increased with COD between the three series of experimental conditions. There was considerable variation, between the data from the individual hens and from the different series of conditions, in the size of the log ratios and the extent of the increases. With no COD programmed the log ratios obtained ranged between -0.05 and 0.61 for the response data and between 0.02 and 0.77 for the time data. With a 12-sec COD programmed these ranges were 0.74 to 3.19 and 0.73 to 2.97, respectively. The log response ratios based on the group data, and averaged across the three series of conditions, increased from 0.25 with no programmed COD to 0.49, 0.58, 0.79, 1.01, and 1.33 with CODs of 1, 2, 4, 8, and 12 seconds, respectively. The log time ratios based on the group data, and averaged across the three series of conditions, increased from 0.35 with no COD to 0.51, 0.66, 0.94, 1.15, and 1.46 with CODs of 1, 2, 4, 8, and 12 seconds, respectively. At each COD value the log ratio of the times spent was greater than the log ratio of the total responses made for these group data. From Figures 3.1 (a) and 3.1 (b) it can be seen that, for

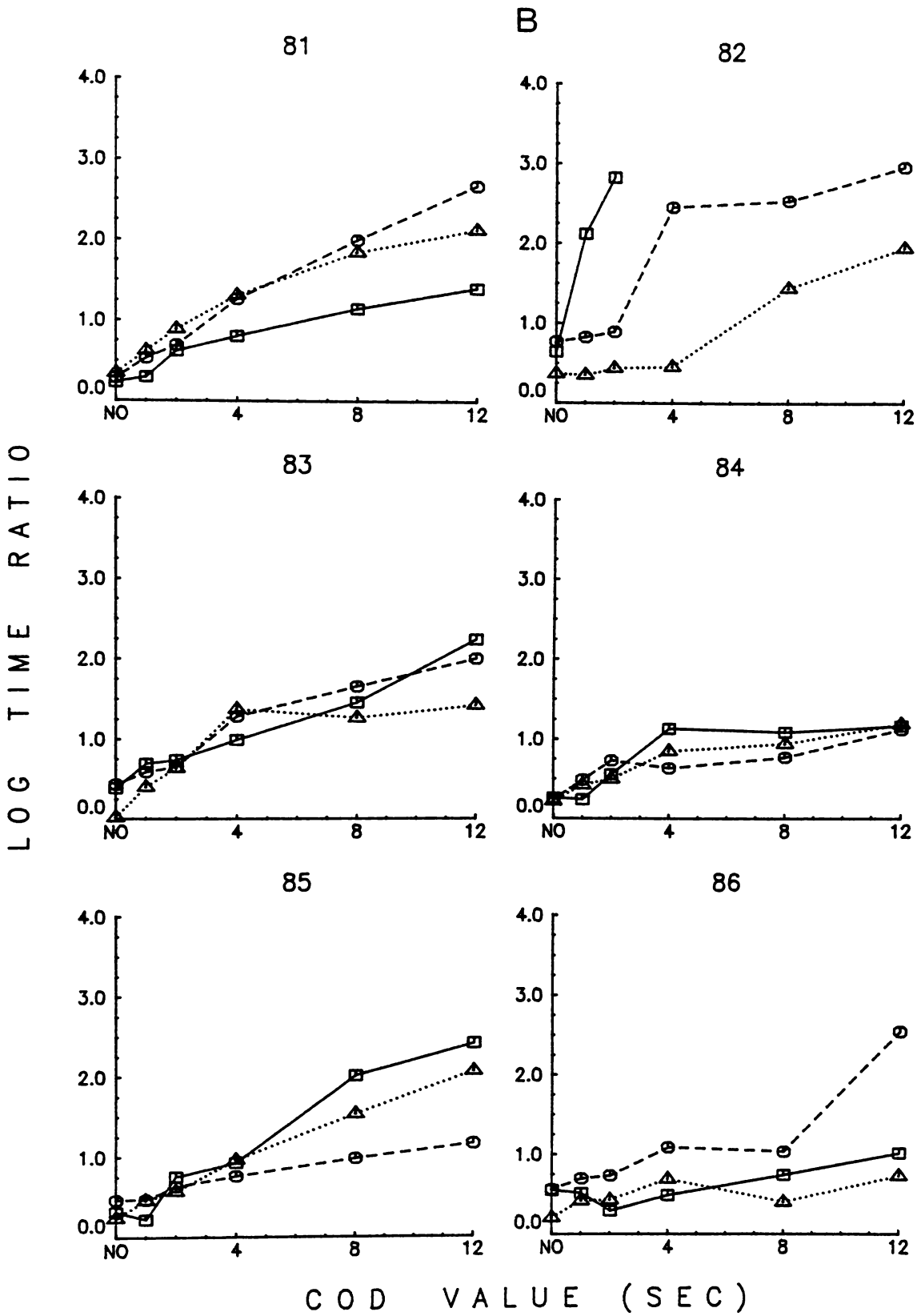
Figures 3.1 (a) and 3.1 (b).

The logarithms of the ratios of responses made and of times spent plotted against COD value, for each hen. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line. Some data are missing because the log ratios were infinite.

a) responses made

b) times spent


A
81
82
83
84
85
86
4.0
3.0
2.0
1.0
0.0
NO
4
8
12
LOG RESPONSE (TOTAL) RATIO
COD VALUE (SEC)


B
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12
LOG TIME RATIO
COD VALUE (SEC)

individual hens, the log ratios of the times spent tended to equal or exceed the log ratios of the total responses made on the schedules at all COD values (the exception was the first series of conditions for Hen 86).

Responses during the COD

The log ratios of the responses made on the two schedules during the COD are plotted, for each hen and each series of conditions, against COD value in Figure 3.2. Three data points are missing for Hen 82.

There were no consistent changes, across hens and series, in the log ratios of the responses made during the COD periods as the COD increased. The log ratios varied around 0.00. The range of the log ratios obtained from the individual hens' data (and, in brackets, the log ratios from the group data averaged over the three series) were -0.27 to 0.27 (0.07) with a 1-sec COD, -0.39 to 0.25 (-0.05) with a 2-sec COD, -0.65 to 0.31 (-0.18) with a 4-sec COD, -0.38 to 0.24 (-0.07) with a 8-sec COD, and -0.24 to 0.84 (0.00) with a 12-sec COD.

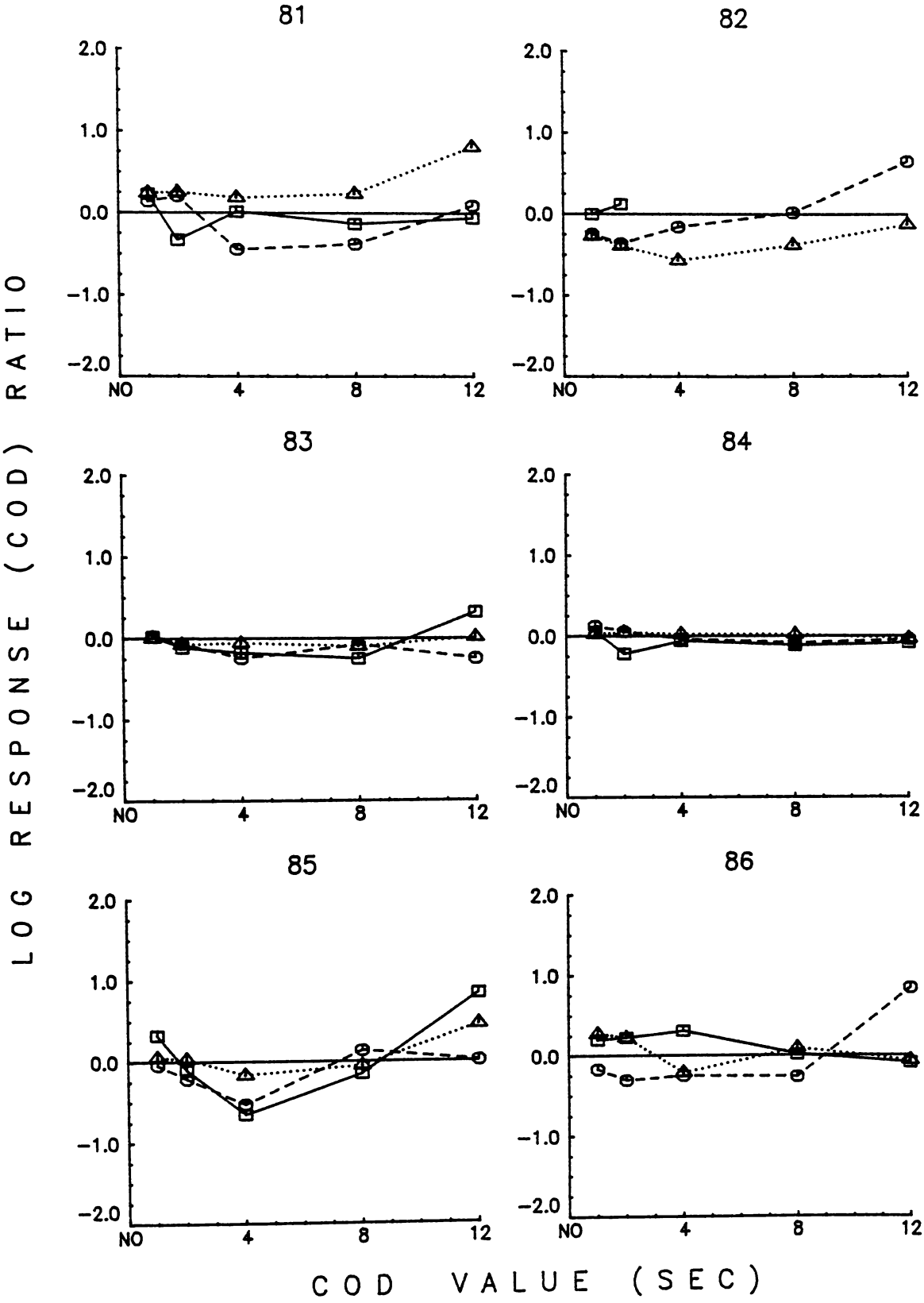
Responses after the COD

Figure 3.3 shows the log ratios of the responses made after the COD plotted against the COD value, for all hens and all series of conditions. The data points missing for some conditions for Hens 81, 82, 85, and 86 in Figure 3.3 could not be plotted because these hens responded exclusively on the VI 30-sec schedule after the COD during these conditions.

In every case the log ratios of the responses made after the COD increased as the COD increased (Figure 3.3). Although for any individual hen there were differences between the series of conditions overall there were no consistent differences. For the group data the log ratios of the post-COD responses, averaged across series, were 0.67 with a 1-sec COD, 0.91 with a 2-sec COD, 1.28 with a 4-sec COD, 1.51 with an 8-sec COD, and 1.95 with a 12-sec COD. The ranges of log ratios from the

Figures 3.2

The logarithms of the ratios of COD responses plotted against COD value, for each hen. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line. Some data are missing because the log ratios were infinite.


81
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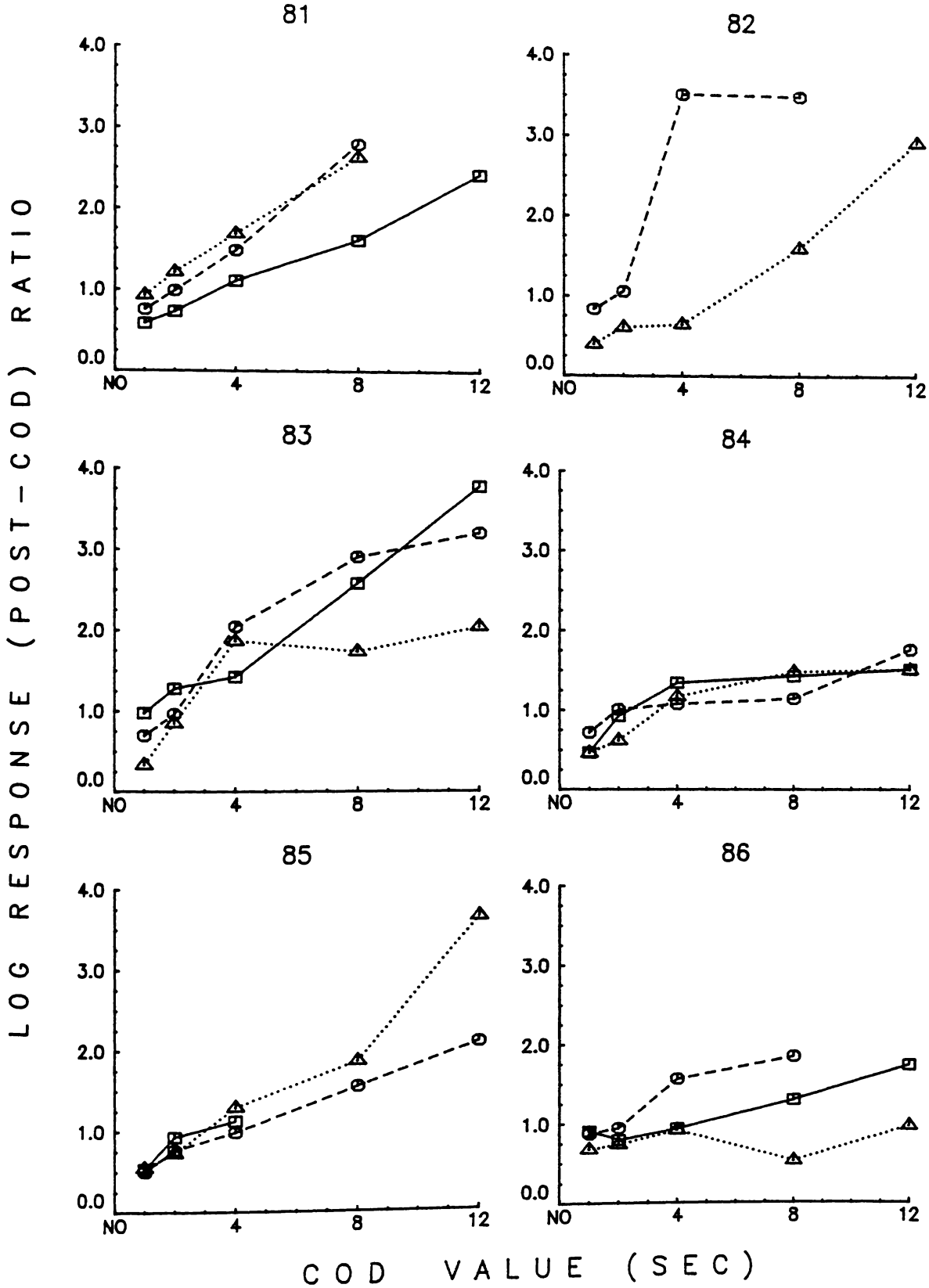
-1.0
-2.0
NO
4
8
12
LOG RESPONSE (COD) RATIO
COD VALUE (SEC)

Figures 3.3

The logarithms of the ratios of post-COD responses plotted against COD value, for each hen. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line. Some data are missing because the log ratios were infinite.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NO
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LOG RESPONSE (POST-COD) RATIO
COD VALUE (SEC)

individual hens' data, for the respective COD values, were 0.33 to 0.98, 0.61 to 1.28, 0.65 to 3.52, 0.53 to 3.50, and 0.97 to 3.79. In all cases the log ratios of the responses made after the COD were larger than the log ratios of the total responses.

Obtained Reinforcements

Figure 3.4 presents the log ratios of the reinforcements obtained on the schedules, for all hens and all series of conditions, plotted against COD value. Hens 81, 82, 85, and 86 obtained all their reinforcements on the richer schedule in some conditions (typically at the larger COD values). The reinforcement rate data from these conditions could not be plotted.

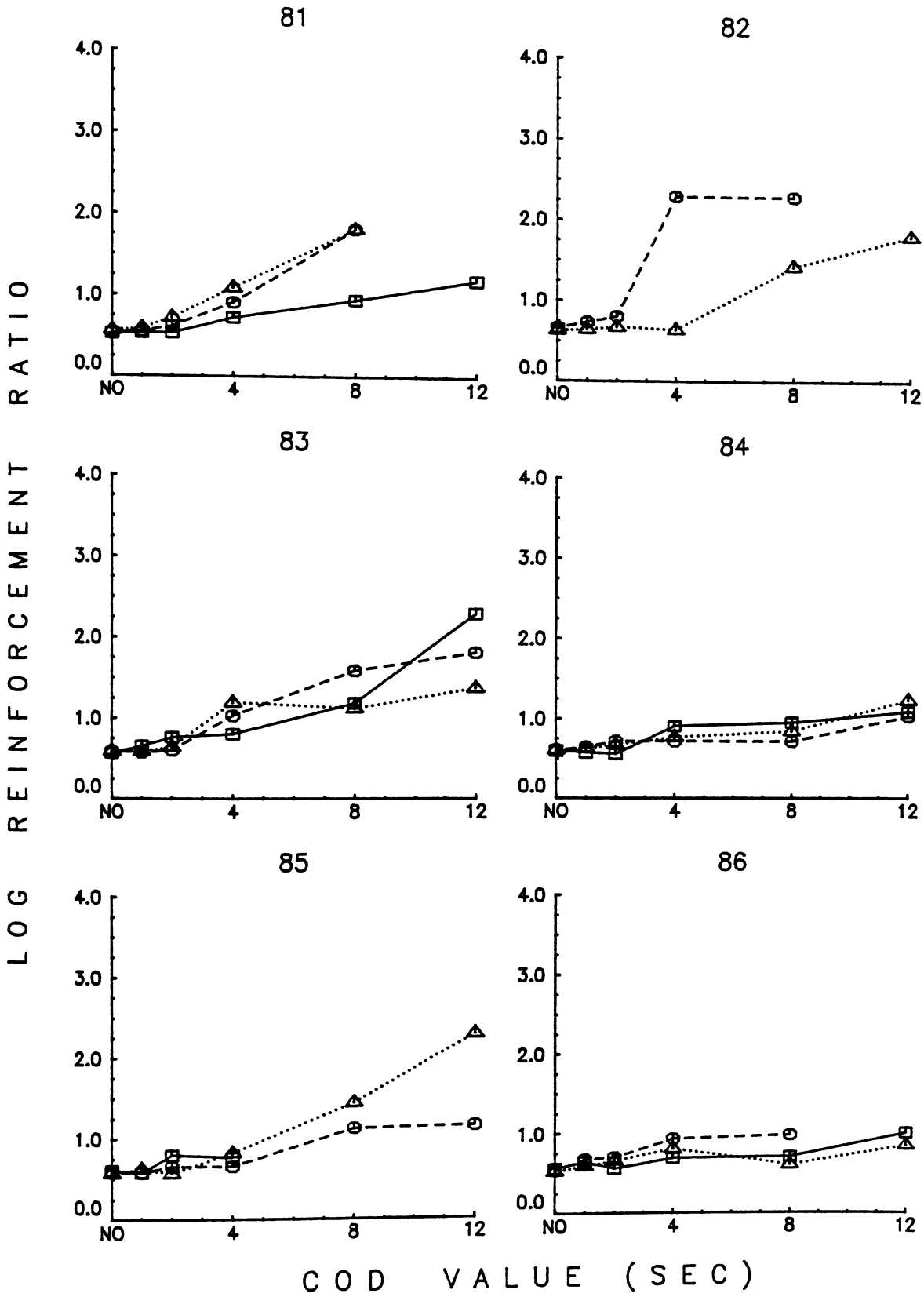
From Figure 3.4 it can be seen that the log ratios of the reinforcements obtained increased, in every case, as the COD increased. There were no consistent differences, across hens and series, apparent. For the group data the log ratios of obtained reinforcements, averaged across the three sequences, increased from 0.58 with no programmed COD to 0.64 with a 1-sec COD, 0.69 with a 2-sec COD, 0.88 with a 4-sec COD, 1.12 with an 8-sec COD, and 1.44 with a 12-sec COD. The ranges of the log ratios obtained from the individual hens' (nonexclusive) data were 0.52 to 0.66, 0.53 to 0.73, 0.53 to 0.81, 0.64 to 2.30, 0.60 to 2.30, and 0.85 to 2.30.

The Relation between Behaviour and Reinforcement Rates

Point Estimates. Figures 3.5 (a), (b), and (c) present, for all hens and all series of conditions, the values of the exponents (a) relating the log ratios of the behaviour (total responses, times, and post-COD responses respectively) to the log ratios of the obtained reinforcement rates (Equation 0.4), plotted against COD value. Bias was assumed to be negligible. Where either behaviour or reinforcements occurred exclusively on the richer schedule a was unable to be estimated

Figures 3.4

The logarithms of the ratios of obtained reinforcements plotted against COD value, for each hen. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line. Some data are missing because the log ratios were infinite.


81
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3.0
2.0
1.0
0.0
NO
4
8
12
LOG REINFORCEMENT RATIO
COD VALUE (SEC)

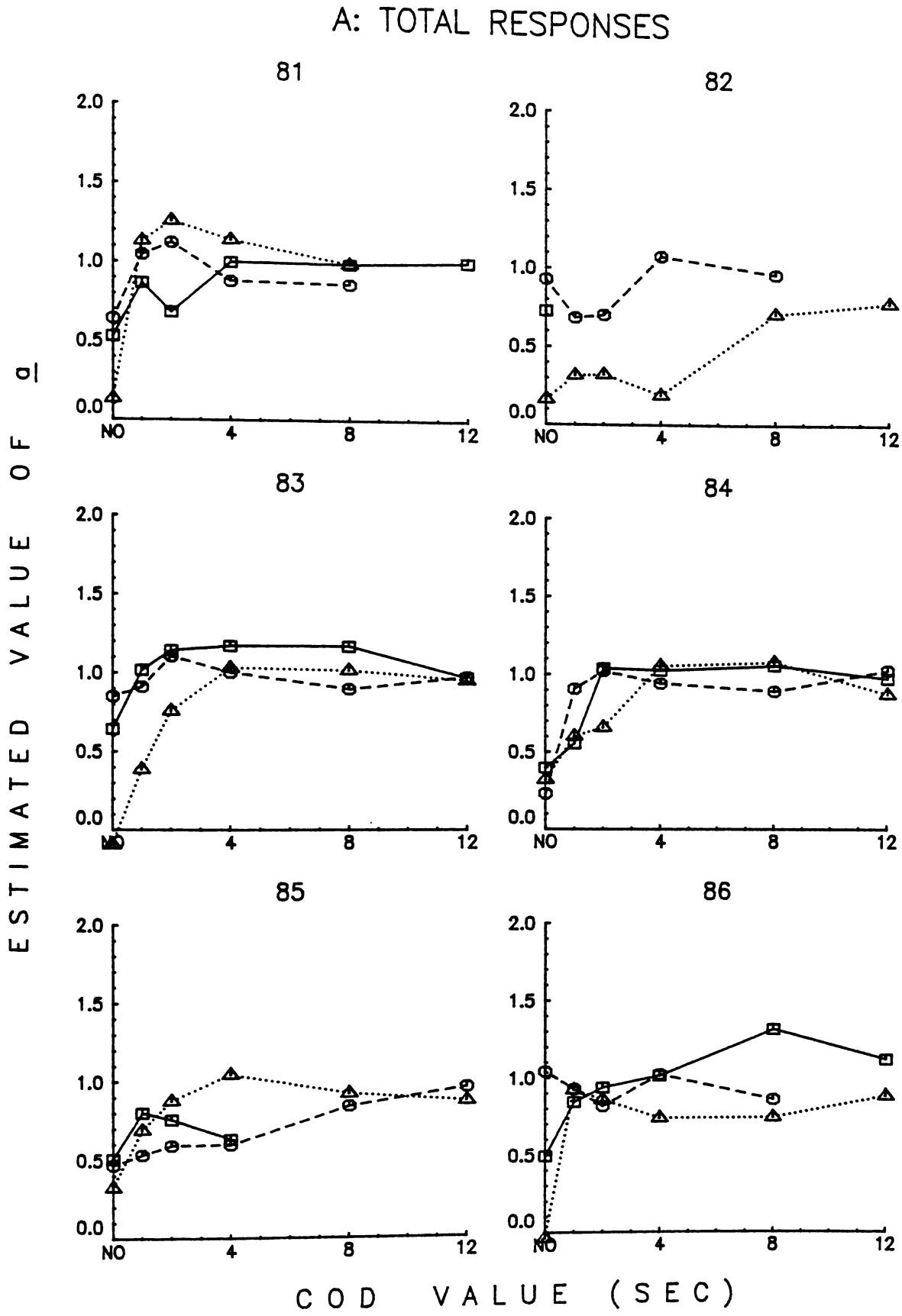
Figures 3.5 (a) to 3.5 (c)

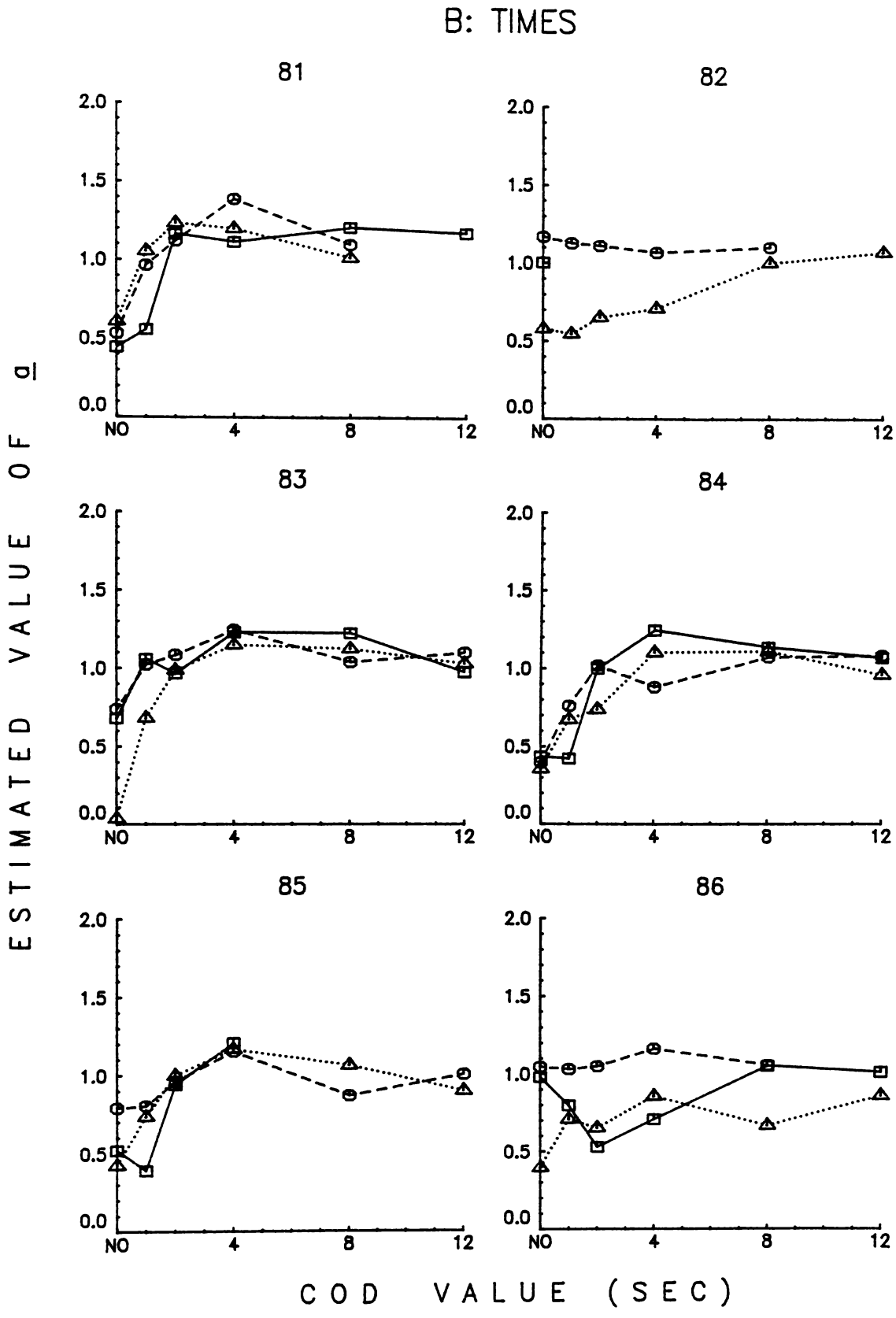
Point estimates of $\underline{a}$ (Equation 0.4) relating the logarithms of the ratios of total responses, of times spent, and of post-COD responses to the logarithms of obtained reinforcement rates (assuming bias to be negligible), plotted against COD value for each hen. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line. Some data are missing because the log ratios were infinite.

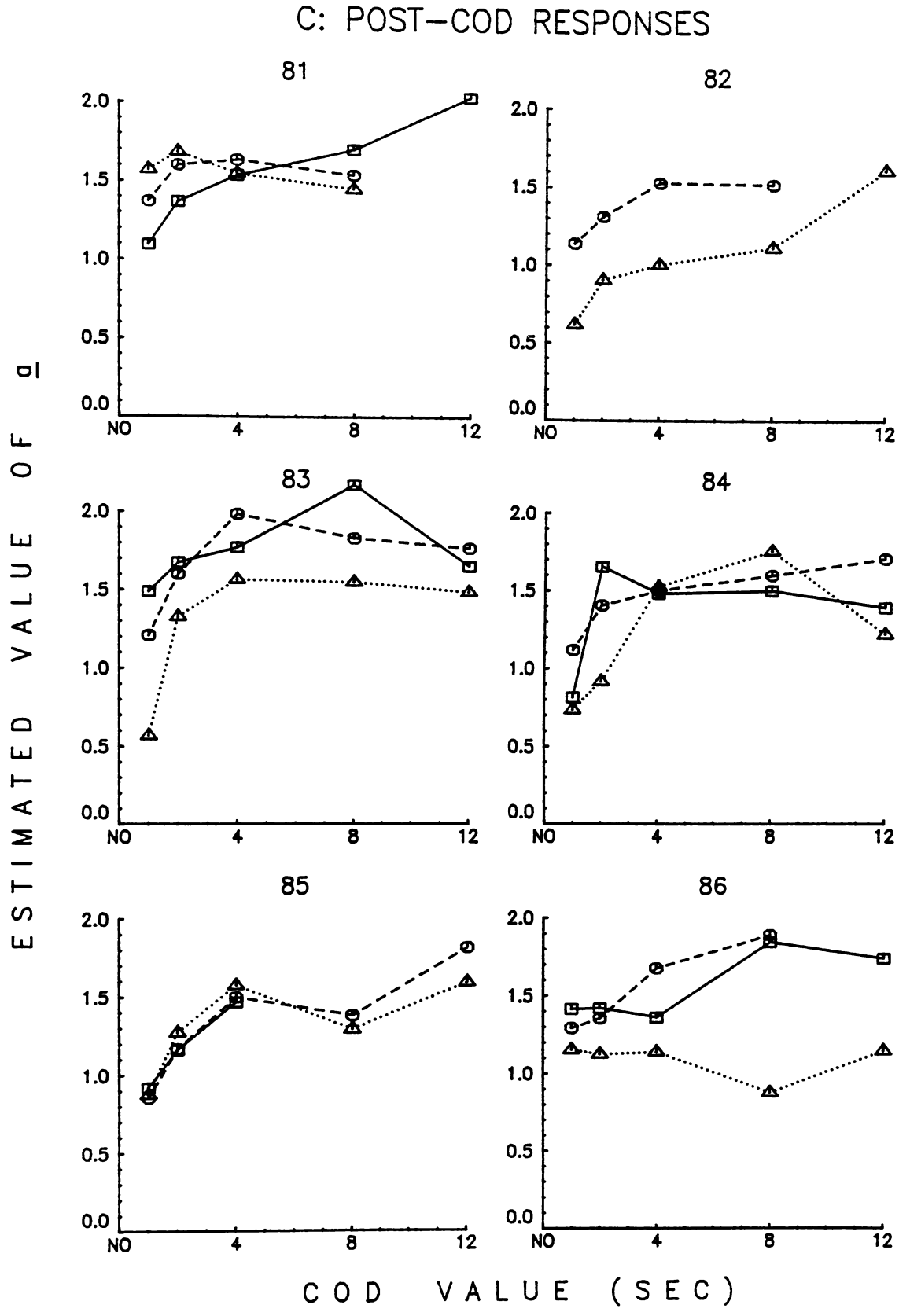
a) total responses

b) times spent

c) post-COD responses


A: TOTAL RESPONSES
81
82
83
84
85
86
2.0
1.5
1.0
0.5
0.0
NO
4
8
12
ESTIMATED VALUE OF a
COD VALUE (SEC)


B: TIMES
81
82
83
84
85
86
2.0
1.5
1.0
0.5
0.0
NO
4
8
12
ESTIMATED VALUE OF a
COD VALUE (SEC)


C: POST-COD RESPONSES
81
82
83
84
85
86
2.0
1.5
1.0
0.5
0.0
NO
4
8
12
ESTIMATED VALUE OF a
COD VALUE (SEC)

and, consequently, some data points could not be plotted.

From Figures 3.5 (a), 3.5 (b), and 3.5 (c) it can be seen that the way in which the point estimates of $\underline{a}$ (based on the total responses made, the times spent, and the responses made after the COD, respectively) changed with COD varied between hens and, for any hen, between the series of conditions. However, none of these differences were consistent across all hens or all series.

Overall, the point estimates of $\underline{a}$ based on total responses or times spent (Figures 3.5 (a) and 3.5 (b)) were lowest when no COD was programmed. When a COD was programmed the point estimates tended to increase initially with COD value and then to remain at this level or to decrease slightly as the COD increased further. The estimates tended to stabilise at a value around 1.00. Within the range of the COD values studied there was no tendency apparent for the point estimates of $\underline{a}$ to change further with increases in the COD value. However, the COD values at which the highest point estimate of $\underline{a}$ were obtained varied from no COD to a COD of 12 seconds, and the maximum estimates themselves varied between 0.73 and 1.39.

At the larger COD values (four seconds or greater) and when no COD was programmed the point estimates of $\underline{a}$ based on the log ratios of the times spent tended to exceed those based on the log ratios of the total responses made (in 50 of 63 comparisons). When the COD was one or two seconds long there were no systematic differences between the point estimates based on the log time ratios and those based on the log response ratios.

The only consistent difference in the exponents from the different series of conditions occurred when the schedules were first reversed on the keys (with no COD programmed). The exponents obtained from the log response ratios under these conditions (range -0.09 to 0.32) were lower, in the case of five of the six hens, than those obtained when no COD was

programmed in the first two series of conditions (ranges 0.40 to 0.73 and 0.23 to 1.04, respectively). Generally this difference did not persist once a COD was programmed nor was it so apparent in the log ratios of the times spent. From Figures 3.5 (a) and 3.5 (b) it can be seen that only for Hen 82 was there a systematic difference, across COD values, between the point estimates of a (whether based on total responses or times spent) obtained from the "reversal" series and the earlier series of conditions.

Figure 3.5 (c) shows that the estimates of a based on the log ratios of the responses made after the COD were generally greater than 1.00 and greater than the estimates based on either the log ratios of the total responses (Figure 3.5 (a)) or the log ratios of the times spent (Figure 3.5 (b)). There was considerable variation, across hens and series, in both the sizes of the point estimates and the ways in which they changed with COD value. There appeared to be no consistent differences, across hens, between the estimates of a derived from the post-COD data obtained in the first two series of conditions. However, the estimates derived from these data obtained when the schedules were reversed on the keys were lower at all COD values for three of the six hens.

Line Estimates. It was possible, at each COD value, to fit lines to the log response ratios (total and post-COD) and to the log time ratios as a function of the log reinforcement ratios, for each hen (because the schedules were reversed on the keys in the third series of conditions). The slopes and intercepts of the fitted lines are presented in Table 3.2. Lines could not be fitted to the data from Hens 81 and 82 when the COD was 12 seconds because there were too few data points (the log ratios of the obtained reinforcements from two of the series of conditions were infinite).

Table 3.2

The slopes and intercepts of the lines fitted to the log ratios of total responses, times spent, and responses made after the COD as a function of the log ratios of the obtained reinforcement ratios, for each hen at each of the COD values.

	COD Value											
	No COD		1-sec		2-sec		4-sec		8-sec		12-sec	
Hen	slp	int	slp	int	slp	int	slp	int	slp	int	slp	int
TOTAL RESPONSES												
81	0.35	0.12	1.05	-0.05	1.12	-0.11	1.05	-0.10	0.94	-0.06	*	*
82	0.50	0.21	0.51	0.13	0.53	0.14	0.88	0.45	0.87	0.22	*	*
83	0.33	0.25	0.69	0.17	0.95	0.12	1.05	0.02	1.00	0.01	0.97	0.01
84	0.32	0.00	0.68	0.04	0.84	0.12	1.02	-0.03	1.04	-0.04	0.93	0.07
85	0.41	0.05	0.68	-0.01	0.78	-0.06	0.85	-0.16	0.89	-0.05	0.90	0.07
86	0.37	0.21	0.90	-0.01	0.86	0.00	0.88	0.11	0.89	0.12	1.01	0.11
TIMES												
81	0.55	-0.03	0.92	-0.08	1.19	-0.03	1.24	0.03	1.07	0.10	*	*
82	0.84	0.16	0.86	0.20	0.90	0.17	0.99	0.18	1.07	0.09	*	*
83	0.37	0.20	0.87	0.11	1.00	0.01	1.19	0.05	1.11	0.00	1.02	0.01
84	0.39	0.02	0.64	-0.02	0.87	0.09	1.11	-0.01	1.11	0.00	1.01	0.07
85	0.54	0.07	0.67	-0.04	0.97	-0.02	1.18	0.00	0.98	-0.12	0.93	0.08
86	0.71	0.16	0.82	0.06	0.75	0.05	0.94	0.04	0.89	0.13	0.94	0.07
POST-COD RESPONSES												
81			1.41	-0.10	1.61	-0.06	1.57	0.02	1.51	0.12	*	*
82			0.90	0.18	1.13	0.15	1.42	0.26	1.37	0.36	*	*
83			0.98	0.24	1.50	0.10	1.72	0.17	1.77	0.27	1.61	0.18
84			0.86	0.07	1.20	0.20	1.51	-0.01	1.64	-0.09	1.37	0.19
85			0.88	0.00	1.21	-0.03	1.53	-0.03	1.33	0.06	1.67	0.17
86			1.26	0.06	1.25	0.08	1.36	0.16	1.47	0.34	1.46	0.27

* Too few data points to fit a line.

The line estimates of *a* (Table 3.2) based on the log ratios of the total responses or on the log ratios of the times spent were lowest, for all hens, when no COD was programmed (the ranges were 0.32-0.50 and 0.37-0.84, respectively). When a COD was programmed the line estimates of *a* tended to increase with COD until they reached a peak (in the range 0.88 to 1.24). The line estimates then decreased slightly with further increases in the COD. This peaking of the estimates occurred when the COD was anywhere from 2 to 12 seconds, depending on the bird, and did not necessarily occur at the same COD values for the estimates based on the response data as it did for the estimates based on the time data (although there were no consistent differences in this between the two measures).

From Table 3.2 it can be seen that the intercepts of the lines fitted to the log ratios of total responses and to the log ratios of times spent were variable. For two of the hens (Hens 82 and 83) the intercepts were in the same (positive) direction at all COD values (range 0.00 to 0.45). For all other birds the intercepts varied to both sides of 0.00 (range -0.12 to 0.12) in a way that appeared unrelated to changes in the COD value programmed.

The line estimates of *a* based on the post-COD responses were, generally, greater than 1.00 (the four instances where they were not all occurred with a 1-sec COD) and were, in all cases, greater than the line estimates based on either total responses or times spent. Nevertheless, the line estimates based on the post-COD responses changed with COD in a similar manner to these other two line estimates. That is, the estimate increased to a peak value with COD and then decreased with further increases in the COD. The COD value at which the highest estimates of *a* were found varied between hens (from 2 seconds to 12 seconds). There appeared to be no pattern linking these COD values to those COD values at which the highest estimates based on either total responses or times

spent were found.

Rates of Changeover

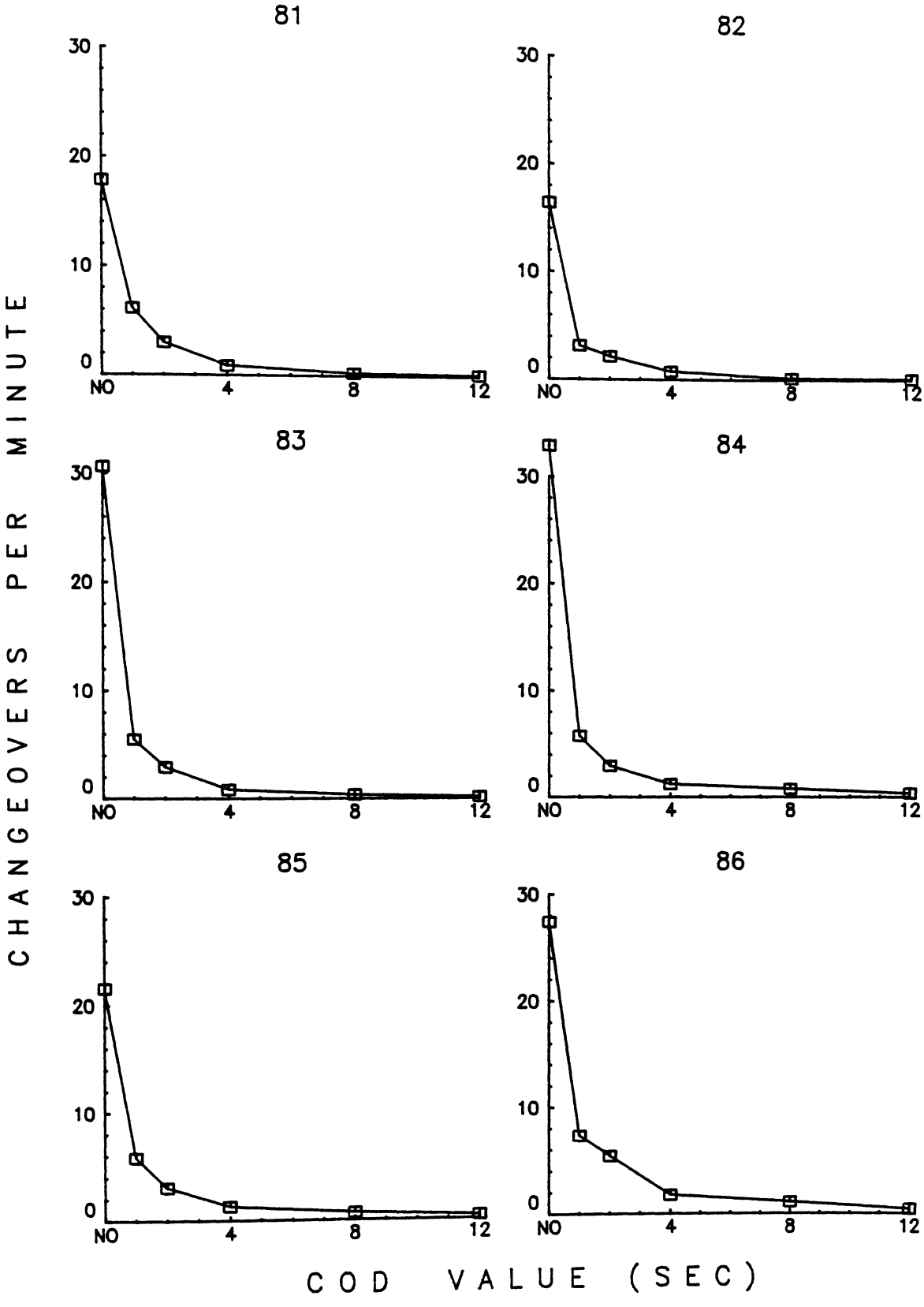
The rates of changeover between the schedules are presented, for each hen (averaged across the three series of conditions), in Figure 3.6. There were no consistent differences between the series of conditions. In all cases the numbers of changeovers made per minute decreased as the COD increased. For the group data, averaged across the three series, the number of changeovers per minute decreased from 24.65 with no programmed COD to 5.54, to 3.23, to 1.13, to 0.57, and to 0.26 with CODs of 1, 2, 4, 8, and 12 seconds, respectively. There was some variation, between hens and series, in the rates of changeover but this was most pronounced when no COD was programmed (and the rates of changeover were highest). The number of changeovers made per minute ranged between 9.30-46.36, 0.49-10.69, 0.06-9.36, 0.00-2.70, 0.00-1.55, and 0.00-0.66 when no COD and CODs of 1, 2, 4, 8, and 12 seconds were programmed, respectively.

Proportion of CODs Completed

The proportion of CODs on a schedule which were completed before another changeover was made are shown, for the group for each series of conditions, in Figures 3.7 (a) and 3.7 (b). There was, essentially, no change in the proportions of completed CODs on the richer schedule as the COD increased. On nearly all occasions (the range was 0.89 to 1.00) the hens stayed on the richer schedule at least until the COD was over. On the leaner schedule there was a tendency, as the COD got larger, to make proportionately more changeovers from a schedule before the COD on that schedule was over. The proportion of CODs completed on this schedule decreased from an average of 0.98 with a 1-sec COD, to 0.91 with a 2-sec COD, 0.89 with a 4-sec COD, 0.69 with an 8-sec COD, and to 0.61 with a 12-sec COD.

Figure 3.6

The number of changeovers per minute averaged across the three series of conditions and plotted, for each hen, against COD value.

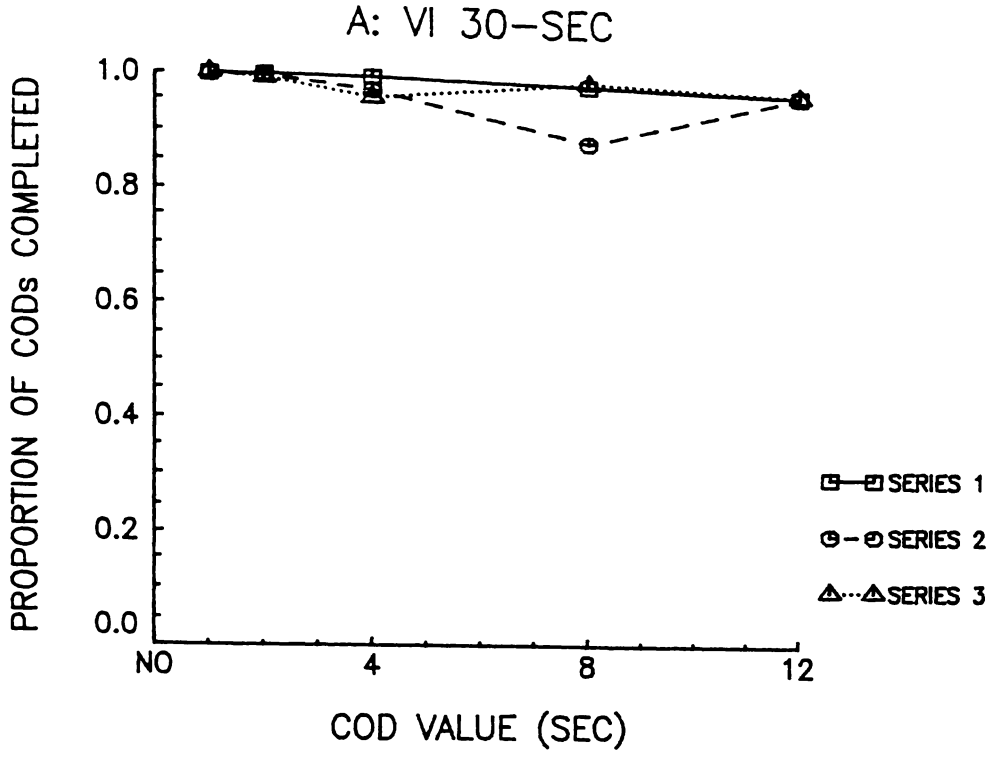

81
82
83
84
85
86
30
20
10
0
NO
4
8
12
CHANGEOVERS PER MINUTE
COD VALUE (SEC)

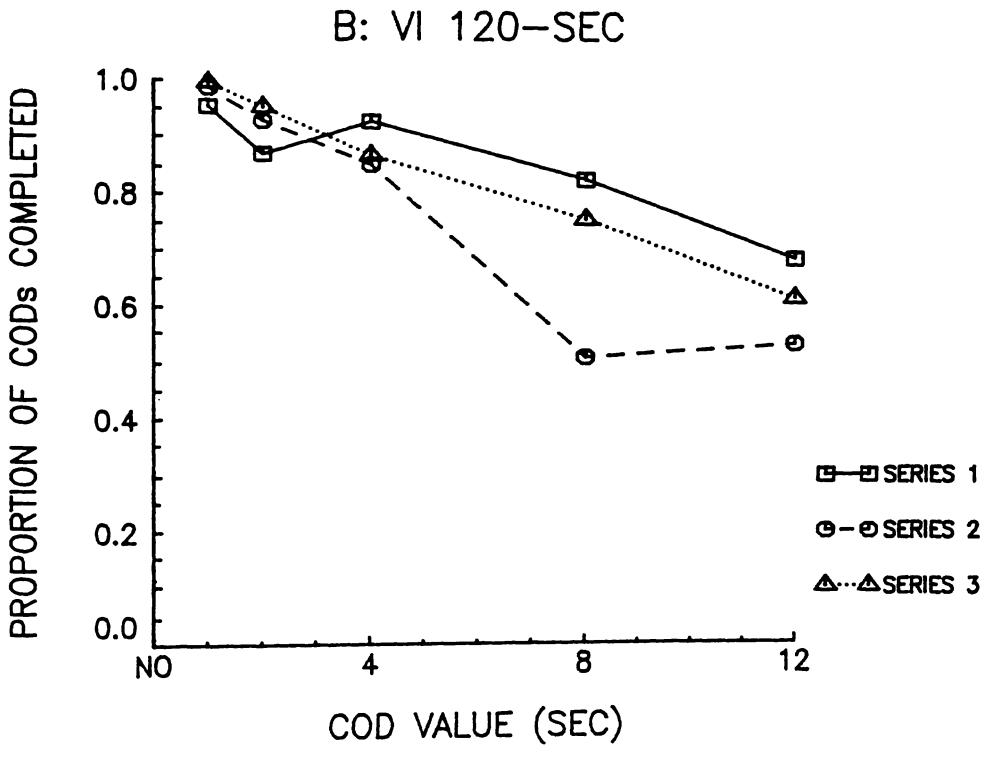
Figures 3.7 (a) and 3.7 (b)

The proportions, for the group, of the changeovers to a schedule in which the hen stayed on the schedule at least until the end of the COD plotted against COD value. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line.

a) VI 30-sec

b) VI 120-sec


A: VI 30-SEC
PROPORTION OF CODs COMPLETED
1.0
0.8
0.6
0.4
0.2
0.0
NO
4
8
12
COD VALUE (SEC)
SERIES 1
SERIES 2
SERIES 3


B: VI 120-SEC
PROPORTION OF CODs COMPLETED
1.0
0.8
0.6
0.4
0.2
0.0
NO
4
8
12
COD VALUE (SEC)
SERIES 1
SERIES 2
SERIES 3

Overall there were no consistent differences between the three series of conditions. The lower proportion of COD periods on the leaner schedule completed during the second series of conditions when the COD was eight seconds is not representative of what occurred for most of the hens. The group data were strongly affected by the data from two hens (Hens 83 and 86).

Times Spent in the COD

Figures 3.8 (a) and 3.8 (b) present, for the group and each series of conditions, the proportion of time spent on each schedule during which the COD was in effect, plotted against COD value. It can be seen that proportionately more time was spent in the COD on the VI 120-sec schedule than on the VI 30-sec schedule and that this difference became greater at larger COD values. The proportion of time on the richer schedule spent in the COD decreased slightly as the COD increased. Averaged across series this decrease was from 0.06 to 0.03. The proportion of time on the leaner schedule spent in the COD increased as the COD increased. The average increase was from 0.21 to 0.56 (at the longer COD values there was some variation between series in the size of this proportion). Overall, the proportion of total session time spent in the COD decreased slightly as the COD increased (from an average 0.10 with a 1-sec COD to 0.04 with a 12-sec COD).

Responses made during the COD

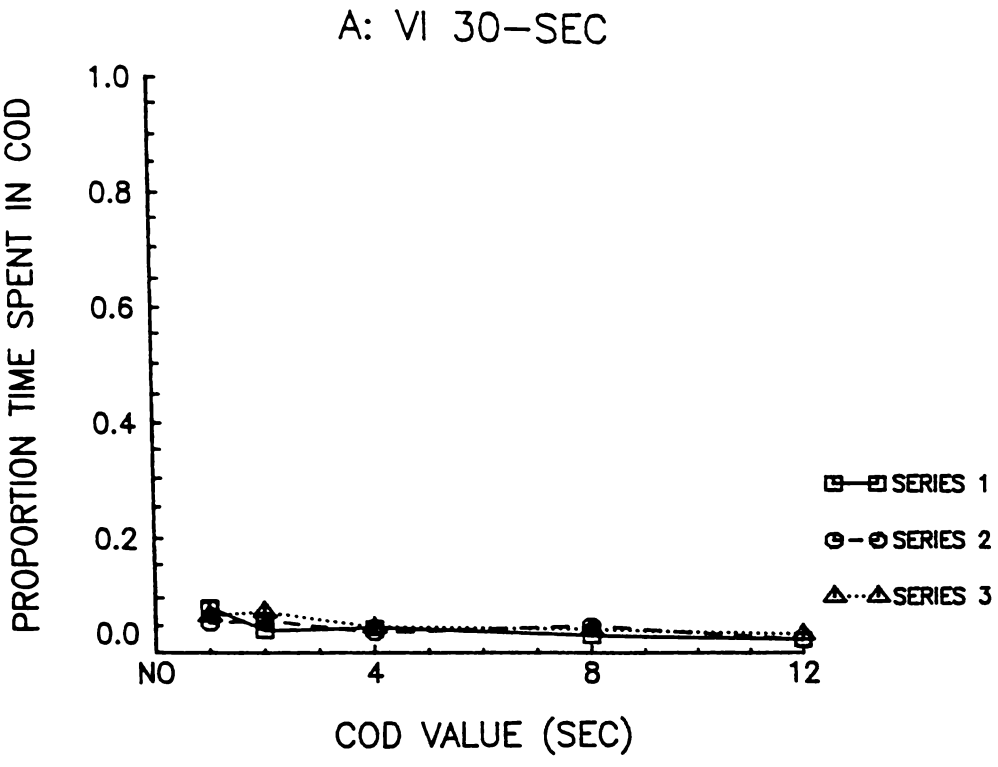
Figures 3.9 (a) and 3.9 (b) present, for the group and each series of conditions, the proportion of the total responses on each schedule that were made during the COD, plotted against COD value. The proportion of responses made during the COD decreased on the richer schedule and increased on the leaner schedule as the COD increased, for all series of conditions. There were no systematic differences between the different series of conditions on the richer schedule (the proportion of COD

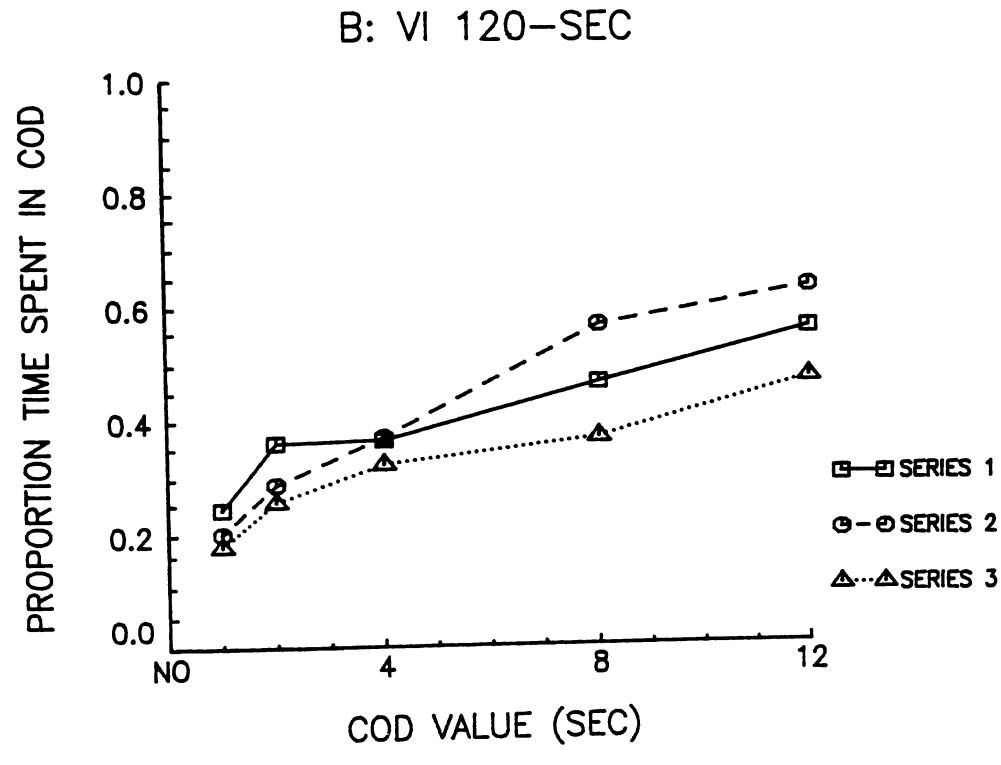
Figures 3.8 (a) and 3.8 (b)

The proportions of the times spent on each of the two schedules while the COD was in effect plotted against COD value. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line.

a) VI 30-sec

b) VI 120-sec


A: VI 30-SEC
PROPORTION TIME SPENT IN COD
1.0
0.8
0.6
0.4
0.2
0.0
NO
4
8
12
COD VALUE (SEC)
SERIES 1
SERIES 2
SERIES 3

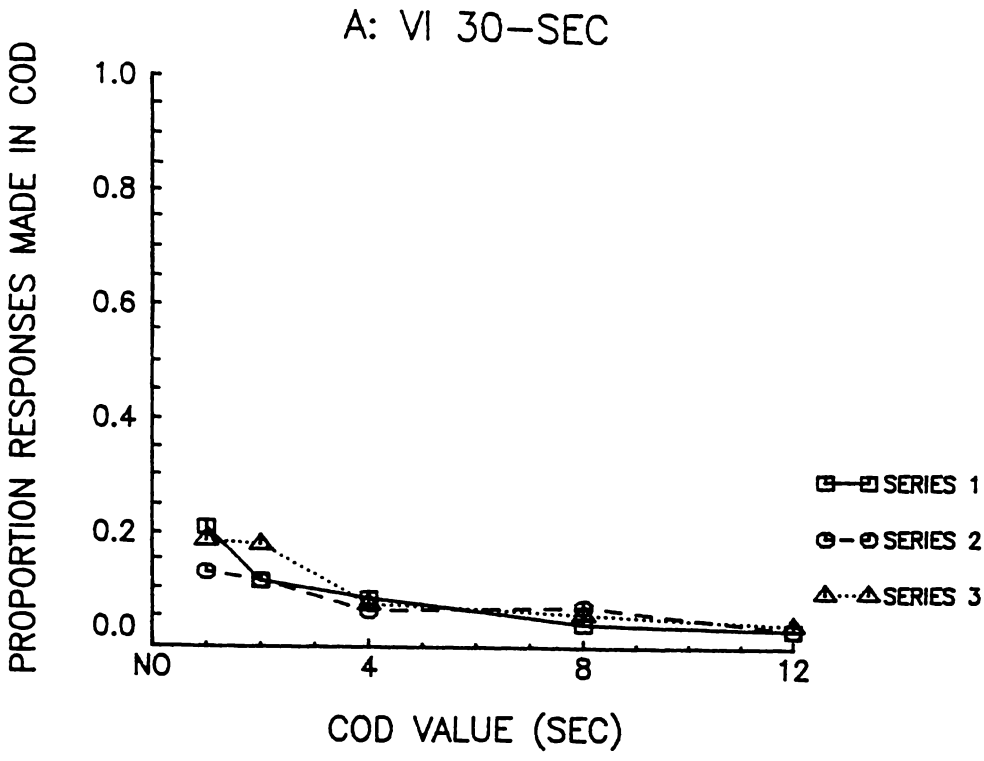

B: VI 120-SEC
PROPORTION TIME SPENT IN COD
1.0
0.8
0.6
0.4
0.2
0.0
NO
4
8
12
COD VALUE (SEC)
SERIES 1
SERIES 2
SERIES 3

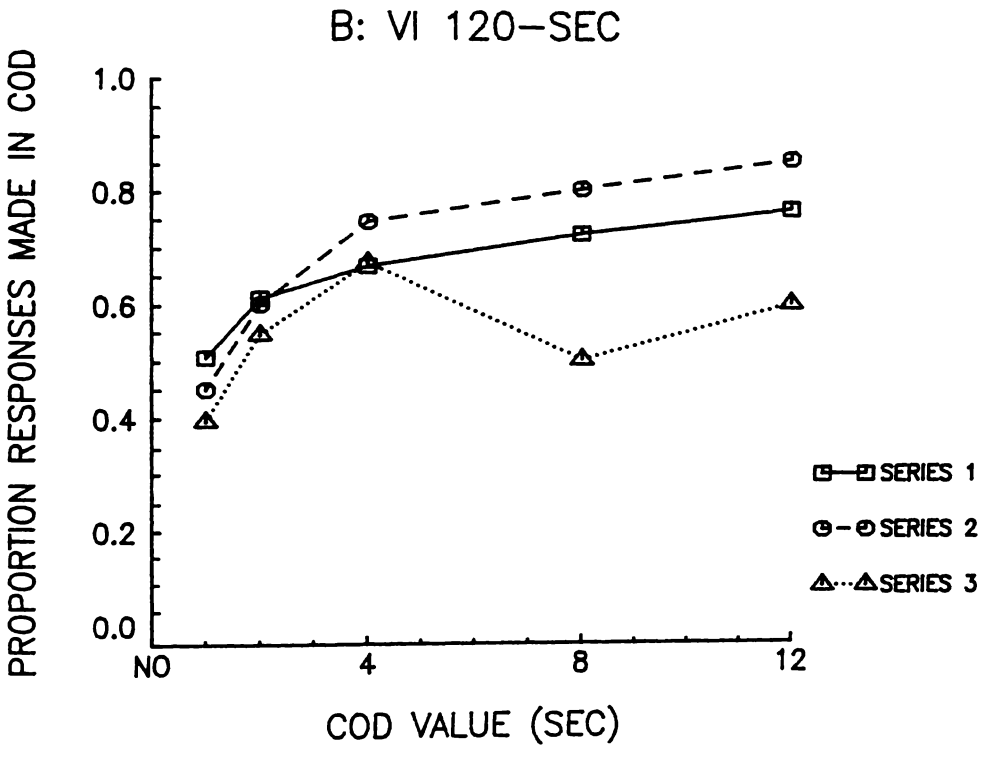
Figures 3.9 (a) and 3.9 (b)

The proportions of the total responses made on each schedule which were made during the COD, plotted against COD value. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line.

a) VI 30-sec

b) VI 120-sec


A: VI 30–SEC
PROPORTION RESPONSES MADE IN COD
1.0
0.8
0.6
0.4
0.2
0.0
NO
4
8
12
COD VALUE (SEC)
SERIES 1
SERIES 2
SERIES 3


B: VI 120–SEC
PROPORTION RESPONSES MADE IN COD
1.0
0.8
0.6
0.4
0.2
0.0
NO
4
8
12
COD VALUE (SEC)
SERIES 1
SERIES 2
SERIES 3

responses, averaged across series, decreased from 0.18 to 0.03) but on the leaner schedule there was some separation at the longer CODs. The proportion of responses made on the leaner schedule during the COD increased from an average of 0.45 to 0.75. The proportion of schedule responses made during the COD was higher, at all COD values, on the leaner of the two schedules. Overall, the proportion of all responses made during the COD (regardless of schedule) decreased as the COD increased (on average from 0.24 to 0.07).

Local Rates of Responding

The local rates of responding both during and after the COD, on both schedules, were variable. During the COD the highest rates (up to 177 responses per minute) occurred with COD values of 1 to 4 seconds and the lowest rates (17 responses per minute or none) occurred with CODs of 8 or 12 seconds. The local rates of responding after the COD tended not to change with COD. At all COD values (as long as the response rates could be estimated) the rates of responding during the COD were greater than those after the COD. However, at smaller COD values the difference between the rates of responding during and after the COD were generally greater than they were at the larger COD values. At the larger COD values accurate estimates of response rates were difficult because the numbers of responses and the amounts of time spent were often near zero.

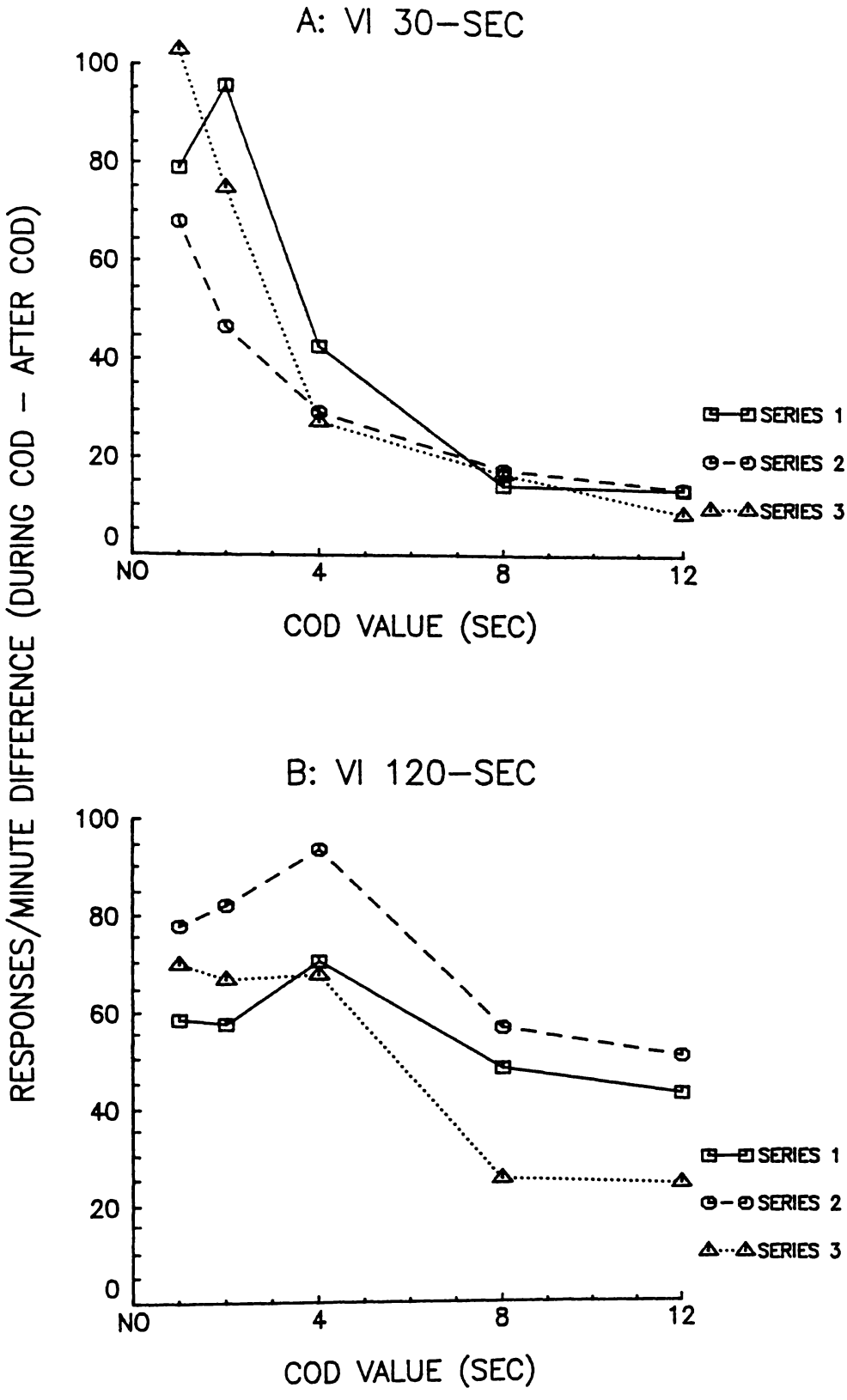
Figures 3.10 (a) and (b) present the differences in the local rates of responding on a schedule during and after the COD periods, for the group data from each of the three series of conditions, plotted against COD value. The differences in the rates were calculated as the number of responses per minute during the COD minus the number of responses per minute after the COD. Thus, a positive difference means that the rate of reponding was greater during the COD than after. Figure 3.10 (a) shows that on the richer schedule the differences between the two rates of responding decreased as the COD increased. With a 1-sec COD the rates of

Figures 3.10 (a) and 3.10 (b)

The differences in the local rates of responding during the COD and after the COD plotted, for the group, against COD value. The data from the first series of conditions are shown by squares joined by a solid line, those from the second series by circles and a dashed line, and those from the third series by triangles and a dotted line.

a) VI 30-sec

b) VI 120-sec


A: VI 30–SEC
100
80
60
40
20
0
NO
4
8
12
COD VALUE (SEC)
SERIES 1
SERIES 2
SERIES 3
B: VI 120–SEC
100
80
60
40
20
0
NO
4
8
12
COD VALUE (SEC)
SERIES 1
SERIES 2
SERIES 3
RESPONSES/MINUTE DIFFERENCE (DURING COD – AFTER COD)

responding during the COD were 70 to 103 responses per minute faster than the response rates after the COD. With a 12-sec COD this difference was between 5 and 20 responses per minute. Figure 3.10 (b) shows a less pronounced decrease in the differences between the two rates of responding on the leaner schedule.

Discussion

In spite of the procedural differences between this study and Experiment 1 the overall pattern of changes in the estimates of *a* (both line and point) found is similar. This suggests that the effect of COD length on the sensitivity of behaviour on conc VI VI schedules is not a weak effect. Behaviour was more sensitive to the rates of reinforcement when a COD was programmed than when one was not (although this was less pronounced in the present study). When a COD was programmed the estimates of *a* increased initially with COD but then remained constant (or decreased slightly) with further increases in the COD. There was no tendency for the estimates of *a* to exceed 1.00 with increased COD value (although values greater than 1.00 were obtained).

Overall the changes in the values of the point estimates of *a* with changes in the COD were replicated across the three series of conditions: The estimates of *a* tended to be lowest when no COD was programmed, to increase rapidly to around 1.00 when a COD was programmed and to remain at this level with further increases in the COD. However, there was considerable variation in the point estimates, whether based on total responses made or on times spent. It is, therefore, possible to make only very general statements about the changes in the point estimates of *a* with changes in the COD values. The details varied considerably between hens, between series, and between the response and time measures. It is possible, with the present data, to select data from particular hens and particular series which support each of the (sometimes contradictory) findings reported by Shull and Pliskoff (1967), Brownstein and Pliskoff (1968), Stubbs and Pliskoff (1969), Silberberg and Fantino (1970), Allison and Lloyd (1971), Pliskoff (1971), and Silberberg and Schrot (1974).

This suggests that some caution is needed when interpreting the data from these earlier studies which have, typically, involved only small numbers of subjects, a single exposure to each COD value and, sometimes, a limited range of COD values (e.g., 0.875, 1.75, and 3.50 seconds, Silberberg & Fantino, 1970). Caution is also needed because these studies have all assessed the degree of matching found at each COD value on the basis of the correspondence between the relative behaviour measure and the relative reinforcement rate obtained. However, there is a problem with any attempt to quantify the degree of such correspondence. Small differences between the relative rates of responding (or of times spent) and the reinforcement rates (e.g.,0.05) imply small changes in a (Equation 0.4) when the relative reinforcement rates are not close to either 0.50 or 1.00 but large changes in a when the relative reinforcement rates are close to these values. Thus, although some of these studies using relative measures may report increased "matching" this does not necessarily imply that a is approaching 1.00, although this may or may not be occurring. It is difficult to see easily whether data show increased matching (i.e., a approaching 1.00) when they are expressed as proportions. A further problem with using proportions lies in the fact that proportions are bounded functions (range 0 to 1.00). As both the proportion of reinforcements obtained and the proportion of responses made (or times spent) get more extreme they must necessarily tend towards each other. One way of quantifying the degree of matching between responses and reinforcements, in terms of the generalised matching law, is to estimate the exponent a relating the response and reinforcement ratios (Equation 0.4).

The data from Shull and Pliskoff (1967), Brownstein and Pliskoff (1968), Stubbs and Pliskoff (1969), Silberberg and Fantino (1970), Allison and Lloyd (1971), and Silberberg and Schrot (1974) were,

therefore, re-analysed using ratios instead of proportions. This allowed values of *a* (Equation 0.4) to be estimated, assuming bias to be negligible. These estimates are presented in Table 3.3. The data from Pliskoff (1971) and the data from two rats in Shull and Pliskoff's (1967) study were not re-analysed because the schedules programmed were equal *conc* VI VI schedules and the log ratios of the obtained reinforcements were, therefore, very nearly zero. Several points worth noting emerged. First, although the estimates of *a* tended, overall, to increase with increased COD there was considerable variability across subjects and across measures of behaviour. Second, although the estimates may have increased with increased COD this sometimes meant a decrease in the degree of matching as *a* increased beyond 1.00.

As mentioned earlier these studies have had to assume that any tendency to respond more on a key than predicted by the relative rate of reinforcement on that key was negligible because they did not vary the relative reinforcement rates (and no estimate of bias was therefore possible). This assumption was also made in the present study when calculating the point estimates of *a*. However, additional data from the present study suggest that this assumption may not be realistic. From Table 3.2 it can be seen that the intercepts of the fitted lines were such as to suggest that key bias was not, truly, negligible. The "line" estimates of *a* are therefore probably a more appropriate measure of the sensitivity of behaviour to the relative reinforcement rates at each COD value.

Changes in the size of the COD produced changes in other measures of behaviour on independent *conc* VI VI schedules. The ratios (or their logarithms), expressed to the richer schedule, of the total responses, responses made after the COD, and times spent all increased as the COD increased. The logarithms of the reinforcement rate ratios were, also, found to increase with increasing COD. The schedules were independently

Table 3.3

The point estimates of a (Equation 0.4) calculated from the response and time data given in the original studies for each COD value (not necessarily in the order given here), assuming bias to be negligible.

Study	Subject	COD (sec)	a resp	a time	Subject	COD (sec)	a resp	a time
Allison & Lloyd (1971)	6311	2.0	0.83	0.83	6862	2.0	0.56	1.25
		5.0	0.99	0.82		5.0	*	*
	6479	2.0	0.61	1.07	1864	2.0	0.77	0.72
		5.0	0.71	1.43		5.0	0.54	0.91
		7.5	0.72	1.33		7.5	0.54	1.07
						12.5	0.66	1.24
Brownstein & Pliskoff (1968)	787	0.0		0.19	6494	0.0		0.27
		0.2		0.00		0.2		0.50
		1.0		0.45		1.0		0.23
		1.5		0.33		2.0		0.56
		3.0		0.41		3.0		0.52
		5.0		0.37		5.0		0.82
		7.5		0.82				
	93	0.0		0.11				
		2.0		0.91				
Shull & Pliskoff (1967)	S1	0.0	0.13	-0.21	S2	0.0	0.16	0.08
		2.5	0.45	0.12		2.5	0.31	0.27
		5.0	0.60	0.60		5.0	0.49	0.41
		7.5	0.64	0.95		7.5	0.77	0.69
		12.5	0.79	1.05		12.5	0.83	0.91
		20.0	0.95	0.90		20.0	0.91	0.87
		20.0	1.00	0.79		20.0	0.90	0.90
		10.0	1.05	0.84		10.0	0.71	0.79
		2.5	1.05	0.67		2.5	0.80	0.58
		0.0	1.00	0.49				
Silberberg & Fantino (1970)	D	0.88	1.44	1.67	K	0.88	0.87	0.95
		1.75	1.37	1.37		1.75	0.73	0.76
		3.50	1.32	0.91		3.50	0.95	1.18
	I	0.88	2.56	1.69	L	0.88	0.83	0.95
		1.75	2.47	2.35		3.50	0.90	0.95
		3.50	3.10	2.56	M	0.88	0.64	1.31
	J	0.88	0.13	1.37		1.75	1.00	1.44
		1.75	1.14	1.00		3.50	1.44	1.52
		3.50	1.08	0.85				
Silberberg & Schrot (1974)	10838	0.0	0.33	1.05	9908	0.0	0.11	1.35
		2.0	0.78	1.39		2.0	1.23	1.58
		10.0	1.27	1.88		10.0	0.28	0.95
		30.0	1.86	1.75		30.0	0.63	1.17
	9905	30.0	0.75	1.04	11917	30.0	2.33	2.10
		0.0	1.02	1.01		0.0	2.14	1.84
	9467	0.0	0.10	0.05	10502	0.0	1.17	1.30
		2.0	1.23	1.24		2.0	0.67	0.71
		10.0	1.53	1.35		10.0	1.51	1.26
		30.0	2.67	2.05		30.0	1.95	1.82
	11838	30.0	1.50	1.35	10868	30.0	1.04	1.38
		0.0	0.61	0.87		0.0	0.65	0.74
Stubbs & Pliskoff (1969)	103	0.0	1.72	1.25	108	0.0	1.10	0.98
		2.0	*	*		2.0	-7.29	-5.62
		8.0	1.40	1.66		8.0	1.15	1.33
		16.0	1.45	1.83		16.0	1.09	1.45
		32.0	1.54	2.04		32.0	1.02	1.65
	104	0.0	1.35	0.97				
		2.0	1.91	1.96				
		8.0	1.46	1.42				
		16.0	1.83	1.38				
		32.0	2.70	1.82				

* a values unable to be estimated

arranged, so altered responding could alter the rates of reinforcement obtained on the two schedules and, presumably, the altered reinforcement rate ratios might alter behaviour. The logical extension of this is for responding to occur exclusively on one schedule if the COD is increased far enough. This was found in the present experiment.

The reduction in the rate of changing over between the schedules with increased COD length is in line with the findings summarised by Stubbs, Pliskoff, and Reid (1977) and, also, with the findings from Experiment 1. As was found in Experiment 1 the greatest change in the changeover rate came with the introduction of a COD. The effect of increased COD length on changeover behaviour was complex. Not only did the rate of changing over between the schedules decrease (Figure 3.6) but the proportion of changeovers to the leaner schedule in which the hen stayed on the schedule for at least the duration of the COD also decreased (Figure 3.7). The proportion of responses to the leaner schedule made during the COD tended, therefore, to increase with COD value. However, the proportion of responses to both schedules made in the COD periods decreased as increasingly longer times were spent on the richer schedule between changeovers.

The proportion of responses made on a schedule which were made during the COD were higher, for both schedules (separately), than were the proportions of time on each schedule spent in the COD (cf. Figures 3.8 and 3.9). This reflects the fact that the local response rates (on each schedule) were higher during the COD than they were after the COD (Figure 3.10). This response burst is reported frequently (e.g., Menlove, 1975; Silberberg & Fantino, 1970) but generally the CODs are not large. In this experiment the difference in the response rates during and after the COD was greatest at the smaller COD values (and on the richer schedule). At the larger COD values there was very little difference between the two rates. Overall the more detailed analyses of

responding in the COD that were possible in this experiment have confirmed the suggestions from Experiments 1 and 2 that the sensitivity of behaviour to the relative rates of reinforcement is not affected by the lack of any discriminable "bursting" throughout the longer CODs.

The generalised matching law, by its nature, has focussed attention on two parameters of concurrent schedule performance (bias and sensitivity to reinforcement). However under conditions where these two parameters are not observed to vary the measures on which they are based may be changing. For example, in the present experiment, and in Experiment 1, the size of the COD strongly influenced performance although this was not so apparent in the a values calculated. In Experiment 3 the ratios of the responses made, the times spent, and the reinforcements obtained on the two schedules changed considerably as the COD increased, although the schedules programmed did not change. The changes in responding and reinforcement are, obviously, interactive. The COD appears to have some effect on where behaviour will settle. Just how the COD influences this is not clear.

GENERAL DISCUSSION

Undermatching

The most common finding for both the total response data and the time data from the present series of experiments was that of undermatching. This is in agreement with the majority of studies investigating conc VI VI schedule performance (Wearden & Burgess, 1982). However, both Baum (1979) and Wearden and Burgess (1982), after reviewing much of the available literature, concluded that the slopes of the lines fitted to the log time ratios tended to be closer to 1.00 than did the slopes of the lines fitted to the log response ratios. This contrasts with the overall finding in the present studies of no such consistent difference between the measures.

A possible explanation for the different findings lies in the way that the comparisons (between the slopes of the lines fitted to the total response data and the slopes of the lines fitted to the time data) were made. In the experiments presented here they were based on data from the same subject whereas the comparisons made by Baum (1979) and Wearden and Burgess (1982) were often between data collected in different experiments. The two procedures will not necessarily yield the same results. For example, if the slopes of the lines fitted to the total response data from Experiment 1 (Table 1.2) were compared with the slopes of the lines fitted to the time data from Experiment 3 (Table 3.2) the conclusion reached would differ from that presented above which was based on a comparison of individual hens' response and time data. Thus it seems possible that Baum's (1979) and Wearden and Burgess' (1982) conclusions may not have been supported if individual subjects' data had been available for consideration. It seems unlikely that the present findings are unique to this species.

The degree of undermatching found was influenced to some extent by the variables manipulated over the series of experiments. A major finding was that the presence of a COD resulted in *a* values closer to 1.00 than did no COD. Once a COD was programmed *a* values tended to increase as the COD increased to some (variable) value and then to stay at this level or to decrease slightly with further increases in COD duration. This pattern was evident in the data from both Experiments 1 and 3 and the *a* values obtained from Experiment 2 (which did not vary the COD) fell within the range of values obtained from the other two experiments with CODs of a similar length. This finding provides some support for de Villiers' (1977) and Baum's (1979) assertion that some minimum COD is necessary in order to obtain matching. However, the problems mentioned in the general introduction concerning the tautologous nature of this argument still hold. It should be noted that even when no COD was programmed the *a* values were significantly greater than 0.00 and responding could not be considered insensitive to the relative reinforcement rates.

The present data provide little support for strict matching. The generalised matching law provides a good description of the response (total and post-COD) and time data obtained in the three experiments. However, at this point it probably must be emphasised that changes (or lack of changes) in *a* with changes in experimental parameters may not necessarily add to the understanding of behaviour since the generalised matching law is, essentially, a descriptive model and does not necessarily imply anything about the processes controlling behaviour. Focussing on the generalised matching law may mean that changes in other measures may be ignored. For example, the tendency when looking at the effects of the COD is to conclude, on the basis of the *a* values, that (beyond a minimum duration) the size of the COD has little effect on behaviour. This is obviously not true. The data in this thesis show that

other measures of behaviour change with COD duration while the *a* values remain essentially constant.

Point Estimates of *a*. It has already been mentioned that many of the studies which have varied the COD have not also varied the relative rates of reinforcement. As Baum (1974b) and Charman and Davison (1982) have pointed out matching implies a process in which the relative rates of behaviour on the two schedules match the relative rates of reinforcement on the schedules as these vary. In this sense matching (and deviations from matching) can be talked about meaningfully only when behaviour is observed across several values of the relative reinforcement rates and it is necessary that these are varied over an adequate range. Unless this occurs deviations from matching cannot be distinguished from possible bias. This point is illustrated nicely by de Villiers (1977) who pointed out that (if the same key is associated always with the richer schedule) it is possible for the relative response rates always to exceed the relative reinforcement rates (overmatching at the local level) although the slope of the fitted line might be less than 1.00 (undermatching). This is the case in the data from two of the pigeons in Silberberg and Fantino's (1970) first experiment (de Villiers, 1977).

The data from Experiment 1 (in which the relative reinforcement rates were varied at each COD value) and the data from Experiment 3 (in which the relative reinforcement rates were not varied) showed essentially the same pattern of *a* value changes with increasing COD. This suggests that the effect of the COD on concurrent schedule performance is not weak (i.e., that its effect will survive changes in the relative reinforcement rates). If the size of the COD had only a weak effect on *conc* VI VI schedule performance this might have provided a possible explanation for the variable and, sometimes, contradictory findings of the earlier studies which had varied the COD. However, a

more likely explanation lies in the fact that any bias present must confound the measures (Baum, 1979). Most previous studies (as mentioned) used relative measures. These are equivalent to point estimates in that both assume bias to be negligible. The variability in the point estimates of $\underline{a}$ obtained in Experiment 3 was sufficiently great to caution against undue reliance on the results from any single study in which the COD is varied (once) without varying the relative reinforcement rates.

If such point estimates of $\underline{a}$ are to be used to investigate the effect of COD length on the sensitivity of behaviour to changes in the relative reinforcement rates then it would seem that the values of such estimates should be

1) recoverable when the particular COD is programmed again,

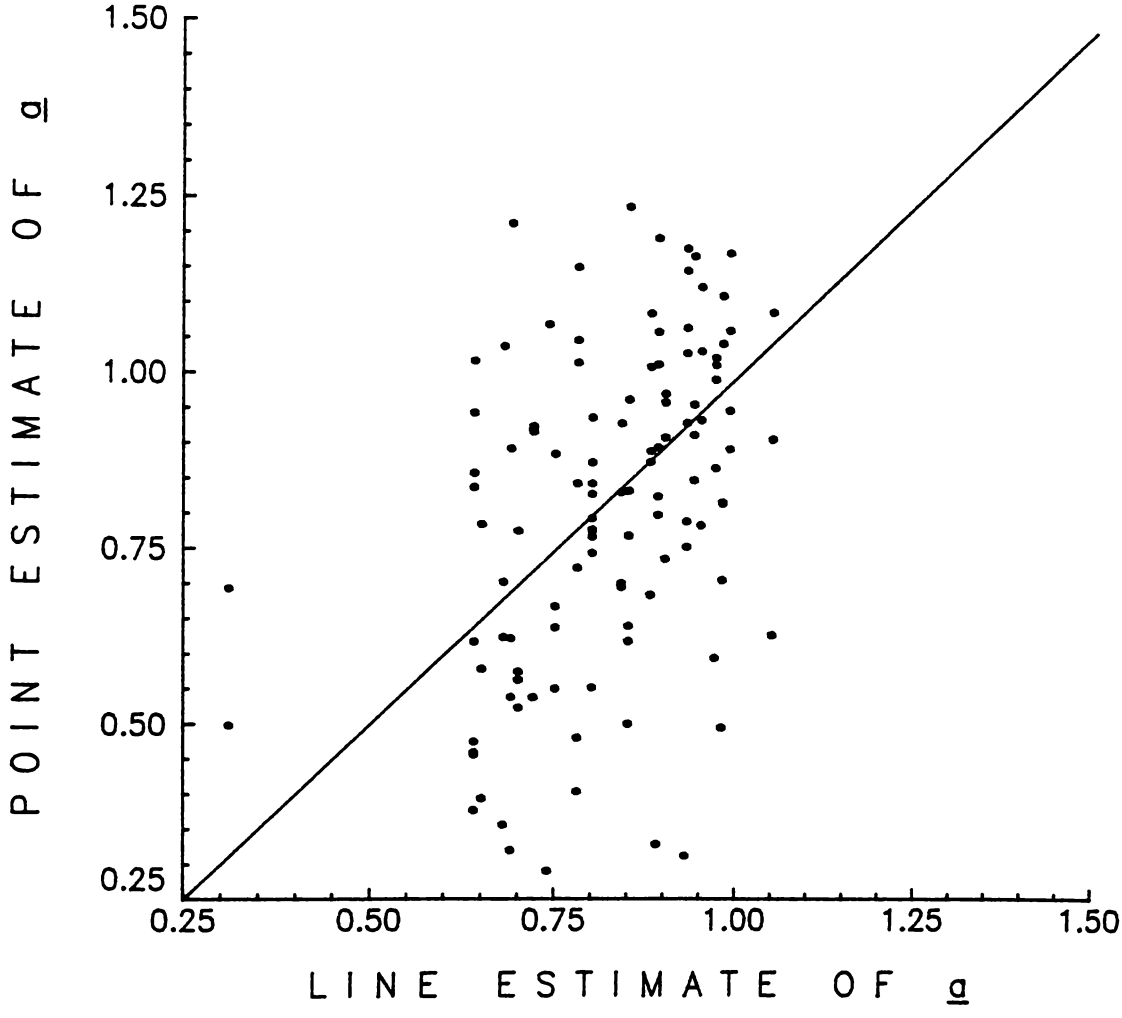
2) independent of the particular schedule values programmed, and

3) similar to the estimates obtained by varying the relative reinforcement rates. The variability of the point estimates of $\underline{a}$ obtained in Experiment 3 suggest that the first condition is not met by such estimates. The data from Experiment 1 were used to investigate whether point estimates satisfied the remaining two conditions.

Point estimates of $\underline{a}$ (based on total responses) were calculated at each COD value for each schedule pair (except equal schedules, for the reasons discussed earlier) and each hen. Figure 4.1 presents these point estimates (within the range $\pm$ 1.25) plotted against the corresponding line estimates (Table 1.2). It is evident that the point estimates obtained from each of the pairs of schedules with a particular COD programmed varied widely around the corresponding line estimate. There appeared to be no relation between the particular schedule pairs and the point estimates obtained. Thus it appears that point estimates meet only the second of the three conditions outlined above (independence from schedule values) and that reliance should not be placed on individual

Figure 4.1

Point estimates of $\underline{a}$ (Equation 0.4) based on the total response data from Experiment 1 (for each hen and each COD value on all but the equal schedule pair conditions) plotted against the corresponding line estimates of $\underline{a}$ (given in Table 1.2). For each line estimate there are (at least) five point estimates unless responding was exclusive under some conditions. The diagonal line represents perfect correspondence between the two estimates of $\underline{a}$.


1.50
1.25
1.00
0.75
0.50
0.25
POINT ESTIMATE OF a
0.25
0.50
0.75
1.00
1.25
1.50
LINE ESTIMATE OF a

point estimates. Practices such as those of Brownstein and Pliskoff (1968) where the COD used in the remainder of a study was chosen by increasing the COD programmed with a single pair of schedules until the relative times spent approximated the relative reinforcement rates closely appear to have little justification.

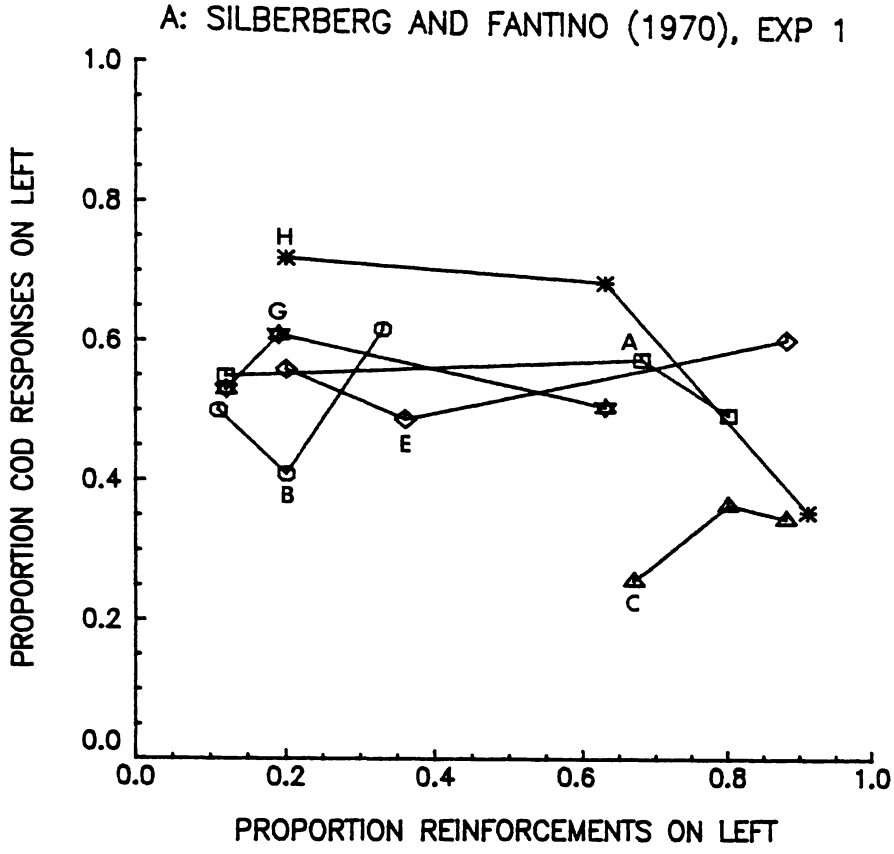
Insensitivity during COD

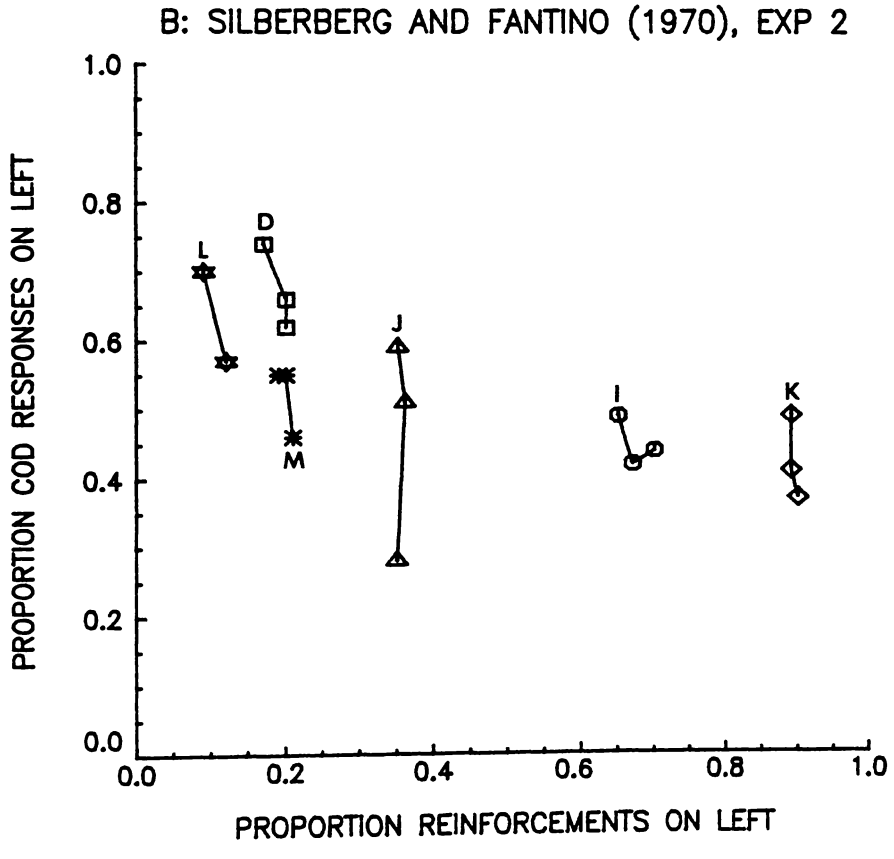
Another finding common to all three of the present studies was the insensitivity of responding during the COD to the relative reinforcement rates. This was found regardless of the COD duration (Experiments 1 and 3) or the stimuli programmed during the COD (Experiment 2). Only with a 7.5-sec COD in Experiment 1 were the slopes of the lines fitted to the log ratios of responses made during the COD (for individual hens' data) all in the same (negative) direction. However, these negative slopes were not found with a 15-sec COD and it was concluded that there was no tendency for the slopes of the lines fitted to the COD responses to become negative as the COD was increased. This conclusion was supported by the point estimates of a based on COD responding in Experiment 3.

Silberberg and Fantino (1970) reported finding a (slight) inverse relationship between the relative COD-response rates and the relative reinforcement rates (i.e., that slightly more responses were made on the leaner of the two schedules). However, closer analysis of their data failed to reveal such a relationship in the data from individual birds. Silberberg and Fantino's (1970) data are presented in Figure 4.2, as they drew them (Figure 2, Silberberg and Fantino, 1970) except that the data points from each bird are indicated and joined. The apparent trend in the data from Silberberg and Fantino's first experiment, shown in Figure 4.2(a), was largely produced by one disparate point from Pigeon H (shown by asterisk's) and the data from Pigeon C (shown by triangles) all of which fell in the bottom right corner of the plot. In their second experiment the relative reinforcement rates were not varied for

Figure 4.2

The proportion of COD responses made on the left key (left-key responses made during the COD divided by all responses made during the COD) plotted against the proportion of all reinforcements obtained on the left key. Data points from the same pigeon are connected. (From Silberberg and Fantino, 1970, Figure 2.)


A: SILBERBERG AND FANTINO (1970), EXP 1
PROPORTION COD RESPONSES ON LEFT
1.0
0.8
0.6
0.4
0.2
0.0
H
G
A
E
B
C
0.0
0.2
0.4
0.6
0.8
1.0
PROPORTION REINFORCEMENTS ON LEFT


B: SILBERBERG AND FANTINO (1970), EXP 2
PROPORTION COD RESPONSES ON LEFT
1.0
0.8
0.6
0.4
0.2
0.0
L
D
J
I
K
M
0.0
0.2
0.4
0.6
0.8
1.0
PROPORTION REINFORCEMENTS ON LEFT

each bird so that the trend implied by their plot may reflect nothing more than individual differences between the birds, as shown in Figure 4.2(b). Thus, for individual birds, the relationship between the relative response rates during the COD and the relative reinforcement rates is essentially flat and compares with that found in all three of the present experiments.

Baum (1979) has suggested that when an animal begins responding on an alternative it will continue to respond (at a constant rate) to that alternative without pause for a certain period. Once the animal pauses it may then resume responding (with pauses) on that alternative or it may switch to the other alternative where it will stay at least until the end of that first response "burst". Baum (1979) adds that unless the CODs are sufficiently long to ensure that the periods of time spent on the schedules before switching again are longer than the length of these "bursts" responding will consist mainly of these constant-rate response bursts. As the number of changeovers to each schedule are typically constrained to be (roughly) equal these response bursts will contribute an approximately equal number of responses to each schedule and will therefore reduce the sensitivity of the total measure.

This explanation for undermatching has difficulty coping with the present finding (Experiment 1) that COD responding was equally insensitive to the relative reinforcement rates regardless of the COD length (Table 1.3) and that the sensitivity did not change appreciably over the duration of the COD (Table 1.4). As previously discussed it seems that either the presence or otherwise of a response "burst" during the COD or the local probabilities of reinforcement (as analysed here) cannot explain this insensitivity. Nevertheless this insensitivity is real. Responses are made during the COD and are not influenced by the relative reinforcement rates. It appears that one effect of the COD on responding is to extend this period of insensitivity for at least the

duration of the COD itself. The question must be asked as to why experimenters add to the complexity of their experimental designs by programming a COD. Most (predictive) models of behaviour on concurrent schedules take the simplest possible case and, therefore, generally ignore the COD. Most of the data available for testing the proposed models were, however, collected using CODs.

The COD itself already complicates the schedules that are in effect. With a COD programmed the schedules are no longer straightforward variable-interval schedules but have, imposed, a fixed interval schedule which results in reinforcement with a certain probability. To determine whether the probability of reinforcement following completion of the COD produces the characteristic response burst during the COD presents difficulties in design. Ideally this probability should be varied and its effect (if any) on responding observed. However, it is difficult, logically, to see how this might be varied without changing the reinforcement rates that would, otherwise, be obtained on the two schedules.

When the schedules are independent (as they were in the present studies) one effect of an increased COD is to make the relative reinforcement rates (and relative response rates) more extreme. This is very clear in the data from Experiment 3. One effect of this is to limit the range over which the COD may be varied and changes in behaviour may be seen. Once responding is exclusive to one schedule no further changes are possible. In an experiment very similar to Experiment 3 but using dependent schedules (which ensured that the reinforcement rate ratios changed very little from those programmed) Temple, Foster, and de Mello (1982) reported finding that the point estimates of $\underline{a}$ went above 1.00 when the COD reached approximately 4 seconds and that they stayed at values around 1.2 as the COD was increased to 24 seconds. The findings of this experiment considerably extend the range of COD durations over

which the exponents a (Equation 0.4) have been found to remain essentially constant.

Overmatching

Another finding common to all three experiments presented here was that the log ratios of the post-COD responses generally overmatched the log ratios of the reinforcements. In all cases the slopes of the lines fitted to the post-COD responses were steeper than those fitted to the total responses.

The treatment of COD responses (and times) poses a problem, as discussed. There appears to be no common agreement on how they should be treated although various unacknowledged conventions seem to exist. A danger is that each treatment will generate its own body of data which will not be easily comparable with other data. To reiterate a point already made, whether matching is found or not is not sufficient grounds to justify a particular procedure.

One of the original purposes of concurrent schedules was to study choice between alternatives (Herrnstein, 1970; Schwartz & Lacey, 1982). The COD was imposed upon the procedure only to separate the two schedules in time and reduce the adventitious reinforcement of response sequences which involved both alternatives (Herrnstein, 1961). If one effect of the COD is to make responding insensitive for the duration of the COD then this, surely, reduces the effectiveness of the procedure. If the insensitivity is a product of the COD then, it may be argued, the responses during the COD reflect nothing about the animal's choice between the alternatives and should, properly, be excluded from such a measure. This conclusion contrasts with that of Silberberg and Fantino (1970) who argued that the different patterns of responding during and after the COD are necessary because without them matching is not found.

In order to understand better the effects of the various procedures on conc VI VI schedule performance it must be useful at least to record separately responding both during and after the changeover requirement. An even more molecular analysis is required if the local changes in the response rates and in the probabilities of reinforcement are to be investigated.

The examination here of some of the effects of the COD on conc VI VI schedule performance has highlighted how little is known about the variables controlling such behaviour. Although the generalised matching law provides a good description of the data at the molar level there are large numbers of models being proposed to describe the data on a more local level. Most of these are largely theoretical accounts and appear not to consider the COD apart from its effect of separating the schedules. It was not the function of this thesis to look at these models. However it is clear from the present data that the COD does more than just separate the two schedules in time. This, together with the results of studies using other means to separate the schedules, suggests that any model must consider and take into account the effects on behaviour of the procedure used to generate that behaviour.

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Appendix 1.1

Experiment 1. The responses (PL & PR) made over the session, responses made during the COD, responses made during the first two seconds after a changeover, times spent (TL & TR), reinforcements (RL & RR) obtained over the session, reinforcements obtained within two seconds of the end of the COD (or following a changeover when no COD was programmed), and numbers of changeovers (COs) for each hen for each of the last five days from each condition. Some data were not collected in the early conditions.

HEN	COND	PL	PR	IN COD PL	IN COD PR	IN 2'' PL	IN 2'' PR	TL	TR	RL	RR	IN 2'' RL	IN 2'' RR	COs
11	1	296	533	155	180			373	596	14	16			76
11	1	390	483	138	158			467	654	15	15			70
11	1	261	684	105	127			302	784	14	16			51
11	1	340	493	137	131			375	724	14	16			63
11	1	253	565	150	198			349	648	14	16			59
11	2	473	178	105	69			516	294	24	6			46
11	2	409	165	89	63			547	269	24	6			44
11	2	331	119	86	66			523	219	24	6			49
11	2	316	146	68	68			521	233	24	6			36
11	2	404	143	64	61			594	224	26	4			35
11	3	146	635	106	81			156	1242	8	22			52
11	3	121	482	87	70			170	1098	8	22			50
11	3	152	536	115	88			179	1045	9	21			63
11	3	147	585	103	60			150	1061	9	21			48
11	3	158	564	127	68			183	1133	7	23			65
11	4	532	396	268	148			716	709	21	9			135
11	4	506	391	242	163			711	695	22	8			129
11	4	654	280	204	125			869	538	23	7			111
11	4	498	326	169	121			761	651	22	8			103
11	4	633	306	213	131			819	598	22	8			111
11	5	59	423	39	22			55	772	3	27			17
11	5	97	383	43	23			91	762	3	27			17
11	5	102	312	63	36			107	614	4	26			26
11	5	60	382	43	25			80	694	4	26			22
11	5	68	389	45	28			79	712	3	27			22
11	6	339	106	62	59			509	134	21	9	7	8	32
11	6	357	85	61	58			509	119	21	9	6	8	31
11	6	260	76	52	48			446	146	21	9	7	8	31
11	6	315	81	52	49			501	130	21	9	4	9	33
11	6	382	78	51	47			500	106	22	8	5	8	30
11	7	278	106			143	23	638	355	17	13	6	10	171
11	7	290	112			145	22	591	353	15	15	11	15	169
11	7	237	95			116	12	615	350	15	15	9	15	155
11	7	257	94			134	16	604	340	16	14	11	14	162
11	7	274	96			126	11	662	353	16	14	11	14	163
11	8	120	198			97	93	335	791	5	35	4	21	167
11	8	119	192			101	95	348	754	7	33	7	21	173
11	8	102	259			98	112	269	846	5	35	5	13	181
11	8	155	321			139	160	350	1032	8	32	8	20	252
11	8	122	218			103	105	477	979	7	33	7	17	185
11	9	277	71			95	67	808	285	35	5	15	5	131
11	9	220	85			89	83	641	320	31	9	13	9	140
11	9	203	62			66	61	703	236	31	9	14	9	118

11	9	241	90			104	80	640	318	31	9	13	9	147
11	9	268	108			133	106	635	328	31	9	19	9	200
11	10	243	325			186	189	555	1077	13	27	12	20	317
11	10	223	309			180	181	551	1132	13	27	10	21	319
11	10	224	367			195	200	481	1247	13	27	13	18	343
11	10	203	350			174	177	457	1257	13	27	13	16	324
11	10	195	311			151	158	500	1223	13	27	12	7	279
11	11	257	161			156	122	645	590	21	19	17	15	230
11	11	290	197			210	153	576	638	20	20	17	13	280
11	11	300	166			191	136	645	618	20	20	17	19	248
11	11	329	211			211	176	643	613	20	20	16	18	279
11	11	432	268			251	246	651	498	20	20	13	20	267
11	12	302	110			165	107	525	297	27	13	14	13	188
11	12	300	89			124	89	590	251	27	13	17	13	168
11	12	273	116			147	113	526	302	26	14	20	14	211
11	12	302	112			157	110	571	323	27	13	19	13	208
11	12	329	121			158	119	592	297	27	13	14	13	206
11	13	490	669	225	188	90	64	627	990	16	24	10	10	55
11	13	589	366	220	170	83	59	798	647	20	20	12	12	55
11	13	506	403	236	173	99	60	738	730	20	20	12	11	58
11	13	431	493	214	183	75	59	620	813	17	23	12	10	58
11	13	322	694	180	150	65	42	471	1104	16	24	10	9	46
11	14	17	583	16	6	4	2	14	1134	1	39	1	1	2
11	14	113	582	29	18	11	6	96	1130	1	39	1	2	5
11	14	0	652	0	5	0	2	2	1134	0	40	0	0	1
11	14	16	572	15	7	4	2	14	1109	1	39	1	2	3
11	14	198	445	45	21	12	6	166	1046	2	38	2	1	7
11	15	702	0	0	0	0	0	1152	0	40	0	0	0	0
11	15	563	197	79	103	24	33	977	271	35	5	6	4	24
11	15	590	79	33	38	11	11	1038	118	37	3	3	4	11
11	15	498	67	36	44	17	15	994	129	37	3	4	3	16
11	15	505	62	32	44	13	14	988	91	36	4	3	2	12
11	16	106	699	75	62	29	25	245	1541	9	31	5	3	26
11	16	58	854	47	30	11	10	118	1922	5	35	4	4	16
11	16	56	1078	33	36	12	11	97	2048	3	37	3	1	13
11	16	92	832	46	45	15	12	193	1748	8	32	4	3	18
11	16	163	808	63	64	20	22	368	1681	7	33	4	4	21
11	17	272	178	27	74	7	14	728	277	29	11	2	4	13
11	17	324	143	20	34	4	6	863	257	33	7	2	3	6
11	17	286	53	19	41	7	9	947	114	36	4	1	4	10
11	17	359	107	31	18	9	6	969	223	36	4	3	2	6
11	17	328	122	19	25	5	6	954	255	35	5	3	3	6
11	18	697	280	91	86	18	17	1360	502	27	13	4	6	19
11	18	223	1010	78	44	11	10	451	1589	11	29	5	3	10
11	18	357	611	89	116	19	21	828	1059	18	22	5	10	27
11	18	397	503	99	152	21	27	968	878	21	19	3	9	30
11	18	429	517	71	102	14	17	925	818	22	18	3	5	19
11	19	1	720	1	7	1	1	11	1145	0	40	0	1	2
11	19	1	712	1	15	1	3	12	1159	0	40	0	2	3
11	19	1	709	1	17	1	2	15	1144	0	40	0	1	3
11	19	31	778	0	10	0	2	69	1132	0	40	0	1	1
11	19	3	782	3	32	2	4	13	1152	0	40	0	2	5
11	20	616	37	11	19	1	3	1088	53	39	1	2	1	5
11	20	658	23	19	9	3	1	1135	44	39	1	2	1	3
11	20	526	59	46	51	7	7	1050	105	38	2	5	2	12
11	20	631	0	0	0	0	0	1138	0	40	0	0	0	0
11	20	542	28	31	24	4	5	1083	57	39	1	2	1	8
11	21	45	1251	43	29	3	3	87	2119	2	38	2	3	5
11	21	17	1372	16	14	1	3	43	2220	1	39	1	2	3
11	21	47	1389	45	61	6	11	78	2214	2	38	2	4	12

11	21	1	1290	1	14	1	3	23	2344	0	40	0	1	3
11	21	2	1414	1	16	1	2	13	2334	0	40	0	0	3
11	22	759	58	25	24	3	5	1127	98	37	3	1	1	4
11	22	847	87	23	27	2	3	1305	154	38	2	1	1	4
11	22	753	172	57	70	11	16	1170	282	35	5	1	1	20
11	22	675	156	31	27	2	5	979	257	35	5	1	1	4
11	22	654	81	14	9	2	3	1076	177	37	3	1	0	4
11	23	456	416	133	142	75	85	759	582	21	19	13	9	52
11	23	401	429	130	178	77	100	746	558	22	18	12	9	64
11	23	502	451	145	171	86	102	915	651	22	18	7	12	69
11	23	568	328	130	154	69	92	954	445	22	18	9	15	55
11	23	475	444	160	169	87	98	830	595	20	20	9	14	63
11	24	65	681	40	41	23	27	105	1089	3	37	3	5	23
11	24	123	586	66	57	29	35	180	894	4	36	4	3	29
11	24	90	637	49	57	29	28	164	994	3	37	3	2	23
11	24	69	603	27	29	13	16	121	906	4	36	3	1	15
11	24	55	697	25	24	13	11	84	960	4	36	3	3	9
11	25	418	79	38	50	22	30	830	142	35	5	3	3	22
11	25	573	25	17	21	8	14	1055	38	38	2	2	1	10
11	25	545	56	26	27	12	14	997	69	37	3	2	3	10
11	25	473	89	52	59	29	36	869	113	34	6	7	6	22
11	25	485	75	31	53	16	35	925	112	35	5	3	3	20
11	26	311	731	150	170	81	94	579	1230	13	27	9	10	77
11	26	267	665	159	164	94	105	557	1307	13	27	11	9	92
11	26	271	725	159	158	86	91	535	1311	12	28	9	9	85
11	26	170	863	96	109	48	59	332	1554	10	30	9	7	59
11	26	134	833	92	116	52	69	277	1578	10	30	10	8	71
11	27	429	76	42	55	25	35	901	115	33	7	6	6	28
11	27	498	46	22	32	14	19	917	74	33	7	2	6	15
11	27	365	133	39	79	20	47	804	190	30	10	6	8	25
11	27	383	65	26	46	16	26	848	98	33	7	3	6	18
11	27	385	67	25	45	14	22	844	117	32	8	6	7	20
12	1	295	194	104	95			639	342	15	15			62
12	1	275	188	116	95			622	341	16	14			71
12	1	260	246	112	93			602	414	15	15			70
12	1	221	249	113	112			541	416	14	16			72
12	1	217	306	127	128			525	488	13	17			85
12	2	227	62	28	33			699	209	25	5			30
12	2	233	110	47	53			607	229	24	6			44
12	2	229	63	34	37			639	169	25	5			30
12	2	216	62	19	30			691	152	26	4			24
12	2	191	65	20	28			597	201	24	6			26
12	3	190	621	68	66			308	995	7	23			18
12	3	136	560	51	57			267	1008	9	21			40
12	3	105	621	44	43			223	1151	7	23			34
12	3	115	670	44	53			280	1156	6	24			43
12	3	93	557	42	41			246	1051	8	22			36
12	4	355	79	32	41			1289	257	25	5			43
12	4	386	133	45	64			1196	343	24	6			50
12	4	319	215	59	108			994	447	22	8			64
12	4	306	294	65	134			1002	561	23	7			76
12	4	359	181	61	80			1097	439	24	6			63
12	5	11	254	5	8			54	749	1	29			9
12	5	18	293	5	9			70	715	2	28			9
12	5	8	360	3	1			24	832	1	29			2
12	5	0	368	0	0			0	838	0	30			0
12	5	0	334	0	0			0	889	0	30			0
12	6	252	33	36	15			651	418	24	6	6	2	26
12	6	177	48	11	10			688	236	24	6	4	2	16
12	6	163	57	18	13			558	311	20	10	3	2	19

12	6	160	89	20	15			505	351	18	12	7	5	18
12	6	215	40	25	16			587	163	23	7	8	5	22
12	7	557	234	90	63	26	13	767	432	18	12	4	3	27
12	7	552	130	95	49	31	12	869	374	18	12	6	3	31
12	7	504	87	74	33	21	8	908	331	18	12	4	3	23
12	7	355	245	83	42	29	6	660	599	17	13	7	4	29
12	7	661	94	58	24	15	1	1178	278	23	7	4	1	17
12	8	45	477	20	18	9	7	107	1064	3	37	2	3	8
12	8	32	522	21	14	6	5	49	1042	1	39	1	3	5
12	8	22	616	16	11	6	3	45	1087	2	38	2	2	4
12	8	100	779	25	19	9	8	189	1355	1	39	1	3	8
12	8	338	1019	77	64	24	30	629	1904	10	30	4	7	24
12	9	470	0	0	0	0	0	1130	0	40	0	0	0	0
12	9	388	33	16	25	7	7	1002	57	38	2	2	2	6
12	9	443	45	19	18	6	3	1054	45	39	1	2	1	4
12	9	434	20	9	12	2	4	1069	21	39	1	1	1	2
12	9	426	16	10	14	3	4	1046	23	38	2	0	2	4
12	10	360	518	58	76	21	29	860	1133	12	28	2	6	34
12	10	400	411	52	57	22	22	1058	1080	14	26	3	5	31
12	10	366	460	53	49	21	19	926	1130	13	27	4	1	28
12	10	176	592	70	61	24	22	447	1390	11	29	9	2	31
12	10	282	518	87	93	35	33	650	1153	11	29	5	7	40
12	11	413	153	46	71	19	29	1111	417	26	14	4	3	30
12	11	319	175	41	44	16	19	1048	562	24	16	5	7	30
12	11	380	215	50	89	22	31	1044	506	24	16	3	6	33
12	11	278	254	37	63	18	26	919	643	22	18	4	6	28
12	11	185	428	62	123	24	43	562	718	19	21	9	9	36
12	12	364	155	33	32	8	12	909	229	33	7	4	4	13
12	12	486	120	32	56	8	17	992	145	37	3	3	3	10
12	12	467	29	12	18	3	6	1043	68	37	3	1	3	6
12	12	437	82	33	43	10	14	944	125	34	6	3	3	11
12	12	301	114	30	47	9	15	774	261	30	10	4	4	16
12	13	260	242			190	144	696	619	21	19	20	12	257
12	13	241	249			156	111	672	695	18	22	16	13	187
12	13	307	285			218	148	724	592	20	20	18	15	252
12	13	243	221			136	107	713	595	19	19	13	14	186
12	13	295	251			171	157	715	562	20	20	14	16	232
12	14	153	375			138	86	339	1041	0	40	0	14	148
12	14	88	259			72	60	256	839	6	34	6	12	111
12	14	112	246			86	74	325	753	6	34	5	11	130
12	14	87	257			79	70	262	827	6	34	6	11	123
12	14	104	253			91	77	319	809	5	35	5	10	142
12	15	275	79			79	73	757	235	32	8	11	8	136
12	15	275	79			87	71	769	200	31	9	13	9	121
12	15	309	72			89	68	827	207	33	7	11	7	134
12	15	327	75			89	72	832	178	33	7	13	7	130
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12	16	360	565			307	310	690	1130	12	28	10	19	448
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12	17	223	138			109	111	544	316	27	13	14	12	166
12	17	218	163			112	123	563	321	26	14	19	12	178
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12	18	315	270	122	103	31	30	956	746	20	20	8	8	45
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12	20	373	0	0	0	0	0	1204	0	40	0	0	0	0
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13	1	226	257	133	106			548	484	16	14			83
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13	8	190	547			96	134	313	716	6	34	5	13	134
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14	16	120	467			112	147	262	1349	13	27	13	12	216
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14	18	86	994	17	43	6	9	232	1960	4	36	1	2	13
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16	13	49	166			42	45	249	1158	18	22	16	9	83
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16	16	141	295			118	107	365	1365	14	26	13	10	198
16	16	132	362			126	131	304	1504	13	27	13	8	222
16	16	139	343			127	129	325	1443	13	27	12	11	221
16	16	116	372			106	129	266	1489	12	28	12	16	207
16	17	209	179			175	170	425	503	27	13	24	12	307
16	17	168	169			144	150	376	560	26	14	23	12	276
16	17	170	190			161	167	322	600	26	14	25	13	314
16	17	176	172			151	146	349	527	26	14	23	13	281
16	17	232	221			195	200	390	543	26	14	23	14	336
16	18	344	229	58	83	14	23	1224	674	24	16	8	7	25
16	18	259	285	75	108	14	19	843	777	22	18	10	2	27
16	18	294	368	72	117	15	18	893	927	20	20	5	9	28

16	18	249	371	61	80	15	17	829	1046	18	22	5	7	23
16	18	188	371	70	99	18	28	663	1158	16	24	8	10	33
16	19	35	369	13	24	3	4	117	1061	3	37	2	3	6
16	19	20	401	13	20	2	3	53	1104	2	38	2	1	4
16	19	21	478	9	16	3	3	64	1163	0	40	0	1	4
16	19	22	414	13	13	2	3	66	1084	2	38	2	2	4
16	19	0	461	0	0	0	0	0	1144	0	40	0	0	0
16	20	514	0	0	0	0	0	1129	0	40	0	0	0	0
16	20	532	174	19	5	2	1	1052	270	37	3	1	1	2
16	20	533	201	21	10	4	1	1080	280	38	2	1	1	3
16	20	521	11	13	10	4	3	1158	27	39	1	1	1	4
16	20	509	50	13	9	2	1	1127	86	39	1	0	1	2
16	21	246	722	33	47	6	7	607	1648	9	31	4	3	9
16	21	50	1002	15	33	3	3	141	2165	3	37	3	0	6
16	21	261	1141	120	111	16	17	418	1781	8	32	7	3	20
16	21	444	856	67	83	9	12	770	1563	10	30	7	5	16
16	21	57	981	24	39	5	6	144	2089	3	37	2	2	8
16	22	564	0	4	0	1	0	1154	14	40	0	1	0	1
16	22	593	0	0	0	0	0	1187	0	40	0	0	0	0
16	22	641	0	2	0	1	0	1159	2	40	0	1	0	1
16	22	647	0	0	0	0	0	1187	0	40	0	0	0	0
16	22	640	0	0	0	0	0	1159	0	40	0	0	0	0
16	23	435	246	66	69	43	40	959	549	23	17	5	11	42
16	23	363	280	62	78	41	47	858	587	22	18	8	14	47
16	23	323	303	73	79	41	45	781	636	20	20	8	13	48
16	23	312	326	77	86	44	51	728	658	20	20	8	15	51
16	23	347	261	65	65	38	34	852	611	22	18	10	9	42
16	24	38	523	16	11	10	9	98	1061	3	37	3	2	10
16	24	32	653	8	4	4	3	63	1067	3	37	2	1	4
16	24	128	603	23	29	12	17	234	953	3	37	1	4	16
16	24	40	709	18	15	10	8	78	1059	2	38	2	2	10
16	24	13	781	4	6	3	4	46	1134	1	39	0	1	4
16	25	282	171	24	21	14	12	788	376	33	7	5	5	19
16	25	349	94	33	24	20	16	884	253	33	7	7	7	22
16	25	371	74	17	19	11	12	959	184	36	4	4	4	14
16	25	359	112	26	27	14	15	855	267	35	5	7	5	20
16	25	504	13	4	3	2	2	1108	38	39	1	1	1	2
16	26	234	337	51	43	29	34	665	1241	13	27	11	5	48
16	26	325	420	52	43	29	26	770	1148	13	27	8	9	40
16	26	204	550	52	54	30	35	498	1426	11	29	8	7	47
16	26	194	483	49	40	29	30	534	1312	12	28	6	4	42
16	26	181	518	55	50	32	31	505	1379	11	29	9	11	42
16	27	305	186	15	19	10	10	816	340	30	10	5	5	14
16	27	253	122	31	29	20	17	747	367	28	12	9	5	24
16	27	313	74	21	19	13	10	807	231	30	10	6	7	18
16	27	233	125	28	19	17	12	667	380	29	11	7	7	23
16	27	219	150	29	25	18	16	647	397	29	11	8	3	25

Appendix 1.2

Experiment 1. The slopes and intercepts, with their standard deviations (SD) and the results of t-tests for the significance of differences from 0.00 or 1.00, of the lines fitted to the logarithms of the ratios of total responses, times spent, responses made during the COD, and responses made after the COD, for each hen and the group, at each of the COD values programmed. Sections A to E present these data for the no COD, 2-sec, 4-sec, 7.5-sec, and 15-sec COD conditions, respectively.

A: NO COD

			t ratio				t ratio
Hen	slope	SD	from 0	from 1	intcpt	SD	from 0
TOTAL RESPONSES							
11	0.65	0.10	6.44 *	3.43 *	0.15	0.05	3.11
12	0.64	0.07	9.78 *	5.57 *	0.11	0.03	3.12
13	0.68	0.11	6.40 *	2.98	0.07	0.05	1.45
14	0.74	0.22	3.32 *	1.15	-0.25	0.10	2.43
15	0.31	0.04	7.89 *	17.59 *	0.10	0.02	5.80 *
16	0.78	0.04	20.10 *	5.74 *	-0.21	0.02	11.21 *
GP	0.63	0.04	17.65 *	10.23 *	-0.01	0.02	0.51
TIMES							
11	0.66	0.11	5.95 *	3.06	0.00	0.05	0.01
12	0.68	0.06	12.06 *	5.58 *	0.10	0.03	3.43 *
13	0.62	0.07	8.84 *	5.49 *	0.15	0.03	4.51 *
14	0.70	0.27	2.65	1.12	-0.34	0.12	2.71
15	0.35	0.06	5.45 *	10.31 *	0.10	0.03	3.36 *
16	0.89	0.11	8.33 *	0.98	-0.36	0.05	6.87 *
GP	0.65	0.04	15.60 *	8.37 *	-0.06	0.02	3.10

* $p < 0.05$

continued

Appendix 1.2 continued

B: 2-SEC COD

Hen	slope	SD	t ratio from 0		t ratio from 1		intcpt	SD	t ratio from 0	
TOTAL RESPONSES										
11	0.85	0.16	5.16	*	0.91		-0.07	0.09	0.74	
12	0.98	0.09	10.37	*	0.19		-0.09	0.07	1.29	
13	0.80	0.07	10.88	*	2.75		0.06	0.04	1.58	
14	0.78	0.09	8.30	*	2.41		-0.04	0.05	0.84	
15	0.69	0.12	5.80	*	2.61		0.03	0.07	0.44	
16	0.64	0.20	3.26	*	1.82		-0.07	0.10	0.69	
GP	0.79	0.08	10.21	*	2.74		-0.03	0.04	0.80	
TIMES										
11	0.98	0.19	5.03	*	0.10		-0.18	0.10	1.76	
12	0.89	0.07	12.58	*	1.51		-0.04	0.06	0.75	
13	0.76	0.07	10.22	*	3.19	*	0.05	0.04	1.37	
14	1.00	0.11	9.27	*	0.02		-0.05	0.06	0.89	
15	0.77	0.11	7.27	*	2.17		-0.11	0.06	1.79	
16	0.59	0.16	3.73	*	2.59		0.01	0.08	0.09	
GP	0.82	0.05	15.76	*	3.35	*	-0.06	0.03	2.01	
RESPONSES DURING COD										
11	-0.08	0.09	0.83		11.93	*	0.11	0.05	2.34	
12	0.03	0.08	0.40		11.42	*	-0.03	0.07	0.52	
13	-0.02	0.07	0.21		14.19	*	0.03	0.04	0.84	
14	-0.12	0.08	1.59		14.64	*	0.02	0.04	0.04	
15	-0.02	0.04	0.50		23.72	*	0.21	0.02	8.80	*
16	0.01	0.06	0.15		15.30	*	0.01	0.03	0.29	
GP	-0.03	0.03	0.84		31.67	*	0.06	0.02	3.16	*
RESPONSES AFTER COD										
11	1.31	0.30	4.30	*	1.01		-0.16	0.16	0.98	
12	1.17	0.09	12.90	*	1.91		-0.06	0.07	0.79	
13	1.06	0.12	8.64	*	0.49		0.05	0.06	0.87	
14	1.18	0.19	6.16	*	0.95		-0.08	0.10	0.78	
15	0.99	0.28	3.51	*	0.03		-0.13	0.16	0.86	
16	0.89	0.31	2.91	*	0.34		-0.14	0.15	0.91	
GP	1.09	0.15	7.26	*	0.60		-0.09	0.08	1.07	

* $p < 0.05$

continued

Appendix 1.2 continued

C: 4-SEC COD

Hen	slope	SD	t ratio from 0		t ratio from 1		intcpt	SD	t ratio from 0	
TOTAL RESPONSES										
11	0.99	0.08	13.05	*	0.15		0.01	0.05	0.17	
12	0.94	0.06	14.42	*	0.99		0.07	0.04	1.71	
13	0.93	0.05	18.67	*	1.46		0.16	0.03	5.10	*
14	1.05	0.09	12.16	*	0.58		-0.21	0.07	2.98	
15	0.93	0.09	10.45	*	0.84		0.02	0.06	0.29	
16	0.84	0.05	15.66	*	3.04		-0.05	0.04	1.28	
GP	0.94	0.03	28.29	*	1.77		0.00	0.02	0.17	
TIMES										
11	1.04	0.09	11.58	*	0.46		0.09	0.06	1.44	
12	0.89	0.04	19.89	*	2.52		0.05	0.03	1.81	
13	0.84	0.04	21.55	*	4.21	*	0.17	0.02	6.89	*
14	0.97	0.09	11.01	*	0.31		-0.08	0.07	1.08	
15	1.02	0.11	9.53	*	0.17		0.01	0.07	0.21	
16	0.80	0.05	16.82	*	4.15	*	-0.02	0.03	0.59	
GP	0.92	0.04	26.28	*	2.17		0.04	0.02	1.57	
RESPONSES DURING COD										
11	-0.09	0.04	2.17		27.55	*	-0.08	0.03	3.06	
12	0.01	0.08	0.14		12.66	*	0.01	0.05	0.18	
13	0.06	0.03	1.94		28.80	*	0.08	0.02	4.10	*
14	0.00	0.04	0.07		23.60	*	-0.12	0.03	3.44	*
15	-0.06	0.06	1.00		17.11	*	0.04	0.04	0.99	
16	0.00	0.03	0.17		35.43	*	0.03	0.02	1.30	
GP	-0.01	0.01	1.41		130.86	*	-0.01	0.01	1.62	
RESPONSES AFTER COD										
11	1.42	0.16	8.94	*	2.66		0.06	0.11	0.59	
12	1.15	0.06	19.12	*	2.43		0.09	0.04	2.41	
13	1.08	0.04	25.05	*	1.78		0.17	0.03	6.37	*
14	1.29	0.15	8.32	*	1.85		-0.20	0.13	1.58	
15	1.30	0.16	8.14	*	1.85		0.04	0.10	0.36	
16	0.94	0.06	14.62	*	0.90		-0.05	0.05	1.17	
GP	1.19	0.07	16.95	*	2.71		0.02	0.05	0.38	

* $p < 0.05$

continued

Appendix 1.2 continued

D: 7.5-SEC COD

Hen	slope	SD	t ratio from 0		t ratio from 1		intcpt	SD	t ratio from 0	
TOTAL RESPONSES										
11	0.70	0.13	5.30	*	2.28		-0.05	0.13	0.39	
12	0.80	0.02	33.89	*	8.30	*	0.04	0.02	1.67	
13	0.95	0.05	17.39	*	0.92		-0.05	0.04	1.26	
14	0.97	0.03	32.17	*	1.01		0.03	0.03	1.13	
15	0.89	0.04	20.96	*	2.68		0.00	0.03	0.11	
16	0.75	0.07	10.01	*	3.41	*	0.08	0.08	1.02	
GP	0.83	0.03	26.05	*	5.40	*	0.01	0.03	0.29	
TIMES										
11	0.86	0.08	10.57	*	1.66		-0.06	0.08	0.79	
12	0.91	0.03	29.53	*	2.84		0.12	0.03	4.43	*
13	1.01	0.04	26.52	*	0.24		-0.01	0.03	0.23	
14	1.02	0.06	17.49	*	0.40		-0.01	0.05	0.25	
15	1.02	0.05	19.70	*	0.47		-0.04	0.04	1.01	
16	0.86	0.07	13.17	*	2.06		0.02	0.07	0.26	
GP	0.94	0.03	32.22	*	2.18		0.00	0.03	0.12	
RESPONSES DURING COD										
11	-0.15	0.04	3.61	*	26.93	*	0.00	0.04	0.03	
12	-0.08	0.05	1.52		19.97	*	-0.06	0.05	1.25	
13	-0.06	0.07	0.85		16.02	*	-0.05	0.05	1.07	
14	-0.19	0.03	6.02	*	38.41	*	0.10	0.03	3.78	
15	-0.21	0.05	3.94	*	23.16	*	-0.01	0.04	0.35	
16	-0.16	0.04	3.56	*	26.11	*	0.02	0.04	0.39	
GP	-0.14	0.02	5.63	*	45.71	*	0.00	0.02	0.01	
RESPONSES AFTER COD										
11	0.90	0.20	4.43	*	0.51		-0.05	0.20	0.24	
12	1.01	0.03	34.94	*	0.32		0.09	0.03	3.61	*
13	1.37	0.11	12.73	*	3.44	*	-0.10	0.08	1.22	
14	1.33	0.09	15.36	*	3.81	*	0.02	0.08	0.23	
15	1.40	0.09	15.16	*	4.29	*	0.01	0.07	0.20	
16	0.87	0.10	9.07	*	1.35		0.04	0.10	0.37	
GP	1.12	0.05	22.85	*	2.43		0.00	0.04	0.03	

* $p < 0.05$

continued

Appendix 1.2 continued

E: 15-SEC COD

Hen	slope	SD	t ratio from 0		t ratio from 1		intcpt	SD	t ratio from 0	
TOTAL RESPONSES										
11	0.98	0.03	35.81	*	-0.89		-0.19	0.03	5.69	*
12	0.85	0.08	11.22	*	2.06		-0.16	0.10	1.71	
13	0.90	0.07	12.51	*	1.35		0.01	0.10	0.07	
14	0.89	0.03	26.03	*	3.24		-0.36	0.04	8.01	*
15	0.88	0.04	21.55	*	2.97		-0.07	0.05	1.45	
16	0.72	0.06	12.59	*	4.81	*	-0.20	0.06	3.16	
GP	0.94	0.08	12.06	*	0.82		-0.20	0.08	2.46	
TIMES										
11	0.93	0.04	24.64	*	1.80		-0.13	0.05	2.83	
12	0.87	0.06	14.09	*	2.19		-0.06	0.08	0.79	
13	0.89	0.06	14.58	*	1.87		0.05	0.08	0.64	
14	0.84	0.03	26.25	*	5.15	*	-0.26	0.04	6.36	*
15	0.90	0.04	20.86	*	2.26		-0.08	0.05	1.62	
16	0.76	0.04	17.46	*	5.53	*	-0.12	0.05	2.51	
GP	0.99	0.12	8.11	*	0.06		-0.05	0.13	0.40	
RESPONSES DURING COD										
11	0.04	0.01	5.99	*	158.75	*	-0.05	0.01	6.98	*
12	0.04	0.04	1.07		27.16	*	-0.05	0.04	1.12	
13	0.03	0.01	2.97		96.63	*	-0.02	0.01	1.79	
14	0.12	0.02	7.01	*	49.78	*	-0.15	0.02	6.55	*
15	-0.03	0.05	0.63		22.64	*	-0.08	0.05	1.61	
16	0.16	0.06	2.63		14.03	*	-0.01	0.06	0.10	
GP	0.10	0.05	2.11		18.99	*	-0.11	0.05	2.14	
RESPONSES AFTER COD										
11	1.51	0.12	13.07	*	4.41	*	-0.49	0.14	3.41	
12	1.00	0.11	9.14	*	0.03		-0.27	0.14	1.92	
13	1.13	0.13	8.75	*	1.00		0.04	0.17	0.23	
14	1.08	0.07	16.63	*	1.30		-0.42	0.08	4.96	*
15	1.04	0.08	13.55	*	0.56		-0.13	0.09	1.51	
16	0.82	0.10	8.03	*	1.74		-0.26	0.11	2.33	
GP	1.14	0.10	11.53	*	1.38		-0.27	0.10	2.59	

* $p < 0.05$

Appendix 2.1

Experiment 2. Total responses made (PR & PG) and times spent (TR & TG) on the red (varied) and green (constant) schedules over the session, responses made during the COD, reinforcements obtained (RR & RG), and numbers of changeovers made (COs) by each hen, for each of the last five days of each experimental condition.

HEN	CON D	PR	PG	TR	TG	IN COD PR	IN COD PG	RR	RG	COs
51	1	531	234	715	313	125	120	30	10	67
51	1	570	192	724	250	100	92	31	9	51
51	1	662	188	814	239	108	104	30	10	54
51	1	506	198	619	267	163	115	31	9	75
51	1	568	191	707	232	134	110	35	5	65
51	2	521	182	771	251	110	108	30	10	57
51	2	569	145	837	201	104	88	31	9	49
51	2	526	136	806	174	73	79	29	10	37
51	2	519	106	852	153	79	74	31	9	37
51	2	480	155	717	218	124	117	30	10	53
51	3	397	158	805	248	80	94	31	9	49
51	3	423	169	720	253	84	93	29	11	50
51	3	465	164	741	226	102	97	30	10	57
51	3	530	172	788	221	104	104	30	10	55
51	3	475	183	744	243	85	93	30	10	48
51	4	368	843	642	2083	137	109	11	29	107
51	4	261	781	586	2152	100	62	11	29	92
51	4	264	783	534	2176	123	89	12	28	89
51	4	287	782	631	2101	105	86	12	28	83
51	4	361	710	691	1851	159	128	12	28	140
51	5	209	624	540	1711	85	66	11	25	94
51	5	239	600	676	1625	75	86	11	25	90
51	5	265	732	706	1742	83	93	11	25	114
51	5	199	598	548	1603	52	77	11	25	84
51	5	246	708	614	1643	60	90	11	25	85
51	6	234	504	564	1209	71	69	10	20	105
51	6	282	511	642	1148	84	90	9	21	110
51	6	280	542	599	1178	103	95	10	20	111
51	6	277	448	635	1096	75	89	10	20	92
51	6	270	628	548	1201	87	91	10	20	78
51	7	259	456	590	1083	94	91	13	17	85
51	7	266	421	623	1023	70	85	13	17	89
51	7	266	412	605	937	93	101	12	18	90
51	7	320	475	657	927	126	163	12	18	100
51	7	272	466	666	984	74	91	12	18	108
51	8	254	328	698	819	79	84	13	17	125
51	8	280	370	755	841	93	100	13	17	125
51	8	268	320	716	854	85	83	13	17	126
51	8	242	366	654	914	103	96	12	17	135
51	8	264	363	723	838	98	105	13	17	121
51	9	250	382	629	972	90	74	13	17	108
51	9	153	384	574	1159	32	33	11	18	44
51	9	230	348	612	945	75	62	12	17	85
51	9	299	390	702	963	81	70	13	17	103
51	9	300	416	682	1035	78	76	13	17	105

51	10	193	750	399	1606	81	74	6	23	66
51	10	206	738	406	1616	66	50	6	24	52
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51	10	154	733	268	1719	60	49	6	23	48
51	10	211	778	453	1581	46	58	6	24	66
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52	5	411	1063	709	1497	204	107	11	25	148
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53	20	389	175	490	232	21	30	22	8	32
53	20	468	134	571	164	24	34	22	8	31
53	20	421	225	509	285	38	52	22	8	45
53	21	505	823	694	1206	86	57	9	21	89
53	21	549	899	714	1160	90	72	9	21	98
53	21	605	969	741	1218	95	80	9	21	94
53	21	629	976	778	1226	102	91	9	21	90
53	21	395	905	635	1394	70	71	8	22	85
53	22	394	852	733	1217	49	44	9	21	98
53	22	459	735	814	1147	45	57	9	21	114
53	22	409	708	762	1188	51	54	9	21	134
53	22	401	852	732	1193	69	76	9	21	110
53	22	272	546	740	1905	46	55	9	20	70
53	23	411	1064	599	1352	79	81	9	21	104
53	23	324	992	537	1393	52	66	8	22	98
53	23	328	772	541	1248	46	54	9	21	93
53	23	496	868	722	1224	53	81	9	21	88
53	23	421	914	647	1259	56	68	9	21	104

53	24	494	660	762	960	69	76	12	18	94
53	24	409	532	842	955	42	52	13	17	74
53	24	474	708	703	1005	51	73	12	18	94
53	24	427	565	757	978	47	59	13	17	94
53	24	536	713	743	973	88	98	12	18	114
53	25	375	747	675	1031	21	33	12	18	76
53	25	508	645	819	991	32	34	13	17	92
53	25	341	552	734	988	29	38	12	18	83
53	25	462	668	754	978	45	44	12	18	86
53	25	403	550	719	989	35	35	12	18	82
53	26	471	665	747	1000	51	66	12	18	98
53	26	484	700	699	988	34	39	13	17	78
53	26	415	738	715	1041	47	64	12	18	72
53	26	468	623	758	935	55	59	12	18	77
53	26	518	770	709	1011	93	90	12	18	101
53	27	234	949	475	2011	45	74	4	26	82
53	27	191	1223	331	2095	41	60	5	25	58
53	27	145	1035	322	2088	26	40	4	26	50
53	27	216	924	445	1916	50	74	4	26	69
53	27	167	1010	372	2095	45	68	4	26	56
53	28	236	1205	525	1923	14	26	4	26	84
53	28	302	1038	572	1867	57	64	4	26	102
53	28	266	1348	514	1948	72	79	4	26	92
53	28	237	1199	576	1892	35	40	5	25	76
53	28	232	1212	826	1862	57	74	4	25	91
53	29	164	1347	343	2084	33	52	4	26	56
53	29	236	1390	403	2026	73	87	4	26	82
53	29	125	1290	304	2123	32	60	3	27	56
53	29	110	1360	219	2169	24	40	4	26	42
53	29	172	1319	310	2127	48	54	4	26	56
54	1	410	209	614	290	89	78	32	8	53
54	1	491	218	730	321	84	85	29	11	56
54	1	512	196	727	258	81	81	31	9	54
54	1	434	197	656	271	96	87	32	8	61
54	1	458	188	618	264	80	65	31	9	53
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54	2	444	202	665	351	45	54	29	11	54
54	2	508	136	730	278	30	38	29	11	45
54	2	537	125	798	249	14	32	30	10	35
54	2	562	143	744	273	32	53	29	11	50
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54	3	492	143	765	291	19	13	30	10	42
54	3	502	142	743	320	29	17	29	11	50
54	3	464	131	700	300	20	22	29	11	49
54	3	413	126	717	287	24	25	30	10	46
54	4	407	808	875	1740	109	125	13	27	159
54	4	368	824	829	1774	136	128	12	28	165
54	4	443	771	910	1778	168	148	12	28	169
54	4	342	626	953	1768	97	71	12	28	140
54	4	318	499	939	1636	78	68	12	28	144
54	5	277	477	979	1407	82	32	12	24	166
54	5	277	337	1057	1398	83	15	12	24	162
54	5	266	324	983	1297	75	15	12	24	152
54	5	256	349	1008	1475	79	15	10	26	157
54	5	287	293	1035	1315	119	18	12	24	185
54	6	98	297	750	1354	5	10	9	21	63
54	6	134	474	567	1536	18	20	8	22	69
54	6	154	499	588	1447	20	34	9	21	81
54	6	204	497	668	1548	36	30	9	21	88
54	6	62	153	1138	1639	14	29	8	22	63

54	7	177	353	733	1071	29	46	12	18	102
54	7	159	266	789	1160	18	24	11	19	86
54	7	145	304	643	1090	20	27	12	18	94
54	7	247	371	802	1012	58	64	13	17	128
54	7	209	341	806	1014	30	60	12	18	133
54	8	286	255	914	819	62	23	12	18	118
54	8	288	281	823	892	74	37	12	18	120
54	8	285	295	838	948	63	19	12	18	108
54	8	340	256	893	893	73	19	12	18	117
54	8	288	267	899	888	62	25	13	17	115
54	9	297	273	960	843	33	17	13	17	111
54	9	288	325	913	916	38	23	12	18	110
54	9	277	257	874	913	49	23	12	18	115
54	9	499	709	780	1148	90	69	10	20	97
54	9	289	232	917	833	25	10	13	17	98
54	10	286	557	653	1569	93	53	6	24	139
54	10	236	548	559	1492	80	44	6	24	116
54	10	189	510	582	1675	38	22	6	24	91
54	10	184	581	542	1672	54	29	6	24	95
54	10	237	696	506	1632	58	32	6	24	84
54	11	157	538	582	1741	52	21	6	24	126
54	11	148	461	519	1485	42	23	7	23	106
54	11	145	505	521	1522	34	24	7	23	97
54	11	112	569	432	1539	19	19	6	24	76
54	11	149	665	495	1623	23	12	6	24	88
54	12	180	462	664	1388	44	29	6	24	104
54	12	180	473	677	1442	41	28	7	23	105
54	12	150	626	473	1824	52	28	5	25	96
54	12	142	501	540	1610	40	17	5	25	112
54	12	134	586	509	1757	34	17	5	25	94
54	13	259	237	577	598	41	17	18	12	76
54	13	270	241	640	659	43	7	17	13	77
54	13	336	233	618	541	55	20	18	12	79
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54	13	334	226	659	501	63	16	18	12	80
54	14	285	203	723	526	47	16	18	12	84
54	14	249	180	658	485	31	18	17	13	79
54	14	268	195	693	481	28	13	17	13	69
54	14	287	203	738	489	39	17	17	13	79
54	14	273	181	702	449	34	11	18	12	72
54	15	311	195	727	530	54	21	18	12	86
54	15	295	192	712	501	64	35	18	12	94
54	15	246	182	647	516	40	13	17	13	81
54	15	272	184	669	511	51	16	18	12	87
54	15	251	181	635	511	34	16	16	14	82
54	16	215	155	682	472	1	0	18	12	69
54	16	212	130	709	434	0	0	18	12	66
54	16	210	178	652	550	2	1	17	13	83
54	16	232	170	655	494	0	1	17	13	73
54	16	219	155	662	522	1	0	18	12	77
54	17	241	131	736	462	33	3	17	13	83
54	17	278	166	750	481	32	2	18	12	79
54	17	240	133	754	497	28	1	17	13	83
54	17	230	146	740	590	20	4	18	12	77
54	17	202	123	721	499	17	1	17	13	79
54	18	304	71	681	175	16	9	24	6	33
54	18	275	66	666	180	21	8	22	8	35
54	18	234	109	577	264	23	12	23	7	42
54	18	300	105	594	235	30	12	23	7	40
54	18	299	73	665	199	16	6	24	6	31

54	19	297	71	605	193	0	0	24	6	28
54	19	355	57	749	152	0	0	25	5	27
54	19	272	55	620	172	1	0	24	6	27
54	19	343	35	758	105	1	0	25	5	15
54	19	308	60	623	191	1	1	24	6	35
54	20	343	50	745	145	8	10	25	5	26
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54	20	282	64	646	168	16	18	24	6	31
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54	21	282	456	727	1218	19	36	8	22	97
54	21	218	545	602	1396	15	31	8	22	106
54	21	206	571	568	1465	29	50	9	21	111
54	21	198	510	596	1426	20	49	8	22	118
54	21	185	473	604	1345	19	45	9	21	119
54	22	171	409	719	1215	5	0	9	21	89
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54	22	149	413	740	1310	4	3	8	22	102
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54	23	157	685	475	1638	41	12	9	21	89
54	23	139	412	595	1384	41	28	8	21	110
54	23	166	561	529	1515	41	14	8	22	89
54	23	140	502	569	1419	21	5	8	22	72
54	23	107	406	719	1296	13	8	9	21	89
54	24	178	326	754	1073	22	11	12	18	100
54	24	215	376	805	995	22	31	12	18	111
54	24	249	388	776	1004	30	21	13	17	119
54	24	192	269	854	1055	29	35	12	18	100
54	24	252	436	736	1068	39	29	12	18	105
54	25	148	384	699	1102	4	0	12	18	102
54	25	150	427	653	1157	2	2	12	18	109
54	25	147	366	716	1001	3	1	12	18	106
54	25	143	368	772	1077	2	3	12	18	102
54	25	164	365	755	1003	1	1	13	17	103
54	26	207	435	693	1133	23	43	12	18	108
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54	26	221	396	728	1123	27	24	12	18	92
54	26	179	344	675	1102	21	19	12	18	89
54	26	252	366	781	978	22	40	12	18	96
54	27	69	577	293	1789	11	5	5	25	58
54	27	111	784	384	1892	15	6	5	25	74
54	27	88	649	360	1905	9	6	5	25	60
54	27	78	506	362	1944	2	6	6	24	62
54	27	94	489	486	1766	2	3	5	25	84
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54	28	89	553	447	1532	2	1	6	24	66
54	28	112	595	564	1835	0	1	6	24	83
54	28	93	519	504	1653	2	0	6	24	78
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54	29	109	618	483	1691	13	6	6	24	79
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55	1	424	131	641	207	81	59	31	9	36
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55	2	609	190	789	347	109	76	30	10	60
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55	2	602	153	857	307	87	46	31	9	42
55	2	545	116	817	234	80	51	31	9	43
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55	3	581	151	796	253	91	66	31	9	42
55	3	708	178	914	258	136	84	32	8	53
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55	4	579	1299	757	1905	246	397	12	28	174
55	4	604	1110	864	1943	230	330	10	30	161
55	4	472	995	705	1937	185	256	12	28	130
55	4	594	1217	874	1951	217	333	10	30	160
55	4	495	982	857	1789	174	308	13	27	159
55	5	611	877	906	1365	219	176	11	25	134
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55	5	556	913	1009	1492	242	242	10	26	163
55	5	485	807	919	1377	193	223	11	25	140
55	6	398	970	603	1364	110	159	8	22	93
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55	7	421	629	709	1015	151	167	12	18	133
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55	7	445	598	734	981	159	181	10	20	142
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55	8	389	526	713	881	134	121	11	19	125
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55	9	368	556	709	966	110	125	14	16	123
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55	9	417	616	762	997	104	142	12	18	110
55	10	302	1324	487	1879	123	235	5	25	118
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55	10	236	1125	429	1756	81	183	6	24	93
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55	11	211	853	426	1584	80	81	5	25	89
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55	12	254	923	452	1700	74	92	6	24	82
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55	13	411	410	649	654	121	96	17	13	97
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55	13	351	340	608	605	115	77	17	13	93
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55	14	351	296	647	580	104	79	18	12	112
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55	15	383	319	630	600	83	70	17	13	96
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55	15	361	298	647	635	102	55	17	13	94
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55	17	323	249	648	575	55	45	18	12	79
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55	18	275	156	435	334	72	35	21	9	55
55	18	278	155	490	311	65	41	23	7	57
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55	18	295	126	468	262	66	33	21	9	50
55	18	270	146	446	288	63	30	21	9	54
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55	19	236	102	500	275	39	38	21	9	57
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55	20	294	65	571	153	21	19	23	7	25
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55	22	228	393	786	1211	32	22	9	21	126
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55	23	250	553	628	1303	51	37	9	21	109
55	23	319	627	701	1307	48	57	10	20	103
55	23	231	625	593	1431	31	41	8	22	89
55	24	236	427	636	1014	60	62	13	17	140
55	24	337	524	684	1024	88	73	12	18	147
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55	24	275	477	677	1105	71	71	12	18	134
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55	25	275	501	602	1035	62	66	12	18	91
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55	25	197	374	623	1036	20	23	12	18	93
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55	26	297	391	636	997	65	50	13	17	105
55	26	316	392	674	942	71	57	12	18	103
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55	26	344	453	749	972	95	79	12	18	117
55	26	384	533	763	1026	109	119	13	17	133
55	27	180	787	365	1903	25	25	5	25	74
55	27	138	526	382	1862	34	41	5	25	52
55	27	324	729	589	1614	97	80	7	23	128
55	27	190	557	470	1789	51	53	5	25	92
55	27	253	663	626	1603	74	113	6	24	128
55	28	272	727	701	1596	51	52	5	25	118
55	28	276	733	751	1662	53	57	5	25	120
55	28	255	639	659	1421	51	56	5	25	121
55	28	171	650	644	1652	19	31	5	25	112
55	28	202	757	565	1741	36	33	5	25	102
55	29	171	980	398	1971	48	59	4	26	80
55	29	261	1049	448	1894	94	81	5	25	98
55	29	186	978	331	1823	63	36	5	25	77
55	29	186	1000	384	1907	57	50	5	25	87
55	29	201	977	398	2006	59	49	4	26	86
56	1	440	201	635	279	110	96	31	9	66
56	1	379	205	594	292	112	98	31	9	75
56	1	443	217	543	294	107	94	29	11	62
56	1	452	183	611	233	120	96	30	10	68
56	1	411	203	637	286	110	92	31	9	77
56	2	447	183	804	289	102	91	30	10	70
56	2	423	183	702	286	112	97	30	10	78
56	2	526	165	803	274	85	62	30	10	58
56	2	412	183	703	524	73	76	29	11	60
56	2	403	215	698	366	108	95	29	11	85
56	3	511	192	725	395	83	60	29	11	70
56	3	494	166	776	309	63	56	31	9	58
56	3	456	125	796	328	37	32	30	10	52
56	3	476	147	760	350	50	40	29	11	58
56	3	483	196	858	269	40	33	30	10	44
56	4	337	714	800	2043	77	99	10	30	128
56	4	258	475	671	1326	71	76	20	20	90
56	4	347	480	869	1414	107	103	16	24	127
56	4	363	539	1055	2017	98	82	10	30	129
56	4	262	585	861	2313	70	75	7	33	83
56a	5	360	919	890	1660	205	292	10	26	227
56a	5	321	902	774	1728	194	268	9	27	194
56a	5	205	821	457	2092	124	127	8	28	102
56a	5	293	865	681	1713	175	188	9	27	135
56a	5	345	910	822	1815	130	129	9	27	101
56a	6	265	779	571	1427	129	157	8	22	124
56a	6	255	758	587	1409	127	157	8	22	118
56a	6	216	944	499	1618	102	131	7	23	96
56a	6	316	721	645	1390	154	164	7	23	129
56a	6	317	785	646	1395	122	144	7	23	109
56a	7	365	528	696	881	83	104	12	18	80
56a	7	333	510	660	901	70	87	13	17	71
56a	7	378	485	679	831	108	117	13	17	84
56a	7	426	564	748	883	127	138	13	17	96
56a	7	349	608	621	934	93	102	12	18	80
56a	8	274	400	708	911	34	45	12	18	87
56a	8	272	405	797	948	59	64	13	17	94
56a	8	259	362	745	837	46	57	13	16	107
56a	8	277	461	718	922	35	69	12	18	90
56a	8	220	370	715	877	17	33	12	18	78

56a	9	385	521	703	903	56	46	13	17	81
56a	9	345	474	684	817	49	49	12	18	71
56a	9	338	577	648	979	48	36	12	18	77
56a	9	328	496	642	862	41	34	13	17	85
56a	9	378	567	723	948	51	42	13	17	91
56a	10	105	836	349	2113	17	22	4	26	42
56a	10	122	928	365	2120	16	20	4	26	48
56a	10	67	897	275	2209	10	12	3	27	42
56a	10	99	828	345	2124	18	29	4	26	46
56a	10	129	909	429	2070	23	38	3	27	62
56a	11	116	970	391	2043	41	44	4	26	80
56a	11	71	941	264	2179	20	32	4	26	44
56a	11	73	971	274	2125	21	28	4	26	54
56a	11	87	1026	323	2130	14	31	4	26	60
56a	11	91	1139	266	2116	20	23	4	26	42
56a	12	129	980	311	2138	44	40	4	26	56
56a	12	99	994	244	2162	33	36	4	26	44
56a	12	52	993	140	2306	11	13	3	27	22
56a	12	82	958	206	2206	23	21	3	27	32
56a	12	105	924	268	2149	30	25	4	26	34
56a	13	309	293	668	552	50	52	18	12	93
56a	13	326	260	684	536	48	31	18	12	72
56a	13	350	323	695	586	50	51	17	13	86
56a	13	298	321	646	613	33	38	18	12	89
56a	13	327	340	656	615	35	42	18	12	87
56a	14	301	331	620	629	43	53	18	12	94
56a	14	322	304	645	557	39	56	17	13	85
56a	14	363	319	643	639	107	71	17	13	112
56a	14	338	336	675	582	38	72	18	12	93
56a	14	318	286	662	572	40	67	18	12	100
56a	15	324	263	650	558	54	49	18	12	85
56a	15	337	303	628	584	37	39	18	12	73
56a	15	352	299	655	548	49	45	18	12	75
56a	15	368	349	671	631	57	55	18	12	82
56a	15	347	253	673	522	46	54	17	13	83
56a	16	304	260	615	587	5	5	17	13	59
56a	16	358	220	717	518	9	8	18	12	81
56a	16	342	211	698	505	19	12	18	12	78
56a	16	334	269	668	609	14	10	19	11	85
56a	16	327	257	652	577	14	12	19	11	83
56a	17	284	263	708	642	54	27	19	11	73
56a	17	469	258	766	509	74	41	18	12	76
56a	17	427	312	727	627	65	28	18	12	76
56a	17	426	278	756	538	40	27	17	13	62
56a	17	357	265	765	591	45	23	19	11	70
56a	18	322	123	560	234	29	26	13	7	44
56a	18	318	145	489	265	34	26	22	8	36
56a	18	418	81	623	137	19	15	24	6	22
56a	18	377	98	584	182	25	17	24	6	32
56a	18	474	57	766	113	10	8	26	4	16
56a	19	200	114	489	340	6	7	23	7	56
56a	19	209	92	519	278	10	7	22	8	41
56a	19	217	100	476	285	5	6	23	7	44
56a	19	312	103	547	212	1	6	23	7	34
56a	19	327	114	551	237	5	10	24	6	39
56a	20	374	126	588	254	56	31	23	7	59
56a	20	366	100	564	216	36	18	22	8	47
56a	20	380	118	557	252	43	19	22	8	56
56a	20	341	152	533	296	62	31	23	7	66
56a	20	368	111	567	239	53	28	24	6	56

56a	21	371	544	828	1052	64	73	9	21	134
56a	21	366	497	823	1009	81	88	10	20	139
56a	21	351	575	770	1176	69	85	10	20	121
56a	21	358	482	808	1004	50	47	10	20	112
56a	21	354	513	821	1114	33	23	10	20	125
56a	22	181	441	664	1202	15	20	9	21	104
56a	22	192	450	697	1225	15	11	9	21	79
56a	22	230	405	765	1101	14	13	10	20	101
56a	22	243	384	870	1102	14	21	10	20	113
56a	22	251	379	770	963	11	13	9	21	98
56a	23	243	587	643	1370	59	66	8	22	128
56a	23	241	542	595	1160	41	65	8	22	107
56a	23	209	642	566	1414	26	45	8	22	104
56a	23	198	628	539	1390	16	28	8	22	89
56a	23	171	605	475	1490	28	29	9	21	90
56a	24	166	289	575	959	19	18	12	18	102
56a	24	172	400	521	1065	34	34	12	18	92
56a	24	255	388	637	945	35	33	12	18	88
56a	24	160	402	489	1137	25	19	12	18	62
56a	24	208	402	607	1001	27	30	12	18	90
56a	25	229	281	735	835	3	2	12	18	65
56a	25	397	840	601	1014	44	43	12	18	86
56a	25	143	375	549	1239	2	3	12	18	25
56a	25	172	299	625	972	7	9	12	18	44
56a	25	207	304	735	995	9	11	13	17	83
56a	26	235	460	572	1020	25	4	12	18	55
56a	26	260	458	709	1144	13	3	12	18	58
56a	26	234	281	736	901	19	9	12	18	45
56a	26	199	360	591	1076	16	4	12	18	58
56a	26	264	357	693	965	40	19	12	18	97
56a	27	89	614	430	2026	19	12	4	26	68
56a	27	68	753	297	2147	18	17	4	26	58
56a	27	54	661	279	2207	12	8	3	27	48
56a	27	75	485	439	2115	23	17	4	26	68
56a	27	39	580	259	2198	10	15	5	25	42
56a	28	36	720	259	2135	4	4	4	26	40
56a	28	69	719	406	2114	8	5	4	26	56
56a	28	37	655	253	2063	0	0	4	26	30
56a	28	30	718	237	2191	4	1	4	26	28
56a	28	29	653	211	2507	3	0	3	27	24
56a	29	44	721	250	2200	17	28	4	26	50
56a	29	83	846	333	2135	26	41	4	26	76
56a	29	76	715	340	2111	16	41	5	26	84
56a	29	61	679	282	2193	21	26	4	26	58
56a	29	60	648	301	2183	16	20	4	26	58

Appendix 2.2

Experiment 2. The slopes and intercepts, with their standard deviations (SD) and the results of t-tests for the significance of differences from 0.00 or 1.00, of the lines fitted to the log ratios of the behaviour measures, for each hen and for the group during each experimental phase (numbers were rounded to two decimal places after calculation).

A: TOTAL RESPONSES			t ratio				t ratio
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Hen	slope	SD	from 0	from 1	intcpt	SD	from 0
SERIES 1: PHASE 1							
51	0.87	0.05	18.78 *	2.74	-0.08	0.02	3.95 *
52	1.04	0.23	4.59 *	0.16	-0.01	0.11	0.13
53	0.86	0.10	8.24 *	1.36	-0.03	0.05	0.69
54	0.70	0.07	10.23 *	4.37 *	-0.03	0.03	0.99
55	0.84	0.07	11.22 *	2.16	-0.06	0.03	1.71
56a	0.94	0.10	9.22	0.56	-0.09	0.05	1.74
GP	0.87	0.04	24.08 *	3.72 *	-0.05	0.02	3.41 *
SERIES 1: PHASE 2							
51	1.10	0.05	20.90 *	1.97	-0.02	0.02	1.05
52	1.18	0.10	11.98 *	1.84	0.06	0.04	1.33
53	0.97	0.07	13.30 *	0.35	-0.05	0.04	1.35
54	0.98	0.16	6.28 *	0.11	0.09	0.06	1.65
55	0.88	0.07	12.02 *	1.58	0.05	0.03	1.39
56a	1.10	0.18	5.93 *	0.52	-0.07	0.09	0.80
GP	1.04	0.05	19.78 *	0.70	0.00	0.02	0.17
SERIES 1: PHASE 3							
51	0.94	0.03	28.62 *	1.98	-0.03	0.01	2.33
52	1.09	0.08	14.44 *	1.14	-0.07	0.03	2.21
53	0.97	0.06	17.09 *	0.53	-0.04	0.03	1.23
54	1.02	0.11	9.06 *	0.19	0.06	0.05	1.37
55	0.94	0.06	15.21 *	1.00	0.01	0.03	0.29
56a	1.04	0.11	9.09 *	0.37	-0.05	0.06	0.85
GP	1.01	0.03	36.38 *	0.21	-0.03	0.01	2.08
SERIES 2: PHASE 1							
51	0.74	0.09	8.10 *	2.81	-0.04	0.03	1.23
52	1.15	0.09	12.99 *	1.74	-0.03	0.05	0.72
53	0.78	0.09	8.96 *	2.49	-0.04	0.04	1.04
54	1.09	0.08	13.25 *	1.08	-0.02	0.04	0.57
55	0.75	0.06	12.64 *	4.20 *	-0.03	0.02	1.50
56a	1.08	0.14	7.87 *	0.60	-0.03	0.06	0.43
GP	0.95	0.07	12.91 *	0.70	-0.03	0.03	0.94
SERIES 2: PHASE 2							
51	0.93	0.09	10.37 *	0.83	-0.10	0.03	3.11
52	1.08	0.12	9.05 *	0.69	-0.03	0.05	0.54
53	0.84	0.03	25.96 *	5.00 *	-0.01	0.01	0.78
54	1.21	0.14	8.71 *	1.50	-0.05	0.06	0.78
55	0.77	0.15	4.98 *	1.51	-0.01	0.06	0.21
56a	1.16	0.17	6.89 *	0.95	-0.10	0.08	1.27
GP	0.97	0.06	15.84 *	0.42	-0.04	0.03	1.58
SERIES 2: PHASE 3							
51	0.79	0.03	26.47 *	7.11 *	-0.08	0.01	6.49 *
52	1.37	0.14	10.04 *	2.71	-0.01	0.06	0.23
53	0.99	0.05	19.80 *	0.11	-0.04	0.02	1.60
54	1.18	0.07	16.05 *	2.43	-0.04	0.03	1.10
55	0.99	0.08	11.71 *	0.17	0.00	0.04	0.07
56a	1.15	0.08	14.42 *	1.84	-0.05	0.04	1.41
GP	1.08	0.05	20.73 *	1.57	-0.04	0.02	1.77

* $p < 0.05$

continued

Appendix 2.2 continued

B: TIMES

Hen	slope	SD	t ratio from 0		t ratio from 1		intcpt	SD	t ratio from 0	
SERIES 1: PHASE 1										
51	0.92	0.08	12.01	*	1.00		-0.12	0.03	3.68	*
52	0.97	0.13	7.35	*	0.20		0.00	0.06	0.01	
53	0.95	0.09	10.54	*	0.54		-0.02	0.04	0.35	
54	0.72	0.03	24.80	*	9.88	*	-0.03	0.01	2.55	
55	0.81	0.05	16.89	*	4.07	*	-0.06	0.02	2.76	
56a	0.84	0.08	10.87		2.12		-0.04	0.04	1.08	
GP	0.87	0.03	27.67	*	4.24	*	-0.05	0.01	3.27	*
SERIES 1: PHASE 2										
51	1.03	0.11	9.40	*	0.23		0.02	0.04	0.49	
52	1.07	0.07	15.96	*	1.07		0.00	0.03	0.00	
53	0.95	0.05	20.86	*	1.02		-0.01	0.02	0.64	
54	0.83	0.10	8.35	*	1.77		0.06	0.04	1.74	
55	0.77	0.08	9.61	*	2.89		0.00	0.04	0.03	
56a	0.92	0.14	6.45	*	0.56		-0.03	0.07	0.38	
GP	0.91	0.05	17.18	*	1.61		0.00	0.02	0.15	
SERIES 1: PHASE 3										
51	1.01	0.05	20.03	*	0.15		-0.01	0.02	0.53	
52	1.06	0.03	32.79	*	1.81		-0.06	0.01	4.20	*
53	0.99	0.10	9.82	*	0.07		0.02	0.05	0.37	
54	0.78	0.06	12.77	*	3.67	*	0.05	0.02	1.85	
55	0.83	0.07	11.61	*	2.45		0.00	0.03	0.13	
56a	0.99	0.16	6.35	*	0.05		-0.03	0.08	0.34	
GP	0.92	0.05	18.85	*	1.58		-0.01	0.02	0.39	
SERIES 2: PHASE 1										
51	0.78	0.10	8.14	*	2.36		-0.01	0.04	0.41	
52	1.03	0.10	10.49	*	0.28		-0.05	0.05	1.07	
53	0.75	0.09	8.62	*	2.84		-0.05	0.04	1.21	
54	0.94	0.05	19.43	*	1.21		0.00	0.02	0.12	
55	0.69	0.07	10.03	*	4.43	*	-0.06	0.03	2.40	
56a	0.91	0.12	7.44	*	0.75		-0.01	0.06	0.22	
GP	0.86	0.08	11.31	*	1.92		-0.03	0.03	0.92	
SERIES 2: PHASE 2										
51	0.73	0.12	6.31	*	2.29		-0.08	0.04	1.73	
52	0.86	0.09	9.76	*	1.58		-0.06	0.04	1.43	
53	0.66	0.03	26.31	*	13.66	*	0.00	0.01	0.02	
54	0.90	0.08	11.18	*	1.27		0.02	0.04	0.68	
55	0.61	0.11	5.37	*	3.45	*	0.00	0.05	0.10	
56a	0.84	0.14	6.19	*	1.20		-0.08	0.06	1.16	
GP	0.76	0.06	13.40	*	4.19	*	-0.03	0.02	1.17	
SERIES 2: PHASE 3										
51	0.79	0.05	17.01	*	4.49	*	-0.04	0.02	1.89	
52	1.06	0.12	8.87	*	0.47		-0.04	0.06	0.69	
53	0.91	0.04	20.98	*	2.18		-0.02	0.02	1.12	
54	0.95	0.02	40.26	*	1.90		0.00	0.01	0.44	
55	0.96	0.08	11.51	*	0.45		0.00	0.04	0.10	
56a	0.91	0.06	14.24	*	1.41		-0.07	0.03	2.20	
GP	0.93	0.04	22.52	*	1.74		-0.03	0.02	1.55	

* $p < 0.05$

continued

Appendix 2.2 continued

C: RESPONSES MADE DURING THE COD

Hen	slope	SD	t ratio from 0		t ratio from 1		intcpt	SD	t ratio from 0	
SERIES 1: PHASE 1										
51	0.01	0.09	0.06		11.18	*	0.05	0.04	1.45	
52	-0.18	0.28	0.65		4.29	*	-0.15	0.13	1.17	
53	-0.13	0.03	5.26	*	44.82	*	-0.13	0.01	10.19	*
54	0.02	0.32	0.07		3.08		0.13	0.13	1.03	
55	0.40	0.08	5.03	*	7.52	*	-0.02	0.04	0.43	
56a	0.15	0.01	11.53		62.99	*	-0.03	0.01	3.90	
GP	0.13	0.07	1.73		11.86	*	-0.01	0.03	0.43	
SERIES 1: PHASE 2										
51	0.18	0.06	3.07		13.81	*	-0.02	0.02	0.81	
52	-0.36	0.32	1.15		4.31	*	0.39	0.14	2.76	
53	-0.02	0.02	1.02		54.08	*	0.03	0.01	2.71	
54	-0.43	0.35	1.24		4.13	*	0.28	0.13	2.20	
55	0.13	0.05	2.53		17.10	*	0.13	0.02	5.41	*
56a	0.03	0.06	0.59		17.51	*	-0.10	0.03	3.75	
GP	0.03	0.06	0.51		16.14	*	0.10	0.03	3.79	*
SERIES 1: PHASE 3										
51	0.00	0.05	0.08		19.20	*	0.02	0.02	0.76	
52	-0.15	0.09	1.75		13.48	*	-0.07	0.04	1.82	
53	-0.06	0.03	2.50		41.65	*	-0.12	0.01	9.39	*
54	0.02	0.26	0.08		3.75	*	0.16	0.11	1.46	
55	0.33	0.08	3.93	*	8.00	*	0.01	0.04	0.18	
56a	0.03	0.10	0.29		10.19	*	0.01	0.05	0.29	
GP	0.04	0.06	0.71		15.35	*	-0.02	0.03	0.58	
SERIES 2: PHASE 1										
51	0.14	0.09	1.51		9.28	*	0.04	0.03	1.26	
52	0.02	0.14	0.18		7.20	*	-0.06	0.07	0.94	
53	0.09	0.11	0.81		8.03	*	-0.04	0.05	0.77	
54	0.36	0.28	1.28		2.31		0.17	0.12	1.40	
55	0.37	0.11	3.25	*	5.49	*	0.09	0.04	2.13	
56a	0.02	0.06	0.35		16.42	*	0.04	0.03	1.32	
GP	0.18	0.06	3.05		13.83	*	0.03	0.03	1.01	
SERIES 2: PHASE 2										
51	0.08	0.02	3.85	*	44.27	*	0.01	0.01	1.06	
52	-0.34	0.02	17.27	*	67.34	*	0.09	0.01	9.38	*
53	0.07	0.02	4.36	*	61.43	*	-0.03	0.01	4.45	*
54	-0.08	0.19	0.44		5.74	*	0.40	0.08	4.87	*
55	0.01	0.04	0.34		25.44	*	-0.02	0.02	1.43	
56a	-0.22	0.13	1.70		9.55	*	0.01	0.06	0.18	
GP	-0.03	0.03	0.87		31.30	*	0.00	0.01	0.34	
SERIES 2: PHASE 3										
51	0.08	0.09	0.85		10.46	*	0.04	0.04	1.05	
52	-0.03	0.25	0.12		4.07	*	-0.13	0.12	1.06	
53	0.03	0.04	0.61		22.40	*	-0.09	0.02	4.43	*
54	-0.08	0.58	0.13		1.85		0.29	0.25	1.16	
55	-0.07	0.02	4.05	*	58.11	*	0.01	0.01	0.68	
56a	0.43	0.23	1.90		2.52		0.20	0.11	1.85	
GP	0.08	0.06	1.31		15.80	*	0.01	0.03	0.41	

* $p < 0.05$

continued

Appendix 2.2 continued

D: RESPONSES MADE AFTER THE COD

Hen	slope	SD	t ratio from 0		t ratio from 1		intcpt	SD	t ratio from 0	
SERIES 1: PHASE 1										
51	1.19	0.12	10.10	*	1.58		-0.09	0.05	1.74	
52	1.24	0.27	4.57	*	0.87		0.00	0.13	0.03	
53	1.07	0.11	9.81	*	0.65		-0.01	0.05	0.17	
54	0.89	0.06	14.04	*	1.67		-0.04	0.03	1.54	
55	1.02	0.10	10.03	*	0.22		-0.07	0.04	1.48	
56a	1.00	0.09	11.61		0.05		-0.11	0.04	2.38	
GP	1.08	0.07	15.15	*	1.16		-0.05	0.03	1.46	
SERIES 1: PHASE 2										
51	1.53	0.14	10.71	*	3.71	*	0.03	0.06	0.55	
52	1.51	0.07	23.09	*	7.75	*	0.01	0.03	0.34	
53	1.27	0.04	31.79	*	6.81	*	-0.05	0.02	2.39	
54	1.22	0.13	9.06	*	1.62		0.07	0.05	1.49	
55	1.13	0.10	11.14	*	1.24		0.02	0.05	0.37	
56a	1.29	0.12	11.08	*	2.52		-0.09	0.06	1.61	
GP	1.33	0.05	25.52	*	6.35	*	-0.01	0.02	0.24	
SERIES 1: PHASE 3										
51	1.30	0.10	13.55	*	3.14		0.00	0.04	0.02	
52	1.41	0.08	16.74	*	4.85	*	-0.05	0.04	1.27	
53	1.26	0.10	12.28	*	2.51		0.02	0.05	0.31	
54	1.14	0.11	10.66	*	1.33		0.04	0.04	1.00	
55	1.14	0.11	10.44	*	1.32		0.02	0.05	0.48	
56a	1.22	0.07	18.45	*	3.33		-0.08	0.03	2.25	
GP	1.25	0.07	19.10	*	3.88	*	-0.01	0.03	0.41	
SERIES 2: PHASE 1										
51	0.96	0.12	7.76	*	0.34		-0.04	0.05	0.87	
52	1.28	0.10	12.65	*	2.74		-0.02	0.05	0.38	
53	0.88	0.09	10.16	*	1.38		-0.04	0.04	1.05	
54	1.12	0.09	12.52	*	1.31		-0.03	0.04	0.89	
55	0.83	0.07	11.67	*	2.40		-0.07	0.03	2.41	
56a	1.21	0.15	7.96	*	1.37		-0.03	0.07	0.47	
GP	1.07	0.09	12.26	*	0.81		-0.03	0.04	0.85	
SERIES 2: PHASE 2										
51	1.00	0.09	11.45	*	0.05		-0.10	0.03	3.21	*
52	1.21	0.10	11.68	*	2.03		-0.01	0.05	0.27	
53	0.93	0.03	28.78	*	2.28		-0.01	0.01	0.56	
54	1.22	0.14	8.82	*	1.57		-0.05	0.06	0.85	
55	0.89	0.20	4.55	*	0.56		0.00	0.08	0.04	
56a	1.20	0.17	7.04	*	1.19		-0.11	0.08	1.28	
GP	1.07	0.07	15.94	*	1.02		-0.04	0.03	1.28	
SERIES 2: PHASE 3										
51	0.97	0.04	21.51	*	0.76		-0.08	0.02	4.65	*
52	1.51	0.17	9.08	*	3.06		-0.01	0.08	0.08	
53	1.13	0.06	20.33	*	2.37		-0.03	0.03	1.08	
54	1.30	0.06	20.16	*	4.63	*	-0.05	0.03	1.82	
55	1.19	0.10	11.60	*	1.84		0.01	0.05	0.16	
56a	1.26	0.10	12.61	*	2.61		-0.07	0.05	1.57	
GP	1.23	0.07	18.58	*	3.51	*	-0.04	0.03	1.42	

* $\underline{p} < 0.05$

Appendix 3.1

Experiment 3. The responses made over the session (PL & PR), responses made during the COD, total times spent (TL & TR), times spent in the COD, reinforcements obtained (RL & RR), numbers of changeovers (COs), and numbers of changeovers where the COD was completed before another changeover was made, for each hen for each of the last five days of each experimental condition.

HEN	COND	PL	PR	COD PL	COD PR	TL	TR	COD TL	COD TR	RL	RR	COs	COMPLETED CODs L	COMPLETED CODs R
81	1	345	156	127	127	721	373	133	130	31	9	252	124	126
81	1	360	169	144	145	721	374	149	151	31	9	288	144	144
81	1	306	174	135	135	681	420	145	143	30	10	268	134	134
81	1	333	197	161	163	726	422	175	177	31	9	323	159	161
81	1	317	180	137	138	644	450	142	151	31	9	274	137	137
81	2	454	139	104	65	793	334	69	66	30	9	128	64	64
81	2	501	139	99	58	788	330	61	58	31	9	114	57	57
81	2	437	171	117	68	739	398	74	72	31	9	136	68	68
81	2	399	144	116	71	755	354	74	69	31	9	134	67	67
81	2	446	177	142	77	649	459	83	82	31	9	152	76	76
81	3	546	216	59	140	930	184	32	65	31	9	63	31	32
81	3	516	228	69	143	890	195	38	74	31	9	72	36	34
81	3	541	240	70	147	867	214	40	78	31	9	76	38	38
81	3	586	233	68	142	855	205	38	72	30	9	70	35	34
81	3	550	266	81	168	812	240	47	84	31	9	84	42	42
81	4	732	210	97	100	938	222	60	60	33	7	30	15	15
81	4	830	100	77	76	1043	118	44	44	34	5	22	11	10
81	4	739	159	112	116	967	162	64	64	33	7	32	16	16
81	4	815	99	72	63	1016	112	41	41	34	6	20	10	10
81	4	628	141	119	103	1058	168	76	76	35	7	38	19	15
81	5	717	15	14	15	1249	18	16	13	39	0	4	2	1
81	5	772	73	44	55	1115	67	40	39	36	4	10	5	4
81	5	611	126	74	99	1033	129	74	68	34	6	18	9	8
81	5	700	78	47	72	1119	79	49	48	35	5	12	6	6
81	5	645	102	57	77	1173	107	64	60	34	5	16	8	7
81	6	708	14	11	13	1244	16	12	11	39	1	2	1	1
81	6	615	74	52	70	1150	75	60	53	36	4	10	5	4
81	6	767	21	35	20	1235	30	36	22	39	1	6	3	1
81	6	760	57	45	54	1241	55	48	39	37	3	8	4	3
81	6	729	58	44	55	1228	60	48	39	37	3	8	4	3
81	7	527	193	211	168	796	326	175	172	31	8	317	151	125
81	7	493	196	207	167	749	356	179	176	30	10	327	147	134
81	7	417	212	210	182	685	412	188	194	31	9	352	152	166
81	7	447	239	206	180	697	416	190	190	31	9	338	148	136
81	7	433	214	192	185	735	393	189	193	31	9	348	158	149
81	8	541	141	75	62	853	220	48	50	31	9	93	46	47
81	8	557	150	72	52	838	235	39	41	32	8	78	39	39
81	8	529	145	92	62	794	270	51	50	31	9	96	47	48
81	8	565	140	102	74	855	230	59	58	31	9	111	55	55
81	8	542	153	102	74	802	266	57	56	31	9	108	53	52
81	9	558	105	102	66	930	196	59	63	32	8	59	29	28
81	9	601	86	78	54	1065	146	49	47	34	6	46	23	20
81	9	521	110	103	64	910	193	63	62	32	8	60	30	28
81	9	542	134	127	71	906	246	74	73	31	9	73	36	27
81	9	476	116	107	71	938	186	64	62	32	8	62	31	25
81	10	369	89	23	67	1154	89	32	36	34	6	17	8	9
81	10	324	74	24	59	1108	90	33	32	34	6	16	8	8

81	10	318	60	17	48	1081	69	28	29	35	5	14	7	7
81	10	367	9	5	8	1280	15	8	7	39	1	4	2	1
81	10	327	39	9	36	1174	53	20	20	36	4	10	5	4
81	11	409	0	0	0	1326	0	0	0	40	0	0	0	0
81	11	447	0	0	0	1275	0	0	0	40	0	0	0	0
81	11	402	18	5	17	1278	15	8	8	39	1	2	1	1
81	11	439	19	12	18	1316	16	16	11	39	1	4	2	1
81	11	273	16	4	15	1420	34	16	17	39	1	4	2	2
81	12	300	0	0	0	1404	0	0	0	40	0	0	0	0
81	12	297	0	0	0	1407	0	0	0	40	0	0	0	0
81	12	282	0	0	0	1306	0	0	0	40	0	0	0	0
81	12	253	4	5	4	1446	14	12	12	40	0	2	1	1
81	12	285	0	0	0	1371	0	0	0	40	0	0	0	0
81	13	275	356	214	199	342	807	195	191	7	33	351	93	176
81	13	280	348	205	176	329	768	173	186	9	31	320	94	159
81	13	281	369	217	195	336	757	183	193	9	31	346	90	171
81	13	305	326	224	204	372	733	209	209	9	31	379	85	189
81	13	307	324	241	199	355	743	199	204	9	31	382	93	190
81	14	147	615	82	158	225	849	65	63	8	32	117	57	59
81	14	147	602	79	146	233	812	61	58	9	31	115	57	58
81	14	141	635	83	137	204	868	57	58	8	32	109	54	55
81	14	129	695	72	120	190	900	47	49	8	32	93	46	47
81	14	123	635	73	112	176	873	45	47	8	32	87	43	44
81	15	67	538	39	73	146	1022	43	43	7	33	42	20	21
81	15	97	482	54	85	193	939	50	54	8	32	49	24	25
81	15	70	461	40	69	150	965	36	38	7	33	37	18	19
81	15	48	531	28	49	86	1050	23	26	5	35	23	11	12
81	15	37	557	21	47	75	1070	24	23	5	35	22	9	11
81	16	23	571	14	31	50	1172	21	24	2	38	11	5	6
81	16	55	542	36	49	80	1069	33	45	5	35	21	7	11
81	16	20	635	9	19	27	1196	8	12	1	39	5	2	3
81	16	12	643	8	17	22	1181	8	12	2	38	5	2	3
81	16	57	544	44	54	97	1039	44	4	5	35	23	11	12
81	17	0	546	0	11	2	1264	0	8	0	40	1	0	1
81	17	0	642	0	15	2	1256	0	8	0	40	1	0	1
81	17	12	555	11	13	24	1210	9	24	1	39	5	1	3
81	17	0	565	0	5	4	1266	0	8	0	40	1	0	1
81	17	31	441	26	20	54	1187	24	32	2	38	7	3	4
81	18	2	496	2	12	9	1292	4	24	0	40	3	0	2
81	18	2	521	2	20	8	1274	3	36	0	40	5	0	3
81	18	2	562	2	11	6	1344	3	24	0	40	3	0	2
81	18	3	504	3	11	12	1255	7	24	0	40	3	0	2
81	18	0	543	0	5	11	1278	0	12	0	40	1	0	1
82	1	405	124	120	120	940	202	122	127	32	8	240	120	119
82	1	387	134	127	127	934	209	133	133	32	8	254	127	126
82	1	379	139	130	131	941	228	138	137	33	7	260	130	128
82	1	387	161	158	156	930	247	166	164	34	6	313	157	152
82	1	400	113	102	103	980	187	108	103	31	8	203	101	98
82	2	544	9	9	9	1342	26	12	10	40	0	18	9	9
82	2	556	3	3	3	1348	4	3	3	40	0	6	3	3
82	2	491	6	6	6	1365	8	6	6	40	0	12	6	6
82	2	478	6	6	6	1365	8	6	7	40	0	12	6	6
82	2	555	4	4	4	1354	5	4	4	40	0	8	4	4
82	3	496	1	2	1	1336	7	2	2	40	0	3	2	0
82	3	561	2	2	2	1357	3	2	3	40	0	4	2	1
82	3	567	0	0	0	1357	0	0	0	40	0	0	0	0
82	3	511	0	0	0	1359	0	0	0	40	0	0	0	0
82	3	578	0	0	0	1362	0	0	0	40	0	0	0	0
82	4	519	0	0	0	1357	0	0	0	40	0	0	0	0
82	4	523	0	0	0	1333	0	0	0	40	0	0	0	0
82	4	541	0	0	0	1293	0	0	0	40	0	0	0	0
82	4	531	0	0	0	1343	0	0	0	40	0	0	0	0

82	4	496	0	0	0	1397	0	0	0	40	0	0	0	0
82	5	446	0	0	0	1359	0	0	0	40	0	0	0	0
82	5	429	0	0	0	1357	0	0	0	40	0	0	0	0
82	5	451	0	0	0	1356	0	0	0	40	0	0	0	0
82	5	570	0	0	0	1373	0	0	0	40	0	0	0	0
82	5	512	0	0	0	1307	0	0	0	40	0	0	0	0
82	6	396	0	0	0	1371	0	0	0	40	0	0	0	0
82	6	465	0	0	0	1357	0	0	0	40	0	0	0	0
82	6	468	0	0	0	1361	0	0	0	40	0	0	0	0
82	6	487	0	0	0	1338	0	0	0	40	0	0	0	0
82	6	456	0	0	0	1328	0	0	0	40	0	0	0	0
82	7	382	84	88	84	981	139	91	86	34	6	167	84	65
82	7	374	88	88	88	971	145	96	93	33	7	175	88	67
82	7	382	82	76	80	972	157	87	82	32	8	152	76	66
82	7	377	100	93	94	959	188	99	98	32	8	186	93	88
82	7	383	111	97	103	935	191	103	110	33	7	194	96	86
82	8	431	110	38	64	1041	130	39	37	35	5	71	36	35
82	8	388	106	35	64	1047	128	38	38	34	6	71	35	36
82	8	384	132	40	73	1000	150	41	44	33	7	80	40	40
82	8	386	155	55	90	983	195	52	54	33	7	101	51	50
82	8	459	141	47	85	1011	152	47	44	33	6	86	43	43
82	9	481	134	30	81	996	128	38	37	34	6	37	19	18
82	9	518	106	27	70	1053	93	37	38	35	5	36	18	17
82	9	503	187	59	130	988	174	62	62	34	6	62	30	28
82	9	522	124	44	98	1020	119	57	54	35	5	55	28	23
82	9	493	130	49	100	1086	138	70	62	35	5	68	32	25
82	10	577	9	4	8	1216	17	9	4	39	1	3	2	1
82	10	732	0	0	0	1383	0	0	0	40	0	0	0	0
82	10	695	0	0	0	1360	0	0	0	40	0	0	0	0
82	10	671	0	0	0	1336	0	0	0	40	0	0	0	0
82	10	631	2	3	2	1347	6	4	4	40	0	2	1	1
82	11	607	15	4	14	1282	13	8	8	39	1	2	1	1
82	11	659	1	6	1	1336	2	8	2	40	0	2	1	0
82	11	653	1	4	1	1325	2	8	2	40	0	2	1	0
82	11	607	2	5	2	1343	2	8	2	40	0	2	1	0
82	11	638	0	0	0	1343	0	0	0	40	0	0	0	0
82	12	643	0	0	0	1287	0	0	0	40	0	0	0	0
82	12	613	1	5	1	1299	2	12	2	40	0	2	1	0
82	12	598	0	0	0	1324	0	0	0	40	0	0	0	0
82	12	618	1	4	1	1290	5	12	5	40	0	2	1	0
82	12	643	0	0	0	1295	0	0	0	40	0	0	0	0
82	13	348	359	312	286	411	749	279	295	9	31	538	108	257
82	13	280	394	266	260	338	850	271	277	7	33	509	56	252
82	13	296	382	280	268	344	855	271	298	7	33	533	50	260
82	13	272	368	256	256	336	833	260	279	8	32	502	44	246
82	13	305	399	287	286	359	858	289	313	7	33	563	47	263
82	14	240	431	126	56	311	855	51	49	7	33	96	48	48
82	14	290	439	130	74	375	811	52	50	7	33	98	49	49
82	14	305	377	99	53	409	737	47	42	8	32	80	40	40
82	14	242	417	125	79	375	790	52	52	7	32	98	49	49
82	14	234	429	120	60	322	823	50	44	8	32	88	44	44
82	15	224	420	150	67	283	849	68	68	6	34	65	32	33
82	15	207	421	140	66	283	867	65	63	8	32	63	32	31
82	15	350	392	228	87	384	856	102	105	7	33	100	50	50
82	15	271	395	177	61	310	863	74	73	8	32	71	35	35
82	15	229	485	152	64	306	880	72	71	6	34	70	34	35
82	16	254	483	186	57	256	889	64	65	8	32	32	16	16
82	16	344	425	244	73	318	880	94	94	7	33	46	23	23
82	16	370	417	263	58	310	859	93	95	8	32	46	23	23
82	16	367	422	275	69	317	829	93	92	8	32	46	23	23
82	16	314	443	263	75	321	919	99	100	6	34	50	24	25
82	17	25	614	24	12	33	1314	17	32	1	39	8	1	4

82	17	3	643	3	4	5	1339	5	8	0	40	2	0	1
82	17	19	513	18	4	19	1319	9	8	1	39	2	1	1
82	17	149	550	85	31	108	1286	48	57	2	37	14	4	7
82	17	73	546	70	33	67	1245	50	78	3	37	20	3	9
82	18	28	517	27	3	29	1303	12	12	1	39	2	1	1
82	18	29	582	28	11	19	1313	13	24	1	39	4	1	2
82	18	6	530	6	26	5	1294	5	45	0	40	8	0	3
82	18	1	524	1	3	2	1346	2	12	0	40	2	0	1
82	18	34	501	33	29	18	1331	18	60	1	39	11	1	5
83	1	850	283	357	265	817	293	239	219	32	8	462	188	59
83	1	826	263	319	253	830	266	221	190	31	8	406	186	76
83	1	724	336	394	308	774	336	259	239	32	8	498	213	95
83	1	715	361	382	332	738	360	268	244	30	10	514	213	107
83	1	827	443	519	424	798	359	339	296	32	8	642	255	121
83	2	1048	270	188	153	936	219	86	86	33	7	162	79	64
83	2	1041	197	124	116	945	172	63	60	32	8	113	56	50
83	2	1004	149	95	95	997	153	51	48	34	6	88	45	42
83	2	855	290	157	164	862	258	81	81	33	7	152	76	68
83	2	1074	167	86	87	961	141	36	37	32	8	71	35	34
83	3	1112	177	88	114	948	183	31	66	33	6	63	31	31
83	3	1121	100	53	65	983	158	20	41	35	5	40	20	19
83	3	1302	215	104	122	911	224	38	73	33	7	72	36	31
83	3	1234	148	70	102	1000	144	28	51	35	5	50	25	23
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83	4	1146	154	83	102	1004	140	48	46	34	6	24	12	10
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83	5	1272	0	0	0	1353	0	0	0	39	0	0	0	0
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83	5	973	75	50	68	1093	63	49	36	35	4	12	6	4
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83	6	1286	0	0	0	1304	0	0	0	39	0	0	0	0
83	6	1273	2	14	2	1313	2	12	2	40	0	2	1	0
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83	7	619	180	253	165	821	296	184	169	31	9	328	158	65
83	7	637	228	301	199	812	325	207	197	32	8	390	185	82
83	7	621	191	229	165	833	311	176	153	32	8	316	147	92
83	7	693	217	282	200	850	295	202	189	32	8	374	172	79
83	7	657	205	262	177	857	311	186	184	32	8	344	161	78
83	8	663	221	94	89	822	233	36	38	30	10	71	35	35
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83	8	722	248	78	79	857	251	32	35	32	8	64	31	32
83	8	800	237	115	105	884	230	44	42	32	8	84	42	39
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83	9	925	131	85	80	938	168	40	42	33	7	40	20	19
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83	13	664	609	571	569	572	650	423	466	8	32	1066	116	93
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83	15	334	787	224	190	265	976	112	119	8	31	113	42	53
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84	1	739	483	590	464	773	467	453	397	31	8	896	255	52
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84	2	730	323	173	153	705	395	84	80	32	8	149	75	73
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85	17	0	1015	0	0	0	1336	0	0	0	40	0	0	0
85	17	114	901	90	62	81	1093	45	65	4	36	15	5	8
85	17	63	962	27	24	42	1214	18	25	1	39	6	2	3
85	17	37	771	36	49	58	1217	41	75	2	38	20	2	9
85	17	0	918	0	0	0	1271	0	0	0	40	0	0	0
85	18	11	881	11	71	17	1335	17	78	0	40	14	0	6
85	18	0	933	0	0	0	1318	0	0	0	40	0	0	0
85	18	35	789	34	58	40	1250	33	72	1	39	12	2	6
85	18	0	1050	0	0	0	1347	0	0	0	40	0	0	0
85	18	0	1004	0	0	0	1348	0	0	0	39	0	0	0
86	1	469	259	346	252	896	302	269	251	32	8	500	250	67
86	1	465	235	342	234	896	278	253	235	33	7	468	233	72
86	1	278	150	158	146	892	237	150	150	30	10	291	145	96
86	1	485	238	291	238	885	277	246	238	32	8	472	232	61
86	1	282	162	160	150	1207	248	160	157	30	10	300	146	94
86	2	639	177	217	140	889	254	129	132	33	7	242	121	105
86	2	675	178	235	131	895	286	128	127	32	7	235	118	110
86	2	600	159	179	115	880	264	106	103	33	7	202	101	100
86	2	454	164	130	89	952	292	70	73	32	8	138	69	65
86	2	675	198	223	146	859	285	120	120	32	8	226	113	112
86	3	663	163	211	117	823	330	92	164	31	8	168	84	62
86	3	636	197	219	128	766	348	96	171	32	8	180	90	56
86	3	671	215	234	135	746	397	108	192	31	9	200	100	70
86	3	655	210	205	140	754	373	94	174	32	8	176	88	68
86	3	700	211	205	115	698	468	90	172	30	10	166	82	77
86	4	623	106	153	64	936	260	107	104	34	6	52	26	22
86	4	698	113	166	70	1018	276	122	123	34	6	61	30	26
86	4	689	144	137	76	917	318	106	105	33	7	52	26	24
86	4	659	135	150	77	890	304	112	111	33	7	56	28	25
86	4	579	154	138	75	911	367	118	115	32	8	58	29	28
86	5	724	98	58	67	1027	172	89	81	34	6	22	11	10
86	5	817	75	46	49	1130	161	72	67	35	5	18	9	7
86	5	810	110	56	54	1085	242	90	88	33	7	22	11	11
86	5	820	98	84	62	1086	204	117	102	33	7	30	14	10
86	5	850	98	59	60	991	192	80	81	32	8	20	10	10
86	6	863	99	72	67	1112	184	96	94	35	5	16	8	7
86	6	909	44	25	37	1155	67	39	40	37	3	8	3	3
86	6	919	80	37	61	1186	123	60	60	36	4	10	5	5
86	6	916	35	24	29	1185	55	36	27	37	2	6	3	2
86	6	880	83	55	69	1110	131	86	82	36	4	16	7	6
86	7	698	170	279	166	952	230	179	176	32	8	329	164	157

86	7	624	170	268	161	885	239	181	174	31	9	322	161	154
86	7	588	180	275	171	872	257	190	184	30	9	339	169	166
86	7	618	176	279	172	876	249	188	189	31	9	344	172	162
86	7	565	165	257	156	837	249	168	174	30	10	312	156	151
86	8	773	178	56	71	949	199	43	39	33	7	73	37	36
86	8	758	220	70	97	886	225	48	46	33	7	88	44	44
86	8	835	160	60	79	990	176	40	39	33	7	72	36	36
86	8	725	162	44	80	948	164	31	34	33	7	63	31	32
86	8	740	192	60	107	955	193	44	45	33	7	84	42	42
86	9	748	172	56	114	982	147	50	49	33	6	48	24	24
86	9	728	155	47	86	945	161	41	40	32	8	40	20	20
86	9	736	194	51	120	922	167	50	52	33	7	50	25	25
86	9	760	244	70	146	952	205	62	60	33	5	58	29	29
86	9	758	246	80	154	931	201	63	60	33	7	60	30	30
86	10	862	110	40	78	1054	98	44	41	35	5	22	11	8
86	10	882	83	48	68	1124	84	49	45	37	3	24	12	6
86	10	911	77	53	70	1107	96	53	44	35	5	26	13	7
86	10	911	59	18	46	1150	51	20	22	37	3	11	5	4
86	10	769	160	50	113	1030	124	53	51	35	5	26	13	10
86	11	692	132	60	115	1070	127	97	75	35	4	24	12	6
86	11	850	71	40	67	1192	74	56	40	37	3	14	7	3
86	11	804	138	66	127	1118	124	88	79	36	4	22	11	7
86	11	787	123	70	108	1131	104	102	68	37	3	26	12	5
86	11	799	109	47	104	1077	95	73	52	35	5	18	9	5
86	12	870	1	10	1	1345	5	12	5	40	0	2	1	0
86	12	803	0	0	0	1249	0	0	0	40	0	0	0	0
86	12	818	6	40	6	1292	11	47	11	40	0	8	4	0
86	12	833	0	0	0	1281	0	0	0	40	0	0	0	0
86	12	765	1	5	1	1340	3	12	3	40	0	2	1	0
86	13	502	483	475	477	469	803	408	522	7	33	950	23	410
86	13	455	444	427	430	440	737	370	465	10	30	854	26	352
86	13	460	446	430	431	446	738	373	461	10	30	857	36	334
86	13	505	465	455	456	472	721	377	479	9	31	910	47	310
86	13	500	485	469	469	477	724	412	472	10	30	937	38	273
86	14	219	846	105	209	299	839	77	76	8	32	142	71	71
86	14	230	867	100	190	301	825	70	71	8	32	134	67	67
86	14	268	776	109	190	357	784	71	70	9	31	134	67	67
86	14	280	853	107	178	349	799	69	68	8	32	126	63	63
86	14	214	881	116	238	287	906	89	86	8	32	168	84	84
86	15	248	935	130	223	314	812	87	84	7	33	84	41	41
86	15	345	974	155	257	388	830	92	91	8	32	90	45	45
86	15	296	951	139	245	349	810	96	96	7	32	94	47	46
86	15	205	1040	98	165	270	904	67	71	7	33	67	33	34
86	15	231	937	113	177	277	913	73	72	7	33	71	36	35
86	16	97	678	63	34	126	1109	38	39	4	35	20	9	8
86	16	255	529	128	90	327	881	83	89	6	34	46	20	20
86	16	170	577	93	49	218	967	59	56	7	33	29	14	13
86	16	157	632	82	50	197	1009	59	58	5	35	30	14	14
86	16	132	760	92	55	173	1106	53	55	5	35	28	13	13
86	17	233	810	87	76	307	980	88	89	8	32	22	11	11
86	17	313	790	72	90	407	945	101	100	8	32	26	12	12
86	17	306	823	69	88	417	992	105	104	8	32	26	13	13
86	17	203	824	67	98	300	1023	99	112	8	32	28	11	14
86	17	345	672	74	103	500	911	130	134	8	32	35	15	16
86	18	67	902	42	31	100	1146	49	48	3	37	8	4	4
86	18	137	856	66	45	183	1101	73	74	4	36	12	6	6
86	18	174	854	73	68	247	1106	93	96	6	34	16	8	8
86	18	204	679	78	71	291	1035	108	109	7	33	18	9	9
86	18	146	750	62	61	211	1091	84	84	5	35	14	7	7